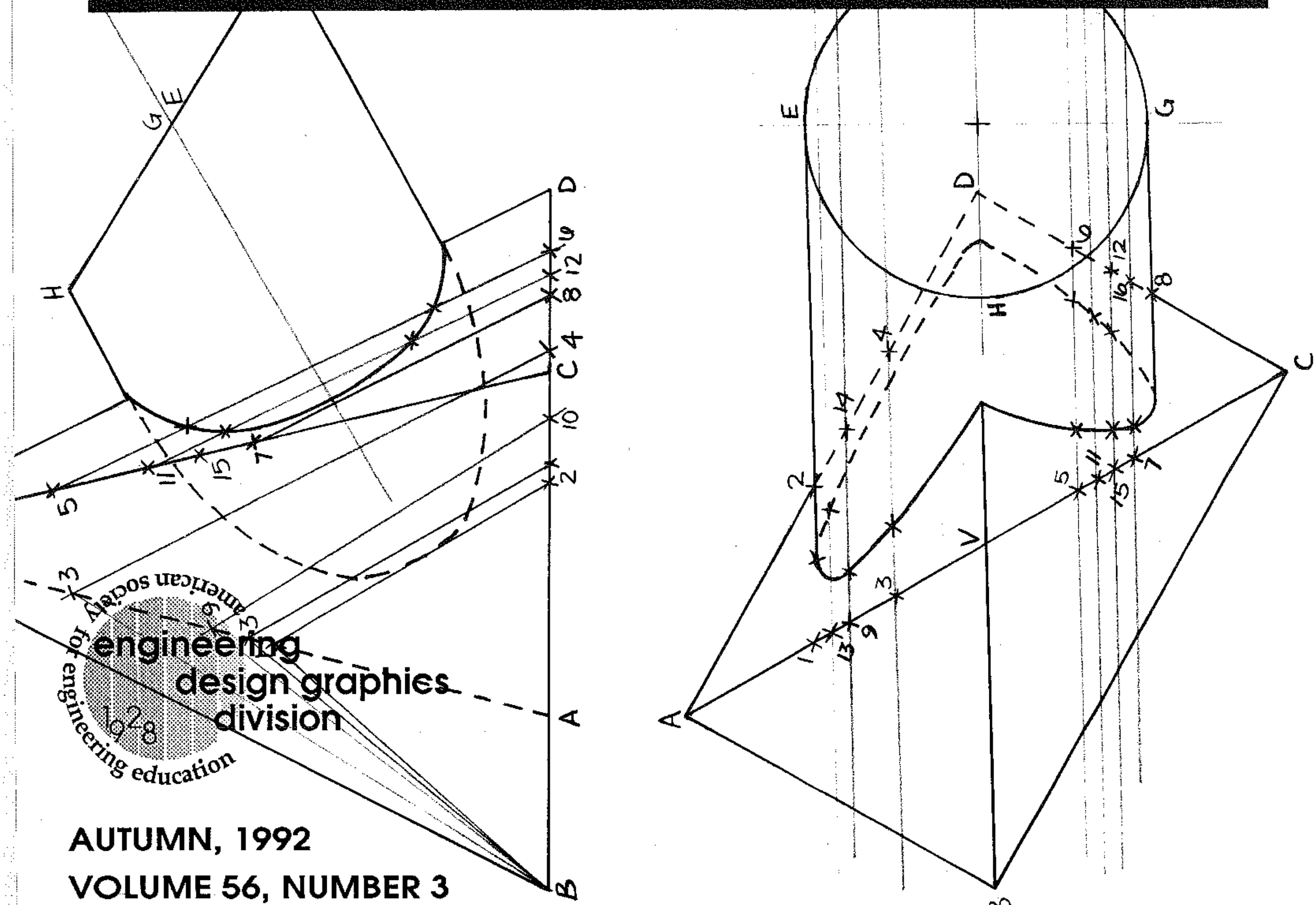
THE ENGINEERING DESIGN GRAPHICS JOURNAL



american society for engineering education
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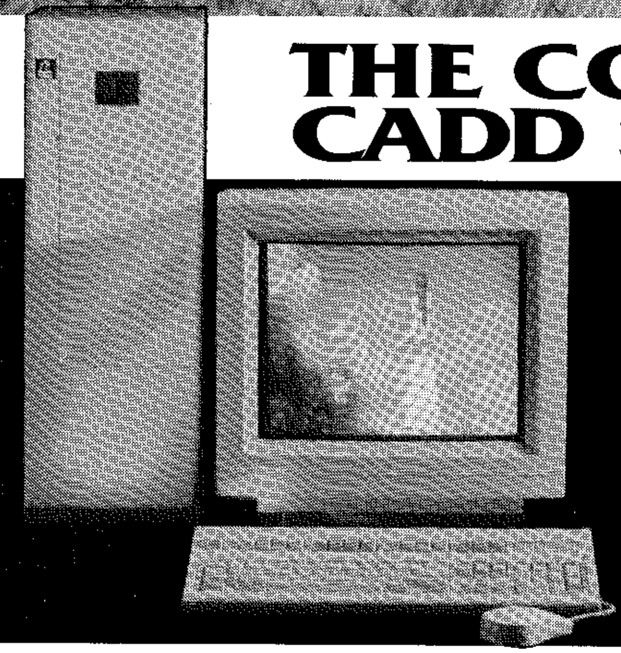

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engineering design graphics division

THE ENGINEERING DESIGN GRAPHICS JOURNAL

Volumn 56 Number 3 Autumn 1992

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

During the recent presidential election, we were inundated with the term *family values*. It seemed that each candidate had the correct version of what was included in family values and how they are perceived by the American public.

I read an article in the newspaper recently and the author pointed out that everyone except anarchists and separatist feminists were in total agreement about what family values should be. While I am still trying to find someone who can offer me a definition of separatist feminist, I did find the definition fascinating. The author suggested that family values encompass many things which have nothing to do with the number of people in a household. He held that family values have to do with the caring and nurturing of all the members of both the primary and extended family. His contention was that family values has to do with who we are and how we treat others.

I know this seems slightly off track for a graphics journal, but let me make my point. The whole issue of family values got me thinking about a term I would like call *Graphics Values*. It seems to me that in graphics there are many schools of thought about how we should approach graphics, where we should be going, and generally what graphics is all about. As I listen to presentations and debates and hear about meetings and gatherings all in the name of graphics, I get the feeling that there are those who feel that they have a lock on the right way or perhaps the only way of approaching graphics. It is my contention that we need to look at graphics values in the same manner as the author above looked at family values. There is no one way to 'do' or describe graphics. There is no 'one' approach that is perfect for everyone.

Just as some families have a better standard of living, so do some graphics families. Not all of us have access to top of the line facilities with the most powerful equipment and the most recent software. Lack of hardware does not mean that we have second-class graphics citizens. We are all trying to teach our students to be able to understand the world visually. We as educators cannot have closed minds about how to teach graphics. We must accept that there are probably as many approaches to graphics as there are types of families. Teachers teach differently and students learn differently. It has been proved that many of us teach in the manner that we learn best ourselves, or in the manner in which we were taught.

As we advance with technology, we must realize that tools (or toys) do not teach the graphics. In fact, I have yet to read a study that has proved to me that students learn to visualize better using computers. I am not suggesting that we cease using computers, but I am suggesting that if we are concerned with visualization we must consider why we are using computers and how we can get the optimum value from them. There was a time when we taught the slide rule. Students were given instruction on how to use the tool that they would be using on the job. Now, I keep hearing how we should be teaching graphics, and that we shouldn't be teaching the tool. I keep wondering if this is because the tool is really so transparent that there is no reason to teach it or if it is because we have become so self-important or lazy that we feel that teaching the tool is beneath us.

If we truly have graphics values, then we must treat our students as part of our extended graphics family and consider their needs. We cannot tell our students what needs to be done without giving them the background to be successful. Giving them the documentation to the software or access to an open lab is not enough. We must teach the tools and strategies that will give them the background to solve the complex problems they will encounter in the future.

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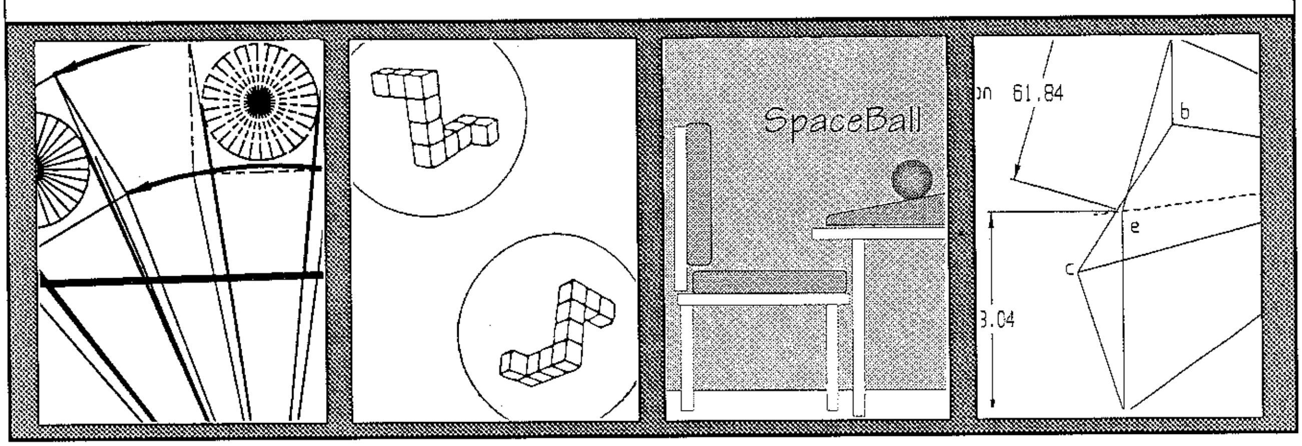

Freshman Engineering Graphics and the Computer

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Abstract

A gradual but definite change in the approach of teaching freshman engineering graphics is occurring at many institutions. The use of the computer in graphics is becoming the norm rather than the exception. This paper presents the approach taken at Virginia Tech and how handout material supplements printed material and supports the graphical solution to traditional engineering problems in mechanics.

Introduction

There has been a gradual change in the attitude of many educators on how engineering graphics should be taught. One reads an increasing number of articles in which the traditional geometric construction and descriptive geometry methods of teaching visualization are being replaced with geometric 3-D modeling (Barr 1991, Bertoline 1991, Van Valkenburg 1983). This change is certainly aided in no small way by the solid modeling capabilities of the personal computer (Eide 1986, Lorimer 1992). In 1984, as part of its drive for excellence in engineering, Virginia Tech became the largest public university in the nation to require freshman engineering students to own their own personal computer. Select software, including graphics programs, were a part of this package. The program was initiated to produce computer-literate students who could use both traditional and more modern methods for graphics visualization and engineering problem solving. Since 1984, computer use in Virginia Tech's freshmen engineering graphics has steadily increased to where descriptive geometry in the traditional sense has been nearly eliminated. This paper, then, will focus on the use of the computer and graphics software in the freshman engineering graphics course at Virginia Tech.

Graphics has evolved from a drafting technology where descriptive geometry was emphasized to analyze 3-D problems with 2-D media to the computer generation of 3-D solid models. As a result, there are a growing number of educators who are de-emphasizing descriptive geometry in favor of the use of freehand sketches to document ideas and concepts, make changes, and gradually arrive at an acceptable solution. At this stage, rather than using paper, pencil, and instruments to record and define a design, many are integrating the computer and using graphics software to accomplish these tasks. Most often the tasks can be completed in much less time, and storing, retrieving, editing and updating the original design is made easier using computer graphics software. Also, the electronic 3-D database is easily and economically transportable and accessible by many users who may be separated by great distances.

The use of the computer to produce graphics is also very appealing to young students. This eager acceptance of computer graphics is a welcome change in the attitude usually displayed by students working with drafting instruments. "After all," students will state, "we want to be engineers, not drafters."

Graphics Software

At Virginia Tech, the educational version of CADKEY was the graphics program used in freshman engineering courses from 1987 to 1990. The College of Engineering unanimously chose the 3-D based professional version (3.55) of CADKEY for use in 1991. In 1992, version 4.04 was used. As a part of the required computer package, each entering freshman receives a professional version of CADKEY for use in Introduction to Engineering (EF 1006), a required engineering graphics course for all engineering students. Its use is continued in other courses, including Advanced Computer Graphics (EF 2004), an elective course for those students wishing to be knowledgeable in the advanced features of the graphics software.

Classroom Configuration

There are four specific classrooms in which EF 1006 is taught. Each classroom is equipped with an instructor's computer station (IBM 70-386 with 120 Mb hard disk) which is connected to color monitors shared by two students (each class section is limited to a total of 32 students). Class assignments, instructional demonstrations and problem solutions are prepared in the instructor's office and transferred to the classroom computer's hard disk. With a large hard disk, an instructor can load an entire semester's lecture files for classroom use. Updates and changes are easily made between the faculty's master files and those in the classroom. With the instructor's station controlling the students' monitors, the computer serves as an excellent tool in the teaching process. Students see firsthand the process of developing and manipulating a graphical 3-D model.

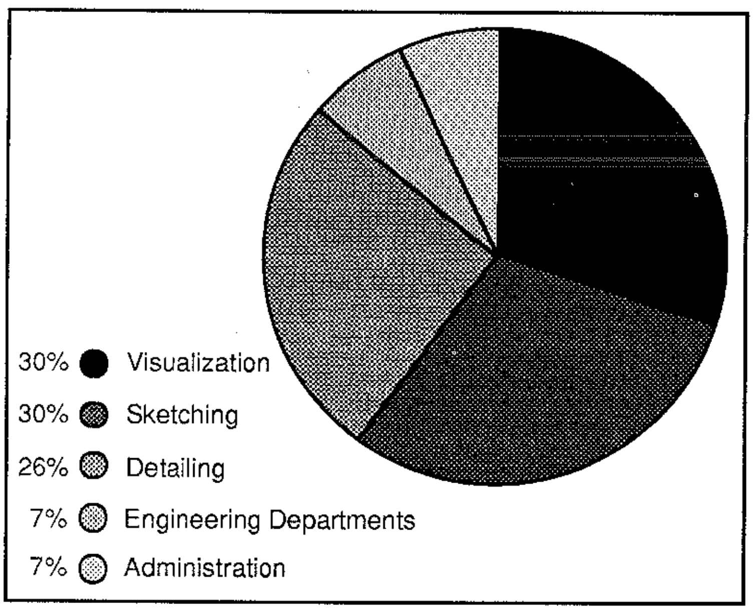

Figure 1: Class Time

Introduction To Engineering Graphics

The goals of the engineering graphics course are to ensure an understanding of the theory of orthographic projection, develop familiarity with the conventional practices of producing engineering drawings, develop 3-D visualization and interpretation skills, teach the rudiments of true 3-D computer modeling, prepare students for entry into an engineering discipline, and continue an emphasis on the standards expected within the College of Engineering and the engineering profession.

The graphics course, EF 1006, is a one-semester, three-credit course which devotes about seven percent of class time to the discussion of the engineering disciplines offered in the College of Engineering; 30 percent on freehand geometric sketching; 30 percent on solid modeling and spatial visualization; 26 percent for detailing, sectioning, tolerances and scales; and seven percent for testing and administration, see figure 1.

The philosophical basis for the course in support of its goals is to maximize the use of the graphics software to enhance the capability to visualize and interpret 3-D models. After learning to use scales, freehand sketching is utilized for pictorial representations and geometric construction and the determination of true length lines, true angles, orthographic projection, auxiliary view development, true size of planes, and detailing of drawings. For accurate results, the graphics software is used. Classwork develops progressively from plotting points, to lines, to 2-D planes, to 3-D planes, to 3-D models.

Since the graphics course utilizes CADKEY software, it was felt, in the interest of minimizing the cost to the student and maximizing the ease of integrating graphics and software, that the text for the course should be directly related to the software. Earle's *Graphics for Engineers with CADKEY* served this purpose. Even though an entire chapter of the text is devoted to CADKEY operations, additional informational (handout) material was developed to aid in the students' understanding and use of the software in the graphics course. The information sheets are complete with an explanation of the steps to be followed to complete a task as well as graphical examples which reinforce the text. Students obtain the information packet from a copy center. See Figure 2 for a listing of the topics included in the packet.

The class syllabus includes the topics to be discussed, text reading assignments, references to particular information handout sheets, and CADKEY topics for each class session. See Figure 3 for an abbreviated course outline.

System and 2-D Handouts

In addition, students obtain material in the information packet which supplements the course text and the information supplied with the software. The first handout (HO 1), "INSTALLATION," gives instructions on how to install the graphics software, CADKEY SOLIDS, and sample and utility files. Handout 2, "SETTING CADKEY CONFIGURATION OPTIONS," provides the steps for configuring the software and includes suggested input for the College of Engineering's recommended computer and printer. Operating systems utilizing windows applications have caused serious resident memory deficiency problems. To overcome this difficulty, "DOS 5 USERS" (HO 3) presents recommended autoexec and system config files for the Disk Operating System that is a part of the student's computer package. Once the software is loaded and running, "CADKEY TUTOR" (HO 4) gives the steps needed to initiate the CADKEY tutorial, which includes explanations and demonstrations using the software for geometric construction.

The initial assignment of the course calls for each student to get the software loaded, configured, and running on their computer. Meanwhile, classtime during the first week of the semester is devoted to the review and discussion of each of the disciplines in the College of Engineering to give students more information and help in their choice of an engineering discipline. Each of the ten departments (twelve majors) at Virginia Tech have developed videos and informational handouts for their department and the discipline in general. The videos, handout literature, and class discussion help prepare the freshmen in petitioning for admission into a department of their choice when they have completed all freshman courses. At that time, the student makes three choices ranked in order of preference; department acceptance is based upon the student's accumulated grade point average and the number of positions available in the department.

Students initially become acquainted with the graphics software through Handout 5, "BLANK FILE AND SCREEN SCALE." This assignment asks them to determine the screen scale factor necessary to print out

EF 1006 HANDOUTS (HO)

HO	CONTENTS
1	Installation
	A. CADKEY4
	B. CADKEY Solids
	C. Sample Files and Utilities
2	Setting CADKEY4 Configurations Options
3	DOS 5 Users
4	CADKEY Tutor
5	Blank File and Screen Scale
6	Border
7	Vector Addition
8	Macros
9	CADKEY Calculator
10	2-D Plane Plot-ev-True Angle-TS
11	Truss Forces
12	Beam Reactions
13	Plotting with Plotfast
14	CADKEY Solids
15	Importing CADKEY Graphics Into MS WORD5
16	Making Old Files Compatible With CADKEY4
17	Convert AUTOCAD DXF Files To CADL Files
18	Slide Show

Figure 2. Summary of Information Sheets

geometry true size. Also with suggested default values for notes and dimension height, aspect ratio, start up view, construction mode, etc., blank files are created in inches and millimeters. These blank files serve to clear the screen and remove from memory all CADKEY database saved during the last exercise.

The second printout assignment, explained in Handout 6, "BORDER," requires students to establish a border with a title strip which is then used on all subsequent computer assignments. While standard border files are available and, indeed, supplied with the software, this exercise introduces line construction, different line types, text generation at different heights and text placement.

The "MACROS" handout, HO 8, details the steps in preparing a macro and subsequently assigning it to a key or key combination. The handout also gives the steps for creating a macro to load a blank file. Other suggestions for useful macros might include a macro to display and then select a file from a listing of part files stored on a diskette under several subdirectories. Another macro might recall a pattern for the replacement of centerlines on a circle or even a macro that creates a vertical and horizontal centerline placed on a circle with the short dashed lines forming a "+" at the circle center. Other possibilities might include a macro to automatically shell out of the software, one which allows for the windowing of a box to delete entities, and one which would create entities by specifying characteristic values.

Another handout, "CADKEY CALCULATOR" (HO 9), explains in examples the steps in using the CADKEY calculator to assign computer-determined values of algebraic expressions to a variable. The steps are given for having CADKEY measure an angle between two lines, assign the display value to a user defined variable, and use the variable to rotate an entity the specific angle previously measured.

Classroom demonstrations and several class assignments are required in creating simple generic 2-D geometric shapes so that students become aware of and familiar with the software menus, status window, coordinate tracking, prompt line, and history line.

EF 1006 - INTRODUCTION TO ENGINEERING

TOPICS - TEXT	CADKEY
Introduction to Engineering	HO 1 - Installation
Departments	HO 2, 3 - Configuration
Lettering, Scales	HO 4 - Tutorial HO 5 - Files HO 6 - Border
Sketching - Multiviews,	HO 7 - Vector Addition
Isometric, Oblique	HO 8 - Macros Coordinate Systems
Orthographic Projection,	HO 9 - Calculator
Points, Line, True Length	Control-Verify, X-Form, Mirroring, Scaling
Parallelism, Perpendicularity,	Perimeter, Area/cn,
Line Visibility, Skewed Lines	Moments of Inertia
Planes, True Size,	HO 10 - Truss Forces
Successive Auxiliary Views	New Views
Design, Working and	HO 11 - Beam Reactions
Assembly Drawings	HO 12 - Plotting
3-D Model Visualization	HO 13 - CADKEY Solids Extrusion, Meshing, Projection
Sectioning	HO 14 - Importing Graphics, X-Hatch, Masking
Dimensioning	Linear and Ordinate Dimensioning, Detail - Change - Attributes
Tolerances	Tolerances
Cap-stone Project	CADKEY - Cutting Edge Milling Machine

Figure 3. Abbreviated Course Outline

Applications To Statics Problem

The first computer graphics application for solving a statics problem is shown in HO 7 "VECTOR ADDITION." Two 3-D vectors in different colors are graphically added, and the vector components for each vector are determined and shown in separate colors. The process of finding the resultant vector with its vector components and the direction cosines is demonstrated in class.

A second statics application is discussed in "TRUSS FORCES" (HO 11). This handout presents the procedures used to solve for the axial force in individual truss members and provides an example truss problem with two loads. Students solve the example problem or a similar problem as an exercise in drawing a 2-D figure to scale, constructing parallel lines, constructing line lengths to a user-defined scale, and measuring (dimensioning) the Maxwell diagram lines to determine the member forces to an accuracy of six places to the right of the decimal. The use of various colors helps students differentiate between tensile and compressive members.

Another statics application is covered in Handout 12, "BEAM REACTIONS" (see Figure 4). This handout presents the procedure for the graphical solution in determining the reactions of an example beam problem with three loads. Having students solve this example problem or a similar exercise problem reinforces the techniques learned in the truss problem. The presentation of graphic solutions to these statics problems are timed to coincide with the coverage of the same material in the student's statics class.

The techniques used in graphically determining the true length, true angle, and true size and shape of a plane are learned by sketching rather than using drafting equipment. Accurate work, however, is accomplished with the computer. Handout 10, "2-D PLANE PLOT-EV-TRUE ANGLE-TS," details the 2-D graphical steps for plotting the corners of a plane in at least two adjoining orthographic views, determining the true length of a line in the plane, obtaining an edge view of the plane, and obtaining the true size and shape of the plane. In the handout, an example problem is presented which duplicates what one does on paper, i.e., measuring distances and plotting a point along a line. The computer solution repeats the sketching techniques, but is technically accurate. The same example problem is solved as a class demonstration with the computer by plotting the plane in 3-D, displaying the plane in the three orthographic views as well as the isometric view, and obtaining the true size of the plane. The proper orientation of the true size plane can then be obtained by measuring angles and utilizing the program's calculator function.

Solid Modeling

The next step in the course is the development of the students' ability to visualize 3-D models. This process is enhanced by using CADKEY SOLIDS. Handout 14, "CADKEY SOLIDS," explains the terms of the solids menus and the procedures involved in preparing a wire frame design to obtain a desired model, creating the necessary CADKEY ADVANCED DESIGN LANGUAGE (CADL) input file, developing the required preprocessing instructions, and obtaining the desired rendering(s). A walk-through example is included in the handout which presents each step and each key stroke necessary to create a hidden, dashed, filled, and four-view rendering of a model. Also, a print out of the correct results is included. In class, additional models are created by combining a wireframe model with solid primitives to demonstrate each of these renderings, mass properties, as well as to produce sectioned view renderings.

Utility Handouts

All students are required to present the results of at least one problem with multiple colors using a plotter. Handout 13, "PLOTTING WITH PLOTFAST," explains how to create a Plotfast disk which the student uses to plot the exercise. Proper plotter setup is given in addition to a printout of the initial screen that is displayed when Plotfast is loaded.

Since all students have Microsoft Word 5 as their word processing software, they receive a handout entitled "IMPORTING CADKEY GRAPHICS WITH MS WORD 5" (HO 15) which outlines the configuration setup, the creation of the HPGL file, the required modification of the file, and the software menu selection sequence for graphic file importation. The handout also explains the procedures for graphic placement, sizing, creation of a graphic border with caption, and anchoring to achieve text flow around the graphic.

Files created with earlier versions of CADKEY cannot be loaded into the latest version, so another handout, "MAKING OLD FILES COMPATIBLE WITH CADKEY 4" (HO 16), outlines the procedure for converting old files so they are compatible with the new software version.

Students occasionally encounter classes in which AUTOCAD graphics software is used, so they will need to be able to convert these files to files that are usable with CADKEY and vice versa. The "CONVERT AUTOCAD DXF FILES TO CADL FILES" handout (HO 17) gives the steps to accomplish this conversion.

The last handout, "SLIDE SHOW" (HO 18), tells how to create slide files and the SLIDE.TXT file that manages the slide show sequence and timing. Also included is the procedure for running a slide show either on a computer hard drive or independently from a diskette.

Cap-Stone Demostration

As a cap-stone to the course, a graphic model is created and entered into CADKEY's Cutting Edge software, where tool paths are defined to direct a milling machine to create the model. A Cutting Edge job file is created and converted (posted) into a numerical control code to drive the machine. The wire frame model and the conversion to the numerical control code are demonstrated with a Spectralight milling machine that creates the model from a wax/plastic stock of material.

Summary

The graphics course is designed to give students a firm grasp of both sketching techniques and computer-assisted graphics while helping prepare them for entry into a specific engineering discipline. In the course, sketching is used to master the basics of geometric construction, pictorial representation, and the determination of true length lines, true angles, orthographic projection, auxiliary view development, true size of planes, and detailing of drawings. However, more accurate work is accomplished with the graphics software, and the tasks develop progressively from plotting points, lines, and planes to 3-D models. Examples primarily concerned with 2-D construction are the border, the 2-D plane plot, etc. exercises and the statics example problems of vector addition, truss forces, and beam reactions. Maximum use of the graphics software's 3-D modeling capability is employed to enhance the student's ability to visualize and interpret 3-D models. Utility handouts then help broaden the students capability in the use of the software.

Conclusion

At the end of the graphics course, students are proficient in using the graphics software to develop 2-D generic shapes and analyze them with the software as well as graphically solve engineering problems. The handout material supplements the available published material and enhances the students' capabilities in the graphics course while serving as a source of reference for later use. Having a chance to see a wire-frame design result in the creation of a 3-D model completes the cycle of idea generation to the reality of the object. In the future, each student will have an opportunity to create a design and be able to make a model of that design through the use of CADKEY's Cutting Edge to drive a milling machine.

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BEAM REACTIONS *Reference: Structural Analysis by Russell Hibbele*

The reactions to a beam with loads, Figure 4a, can be found graphically by using a force polygon and a funicular polygon.

Procedure:

1. Draw a free body diagram, Figure 4b, of the beam to scale with the pinned support on the left and indicate all external loads. Label between the loads and reactions sequentially clockwise with a lower case letter.

2. To a suitable scale, draw a force (load) polygon by connecting end to end all loads as one passes from left to right along the beam. Pick an arbitrary point P to the right and approximately mid-height of the string of external loads. Connect the start and end points of all external loads with point P. Hence, loads are broken into components through point P (Figure 4c).

3. Draw the funicular polygon (Figure 4b) by starting at the pinned support of the free body diagram. Draw the load components parallel to the force components of the force polygon, Figure 4c, at the intersection of the line of action of each load. Extend the last load component until it intersects the line of action of the roller reaction (direction is known).

4. A line from this intersection with the roller line of action to the pinned support closes the funicular polygon (dashed line in Figure 4b. A line parallel to this dashed line drawn in the force polygon, Figure 4c, through point P establishes the proportionality of the two reactions.

Example Problem:

1. Draw beam to scale and indicate loads. Label between loads, a, b, c, d, and e, Figure 4b.

2. Using a suitable scale, start the force (load) polygon, Figure 4c, by connecting the 30K, 60K, and 50K loads. Load lines are drawn parallel to the lines of action of the loads in Figure 4b.

3. Select an arbitrary point P to the right and mid-height of the string of loads lines and connect the start and end of each load with point P, Figure 4c.

4. Start the funicular diagram on the free body diagram, Figure 4b, by drawing a line parallel to line aP, Figure 4c, from reaction A to the extended line of action of the 30K load, from here draw line bP parallel to bP in Figure 4c until it intersects the extended line of action of the 60K load. Line cP connects the 60K and 50K extended lines of action. Continue until line dP intersects the roller line of action at B.

5. Connect the last intersection in Figure 4b with the start of the funicular diagram at A (dashed line). Draw a parallel line to this dashed line in Figure 4c through point P. A vertical line from the end of the last load (d) to this dashed line establishes point e and magnitude and direction of the roller reaction. Connecting Point e with point a in figure 4c results in the magnitude and direction of the pinned reaction at A.

6. Dimension line de in Figure 4c: DETAIL-DIM-VERTICAL-select line de near point d and point e - locate dimension - accept yes or no. For line ea: DETAIL-DIM-PARA-select line ea near

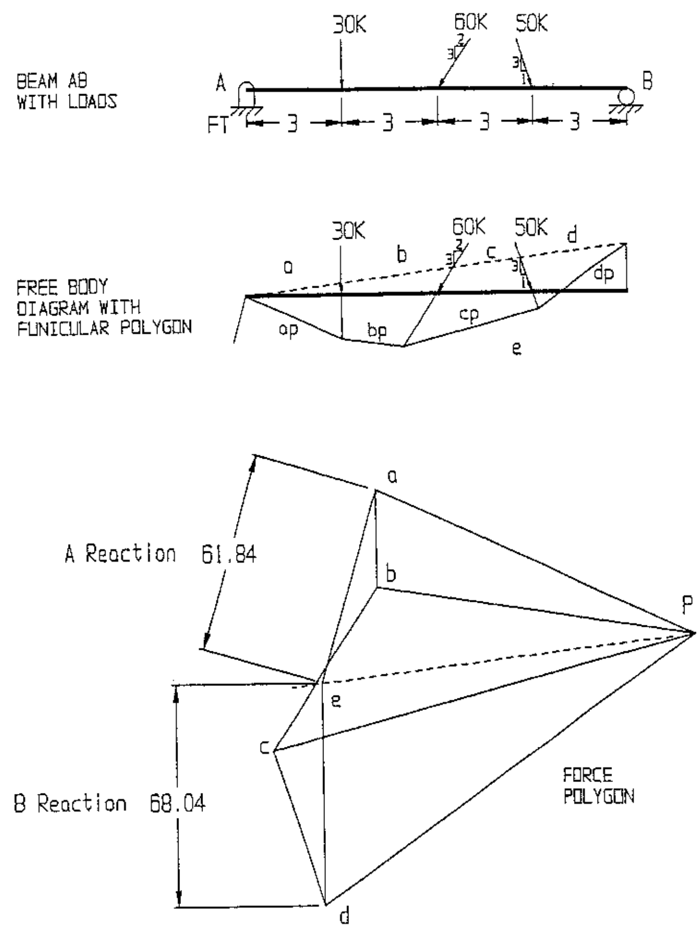

Figure 4: Beam Reactions Handout

The Performance of Graphical User Interfaces in 3-D Interactive Animation (Virtual) Environments

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Abstract

Although the popularity of graphical user interfaces (GUIs) is widely known, little is known about the usability of GUIs in 3-D interactive animation (virtual) environments. Experimental data on the effect of GUI parameters on task performance in a 3-D interactive animation environment is presented. Subjects performed an object recognition and 3-dimensional manipulation task in a virtual environment given real-time visual feedback by dynamic display techniques. The subjects controlled a "virtual crane" by the movements of a SpaceBall ™ input device. The interaction of stereoscopic depth cues with viewpoint position is evaluated in this experiment. Six conditions were tested by the combination of one of two values of stereoscopic depth cues (present and not present), and one of three viewpoints (elevation angles of 0°, 45°, and 90°). The data indicate that choice of viewpoint and the presence of stereoscopic depth cues is important to the performance of this task. The presence of stereoscopic cues does not guarantee increased usability for all display tasks, but as this investigation confirms, stereoscopic cues can increase user performance of complex interactive tasks.

Introduction

As the graphics capabilities of computers increase and hardware costs decrease, graphical user interface (GUI) displays are being used more frequently in science, industry, engineering design, and technical graphics. Graphic interfaces offering dynamic stereoscopic visual displays of environments provide the user with a new tool to assist in performing interactive tasks requiring visual feedback. Stereoscopic interfaces place the user in a virtual environment, providing a potentially useful, but as yet an under-evaluated, dimension in visualization and interactive task visual feedback. Stereoscopic cues can be used to augment an existing set of visualization cues to achieve increased performance in tasks performed in a virtual environment. However, due to its rapid and recent rise in availability, the usability of the stereoscopic display has not been well established. Recent research indicates that stereoscopic displays provide better user performance at many 3D visual tasks than perspective 2D displays. Recent studies have compared user performance with 2-D perspective display versus time-multiplexed stereoscopic display for both accuracy and reaction times. Stereoscopic displays have been judged superior for visual search and interactive cursor positioning tasks [Beaton, 1988], and for spatial judgment tasks [Yeh and Silverstein, 1990, and 1990a].

In this experiment, the interaction of stereoscopic depth cues with viewpoint position in a dynamic virtual environment was evaluated. The results of this investigation may be helpful in the design and use of GUIs in 3-D interactive animation (virtual) environments.

Previous Work

Previous studies by the authors (McWhorter, Hodges, & Rodriguez,1991) indicated subjects perceived stereoscopic CAD displays as providing more geometric information than non-stereoscopic CAD displays. Stereoscopic wireframe, hidden line removed, and flat shaded images of an engineering model were subjectively judged to provide more geometric information than equivalent monoscopic images of the model.

Yeh and Silverstein [1990a] have suggested that the addition of stereoscopic depth cues improved the speed of altitude and distance judgements for static visual displays. In that investigation, three viewpoints (15°, 45°, and 90° elevation) were tested. Subjects' altitude and distance judgement reaction times were found to be consistently faster across all viewpoints when presented stereoscopically.

Kim, et al. [1987] investigated the effects of visual enhancements for monoscopic and stereoscopic displays. Results suggest that stereoscopic displays permit superior tracking performance. In addition, they show that the choice of viewpoint parameters also greatly affects the users' performance in a three-axis manual tracking task.

The effect of depth cues on relative depth judgements, visual search, cursor positioning, and subjective image quality judgements was investigated by Beaton [1990]. Results indicate that stereoscopic cues improve the user's performance of visual search and interactive cursor positioning tasks, both of which are essential operations for successful performance in a 3D interactive environment.

Method

Subjects

Thirty undergraduate students, 7 females and 23 males, of engineering graphics and design visualization at the Georgia Institute of Technology in Atlanta served as subjects for this study. The subjects received compensation (class credit) for their participation. All subjects had prior exposure to the type of computer equipment used in this experiment. One subject dropped from the experiment due to an insufficient understanding of the instructions.

Apparatus

Figure 1 shows the experimental setup. The stimuli were generated by a Silicon Graphics 4D/120 GTX graphics workstation and displayed on a 21" 120 Hz. monitor equipped with Crystal Eyes™ hardware for producing time-multiplexed stereoscopic images, permitting each eye's image to be updated at a rate of 60 Hz. All subjects wore a pair of active liquid-crystal shutter glasses linked to the hardware by an infrared signal. A SpaceBall™ served as the input device through which the subject responded to the presented stimuli and performed the task. The subjects were seated in a darkened cubicle 100 cm from the display, and were permitted to use the input device with either their left or right hand. All visual stimuli presented to the subjects followed guidelines (Yeh and Silverstein, 1990) for appropriate values for maximum visual angle, and for other factors affecting image quality. Disparity did not exceed 1.6° visual angle as suggested by Hodges [3], and colors were chosen to minimize ghosting effects due to differing phosphor persistence.

The model geometry for the stimuli is depicted in figures 2 and 3. Figure 2 shows

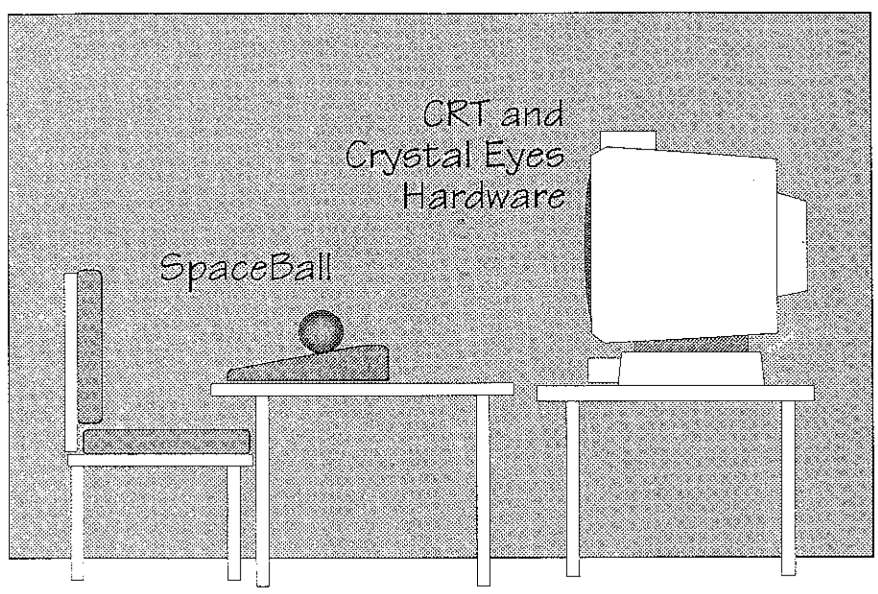

Figure 1. The experimental setup

the stimuli as presented in the 45° elevation stereoscopic condition. For the purposes of this illustration, the left and right eye images are shown side by side and reversed. This figure can be viewed stereoscopically by crossing your eyes to merge the two images into a central 3D image. Figure 3 depicts the 90° monoscopic view of the model.

Procedure

The subjects performed an object recognition and 3-dimensional manipulation task given real-time visual interface feedback by computer graphic animation. The subjects controlled a "virtual crane" model by the movements of a SpaceBall™ input device. The subjects' task was to manipulate a virtual object with the crane and place the object into an appropriate virtual bin of similar shape. The virtual space was presented by the interface as prescribed by the experimental conditions. The object type varied randomly across three simple geometric solids: a three-sided, four-sided, or five-sided prism. The goal of the task is to place the object in the bin of the same shape. After the subject successfully placed the virtual object in a bin, the crane reset its position, and a new object was presented to be recognized and manipulated. The task ended when the subject placed all the pre-determined number of objects into bins.

This investigation was composed of a 2 by 3, two-factor, between-subjects independent measures design. The subjects were assigned randomly to each experiment and condition, with 5 subjects tested per condition. The independent variables in this experiment were the presence of binocular cues and viewpoint location. The dependent variables in this investigation were measures of task performance, defined as the time for task completion and position error measures. Task completion time was recorded as the subject's object retrieval time and release time. Task error measures were recorded as distance in X, Y, and Z coordinates to the correct release location. All other display parameters, such as color, occlusion, shading, and frame rate, were held constant in this investigation. All objects were rendered as semi-transparent with a diffuse lighting model and single light source across all conditions.

The subjects were assigned to one of six conditions as illustrated in figure 4. The six conditions were defined by the presence or absence of stereoscopic cues, and by the viewpoint from which the stimulus was rendered. Three viewpoints were tested in this experiment: 0°, 45°, and 90° elevation. All conditions were presented at 0° azimuth, and at 20° field of view. The conditions were assigned as follows: Conditions 1, 2, and 3 are stereoscopic, and conditions 4, 5, and 6 are monoscopic. In conditions 1 and 4, the stimuli were presented at 0° elevation, conditions 2 and 5 at 45°, and conditions 3 and 6 at 90°. The 90° elevation angle is a top-down view, and the 0° angle is from "ground level."

Four of each of the three object types were presented in randomized order to the subjects to be manipulated. The subjects were assigned randomly to the six conditions.

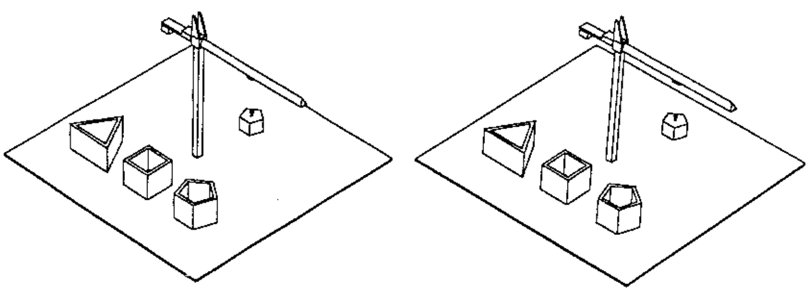

Figure 2.
The left-eye images of the model as presented in the 45 degree elevation stereoscopic condition. This figure can be viewed stereoscopically by crossing one's eyes so as to merge the two images into a central 3D image.

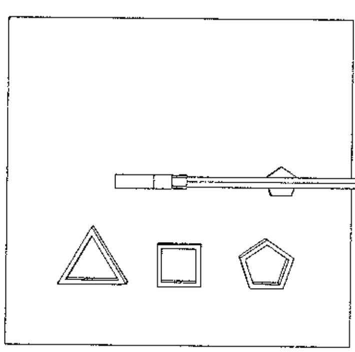

Figure 3.
The 90 degree elevation monoscopic view of the model.

Results

Figure 5 compares the subjects' object retrieval times. A major effect across the three viewpoint conditions is seen. In the 0° elevation viewing angle conditions (ground view), the subjects required more time to accurately position the hook to retrieve the object. The effect of stereoscopic display presentation is also apparent. Retrieval times were consistently faster across all viewpoints for the stereoscopic display conditions.

Figure 6 compares the subjects' object release times. Although the subject was not required to satisfy a measure of accuracy to release the object as when retrieving the object, the release time data exhibit a similar relationship to the conditions as the retrieval time data. However, the difference between the data from the 45° stereoscopic and monoscopic presentations cannot be shown to be significant due to the large variance in the data.

The release position errors for each condition are shown in figure 7. An error of 0.0 resulted if the subject released the object at the height of the bin opening. The subjects' object positioning performance was most accurate in the 45° elevation conditions. The differences between stereoscopic and monoscopic release height errors cannot be shown to be significant.

No significant speed-accuracy tradeoff is apparent from a review of release time versus positioning error scatter plots. The Y (height) error data show a significant trend around the 1.0 value, particularly at lower (quicker) release times.

Retrieval times across all subjects are shown for each condition in figure 8. Although release times did not significantly change over the course of the experimental trials, the retrieval times for each condition show a learning curve over the course of the experiment. There is no systematic difference between conditions shown in the learning curve data.

Discussion

Some subjects verbally noted difficulty in using the SpaceBall™ input device. The data shows, however, that they rapidly overcame any initial difficulties.

VIEWPOINT

	0°	45°	90°
Stereoscopic	1	2	3
Monoscopic	4	5	6

Figure 4. The experimental design.
The subjects were assigned randomly to the six conditions. The six conditions were defined by the presence or absence of stereoscopic cues, and by the viewpoint from which the stimulum was rendered.

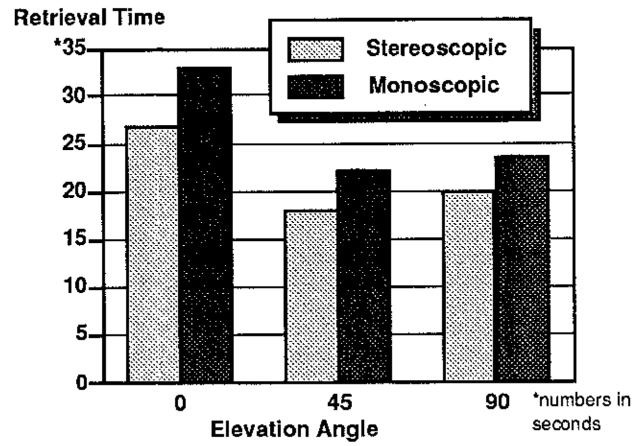

Figure 5. Object retrieval times.
Retrieval times are consistently quicker across all viewpoints for the stereoscopic display conditions.

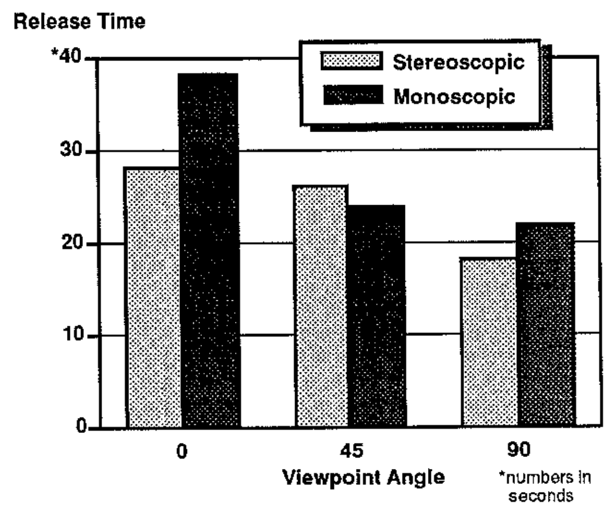

Figure 6. Object release times.
The release time data exhibit a similar relationship to the conditions as the retrieval time data. The difference between the stereoscopic and monoscopic presentations cannot be shown to be significant in the 45 degree elevation condition due to large variance in the data.

To retrieve the object, the subject was required to accurately position the hook of the crane near the object; therefore, the accuracy of the retrieval task was fixed. To release the object, the subject was free from any accuracy constraint. However, the data show that the retrieval and release times were of the same order. The subjects showed apparent mastery of the retrieval task by the second trial, but the data on release task showed no significant improvement in each subject's accuracy or time of release over the course of the experiment. This is possibly due to feedback presentation. Feedback for accurate retrieval of the object is provided by the object becoming attached to the hook of the crane. No feedback (except visual inspection) was provided to the subject upon release of the object.

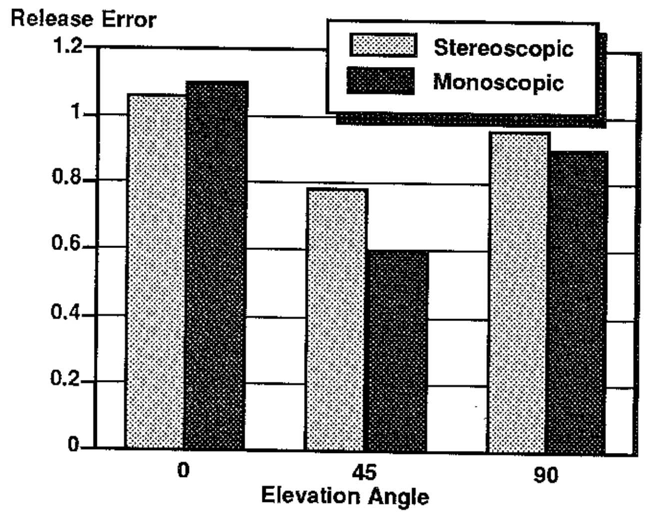

Figure 7. Release position errors.

An error of 0.0 results if the subject releases the object at the height at the bin opening. The subjects' object positioning performance was most accurate in the 45 degree elevation conditions. The differences between stereoscopic and monoscopic release height errors cannot be shown to be significant.

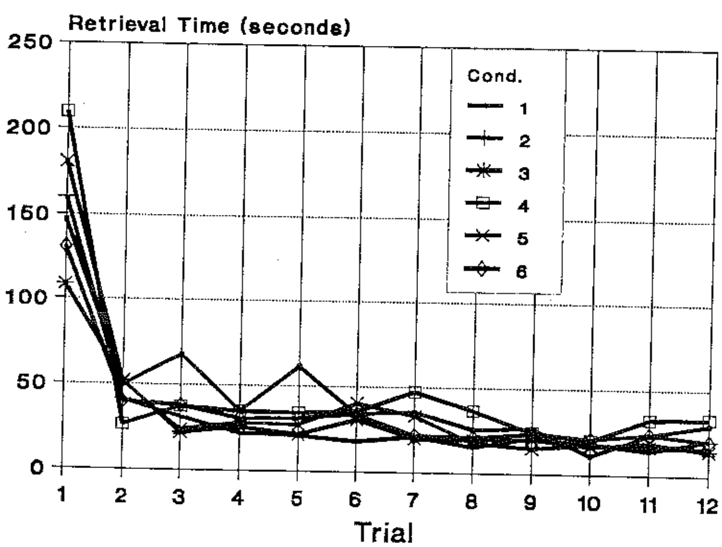

Figure 8. Retrieval time trial.

Although release times did not significantly change over the course of the experimental trials, the retrieval times for each condition show a learning curve over the course of the experiment. There is no significant consistent difference between conditions shown in the learning curve data.

The data indicates that choice of viewpoint and the presence of stereoscopic depth cues is important to the performance of this task, as observed by Kim, et al. The data also confirms a consistent difference between the stereo and monoscopic conditions when positioning accuracy is fixed, as seen by Yeh and Silverstein.

The position error as a function of elevation angle confirms the findings of (Kim, et al, 1987). For tasks of this nature, a viewpoint at 0° azimuth and 45° elevation produced increased performance. As these findings suggest, the presence of stereoscopic cues may diminish the effect of viewpoint choice.

This study also revealed that some subjects were not sufficiently briefed on the functionality of the crane system. This was partly due to differences in a subject's prior exposure to crane terminology. A complete briefing and sufficient practice trials would provide a more homogeneous sample of subjects.

In conditions 1 and 4 (0° elevation), a greater variability in X accuracy was observed. From this "ground view" perspective, the bins were partially occluded along the X direction. Subjects assigned to this condition verbally noted difficulty in distinguishing among the three bins. Under all conditions, an error of 1.0 is predominant in Y (height). The subjects were asked to align the top of the object with the top of the bin, producing an error value of 0.0. Most subjects, however, did not note this requirement, and placed the objects as far down as the software permitted, a value of 1.0 in screen units below the requested position. Feedback about the accuracy of the placement of the object would alert the subject to this error.

The need for practiced and briefed subjects suggests a within-subjects design for further studies. A significant percentage of the subject's time to perform this between-subjects experiment was required for briefing (approximately 50%). Between-subjects variability was also significantly greater than the within-subjects variability, and suggests a within-subjects experimental design for further studies.

The results of this investigation may be helpful in the design and use of GUIs for 3-D interactive animation applications, such as virtual environments. The predominant findings of this experiment, supported by (1987), suggest that viewpoint considerations are not trivial. Other parameters of a virtual environment display, such as the presence of stereoscopic cues, can interact with the choice of viewpoint. Yeh and Silverstein's (1990) investigation of static displays seems to support the findings of this investigation of dynamic displays -- that the presence of stereoscopic cues can positively affect the performance of a task dependent on visual feedback. As Beaton (Beaton, 1990) warns, the presence of stereoscopic cues does not guarantee increased usability for all display tasks, but as this investigation confirms, stereoscopic cues can increase performance of complex interactive tasks, such as found in a virtual environment.

Acknowledgments

This work was supported in part by the National Science Foundation under Grant MSM 9196186. Stereoscopic equipment support was provided by StereoGraphics Corporation, San Rafael, CA. Prototype display software was provided by Steve Adelson, GVU Center, Georgia Tech.

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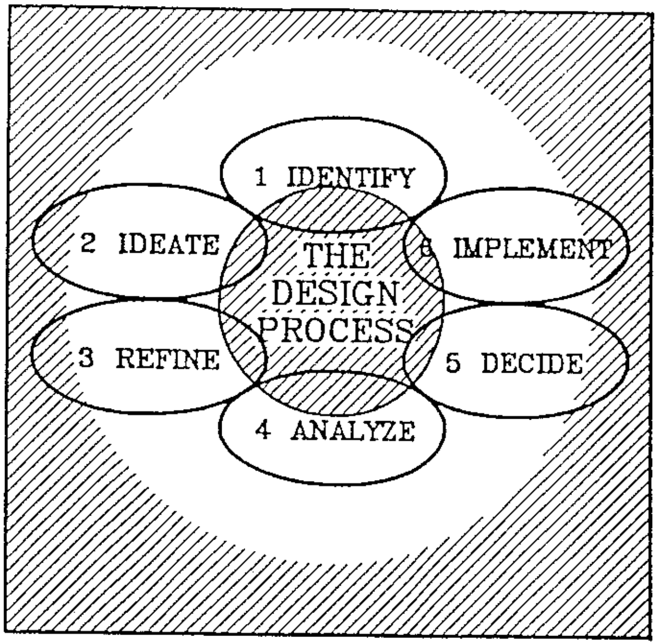

Figure 2. The Design Process by Earle (1989)

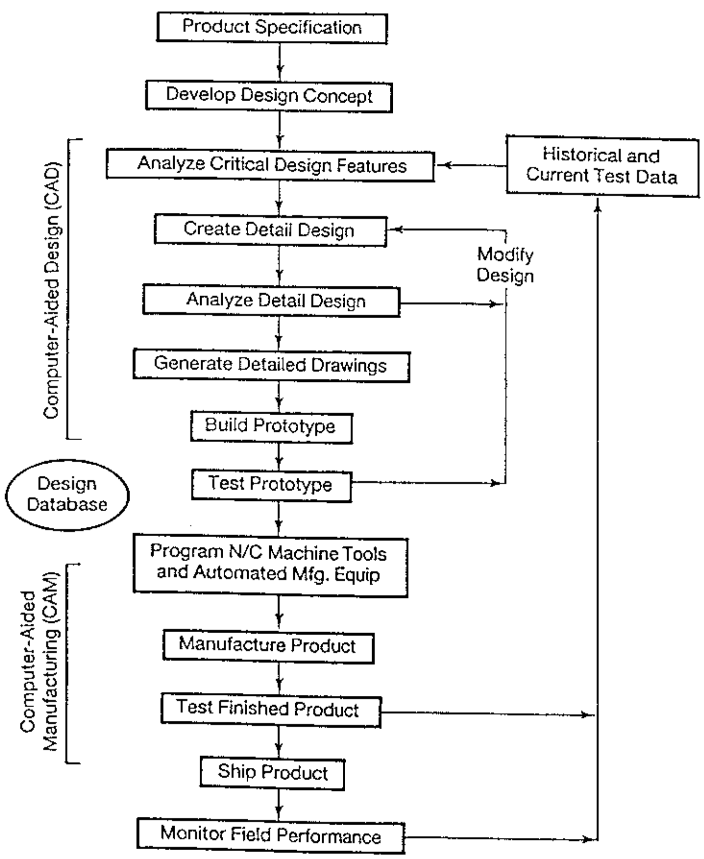

Figure 3. The Design Process by Dieter (1991)

matters. Central to the practice of engineering is *design*, which is the creative engineering problem-solving activity. A universally-accepted definition of engineering design is elusive, and no formal attempt will be made here. However, according to Archer (1965), "the key element in the act of designing is the formation of a prescription or model of a finished work in advance of its embodiment." Hence, the methodology for design representation (i.e., Engineering Design Graphics) is fundamentally important to this activity called design.

Most engineers agree that design is a step-by-step, goal-oriented process that starts with a recognition of a problem and concludes with a detailed specification for its solution. The *design process* has been defined in many different ways by many different authors. No single unique description of the design process is applicable for all cases. However, all descriptions include some generic stages which form iterative pathways for the engineering designer. The process generally starts with a *definition* stage in which the problem is identified and ideas are generated. Some preliminary design solutions are developed during a *synthesis* stage. These design solutions are then evaluated for correctness and performance during an *analysis* stage. Iterations often occur to find an optimal design solution and the pathways may be re-traversed. Ultimately, the final specifications are detailed and conveyed during a *presentation* stage.

To illustrate this design process, it may be instructive to examine a few prevailing examples of the design process that are used in engineering education today. For students of Engineering Design Graphics, the design process by Earle (1989) has proven to be most useful. His design process comprises six fundamental stages consisting of the following activities:

1. Identify,
2. Ideate,
3. Refine,
4. Analyze,
5. Decide, and
6. Implement.

His design process logo (Figure 2) places each stage in a bubble sequentially forming a circle, which insinuates the iterative or recycling nature of the design process. Each of the stages are further broken down into activities which are readily identifiable by the novice student. His approach places emphasis on the graphical activities required at each stage, such as sketching during the ideation stage, scale drawings during the refinement stage, and working drawings during the implementation phase.

A design process commonly used in upper division engineering design courses is the one proposed by Dieter (1991) and illustrated in Figure 3. The key stages in his process include the following generic activities:

1. Feasibility Study,
2. Preliminary Design,
3. Detail Design,
4. Planning for Manufacture, and
5. Planning for Use.

His process emphasizes the need for creating details and modifying the details when needed. His block diagram portrays the traditional design representation era in which engineering drawings are the central link between design and manufacturing. However, there is also a recognition of the evolving design paradigm in this illustration. By including a design database component, Dieter is indicating an automation link between the computer-aided design (CAD) and computer-aided manufacturing (CAM) stages.

A final example of the design process is the ISI model recently articulated by Rodriguez (1990) and illustrated in Figure 4. His ISI model emphasizes the three process stages:

1. Ideation,
2. Simulation, and
3. Implementation.

The ideation phase starts with problem identification and includes the development of preliminary ideas. The simulation stage includes geometric modeling and design evaluation through analysis and animation activities. The implementation stage constitutes the final presentation of the design results. The iterative nature of the design process is emphasized by the circular orientation of the three phases and by the bidirectional pathways of the connecting arrows. The sharing of common data

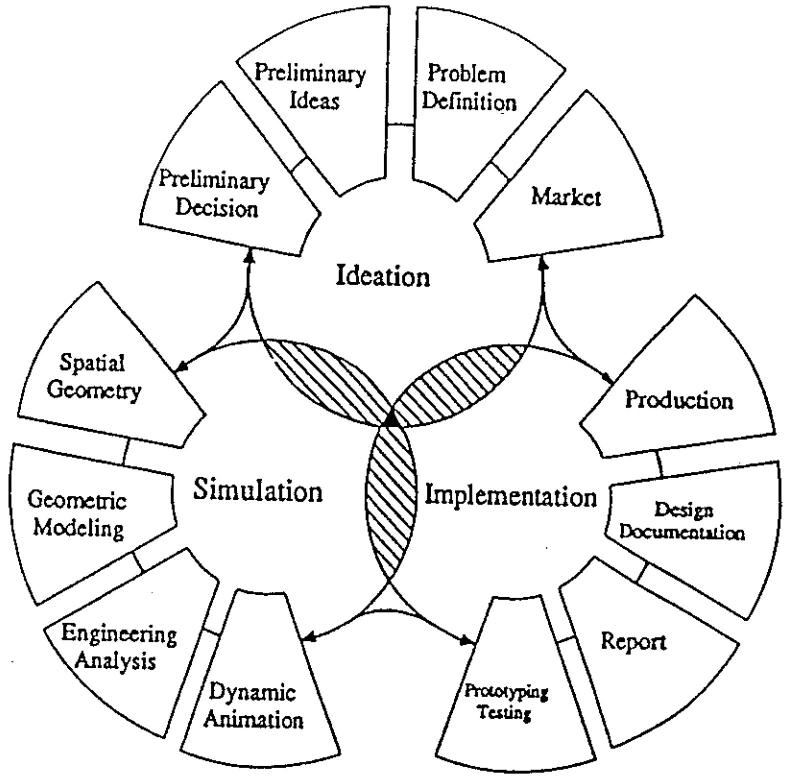

Figure 4. ISI Model of the Design Process (Rodríguez, 1990)

throughout the three stages of his design process can be inferred by the center intersection area in his diagram.

These previous examples illustrate the elusive nature of trying to formally define and depict the engineering design process in a manner that would be acceptable to all engineers. Many other examples could be cited which would only further point to the fact that *describing the design process seems to be a matter of personal choice.* Nonetheless, some general observations can be stated about the engineering design process. The engineering design process is a goal-oriented activity which starts with a definition of a problem and concludes with a presentation of its solution. This problem solving activity occurs in a methodical sequence of stages or sub-activities that are inter-related. The open-ended nature of engineering design problems suggests that the designer may have to recycle through the various stages in search of an optimal solution. These stages can be described with many different terms which seem interchangeable (see Figure 5). A general model for these engineering design stages that seems appropriate to relate the design process and the EDG process is proposed here as follows:

1. *Definition*,
2. *Synthesis*,
3. *Analysis*, and
4. *Presentation*.

The EDG Process and Its Relation to the Engineering Design Process

The EDG *Process* is the engineering function concerned with the development of design representation and with the conveyance of this design representation between the various stages of the design process. In the traditional EDG paradigm, the conveyance of design representation was based on engineering drawings. In the modern EDG process, the design representation shared between the process stages is the geometric data base. As in the case with the engineering design process, the EDG process enjoys no universal definition. However, since the EDG process is directly supportive of the engineering design process, its description should be a direct reflection of the design process description. One proposed model of the EDG process which has gained recent support (Rodríguez, 1990; Barr and Juricic, 1991; Bertoline, Bowers, McGrath, Pleck, and Sadowski, 1990) is:

1. *Ideation*,
2. *Development*,
3. *Communication*, and
4. *Documentation*.

In the present design paradigm, *Ideation* is the generation of creative ideas, usually through sketching. It is the first step in the EDG Process and is an activity that reflects the early stages of the design process. This step is best exemplified by McKim's (1972) circular process of seeing-imagining-drawing in which sketched ideas are defined and clarified in one's mind. *Development* is a stage in which the preliminary sketched ideas are transformed into accurate geometric descriptions or models. Traditionally, these descriptions consisted of scaled drawings which permitted accurate preliminary analysis of the design. Geometric computer models now seem to be the superior method for design development and synthesis.

Communication is the conveyance of the developed geometry for the purpose of design analysis. This could be, for example, the submission of a design drawing to a prototype shop where a preliminary model would be built and tested. It could also mean the communication of a geometric data base to a finite element analysis software package to test structural integrity. Here, communication implies an on-going, active process in which graphical descriptions and geometric models are revisited and optimized in accordance with analysis results. The final stage of the EDG process is *documentation* where a final set of detailed specification drawings

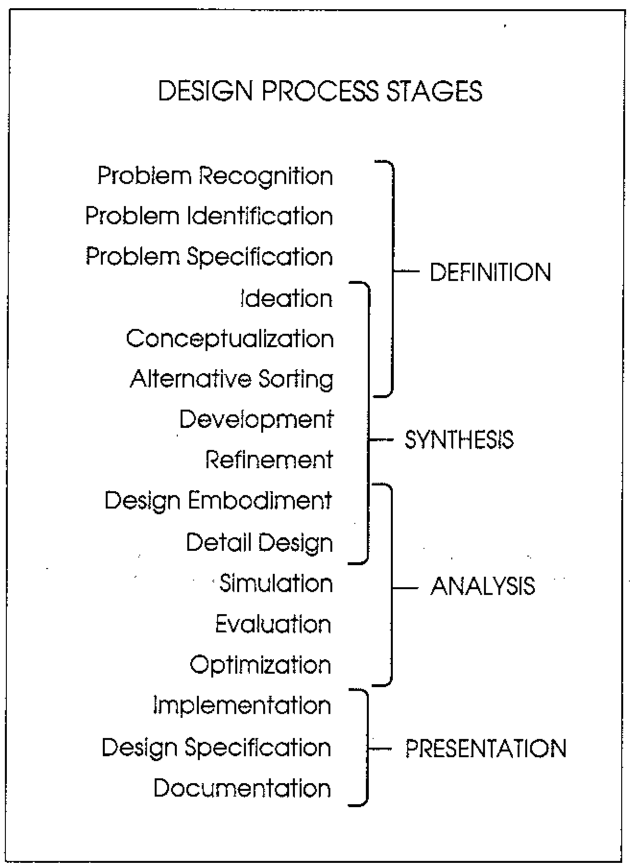

Figure 5. Variations for Terms Used to Describe the Engineering Design Process Stages

is presented. This is a less fluid stage than communication, since it is presumed that a final solution has been attained and the final drawings represent a terminal solution of the design.

The EDG Process Based on Geometric Modeling

Engineering Design Graphics is a field dedicated to the "knowledge and application of the [design representation] methodology and procedures needed for the development and conveying of design ideas" (Juricic and Barr, 1989). Traditionally, EDG was viewed as the intersection between the engineering, design, and graphics world spaces. With the development of modern 3-D computer graphics hardware and software technology, the knowledge and capabilities in each of these world spaces are changing. The traditional role of 2-D engineering drawings for design representation is being supplanted by the use of geometric models generated digitally through computer software. Indeed, the essential concept of *graphics* in the EDG process could be challenged by more appropriate terms like *modeling or representation.*

As illustrated in Figure 6, the Engineering Design Graphics (or Modeling, or Representation) Process can be represented by four generic stages: ideation, development, communication, and documentation. During the *ideation* phase, the engineer defines the problem and explores new ideas to solve the specified design problem. Freehand sketches are often used during the exploratory phase for "seeing ideas emanating from one's mind." These sketches can be made on whatever media is available, whether it be pencil and paper, chalkboard, or even a napkin. Since we inherently visualize in a 3-D world, sketching should concentrate primarily on pictorials.

The *development* phase begins with the creation of a geometric model, often initiated by the engineer's preliminary design sketches. Profile outlines in 2-D and 3-D solids can be created for initial geometric description. Quick software prototypes can be constructed and visualized in 3-D through the rendering capabilities of the computer graphics system. Feature-based systems, parametric techniques, and knowledge-based engineering would be particularly useful during this developmental modeling phase, when design changes are driven by visual observation, customer preferences, and professional experiences.

As the preliminary design solidifies, the refined geometric model and associated data base can be used as a means of *communication.* This communication link can be both model-to-human and model-to-machine. The computer-rendered geometric model can be used for discussion and evaluation by engineering groups. A rapid "hardcopy prototype" could be generated which could be viewed and felt by human touch. In the near future, the modeling software could drive a stereoscopic display and perhaps produce an "artificial sense of reality."

The geometric model data base can also communicate to other application software. The design can be analyzed for stress, flow, and heat transfer properties using Finite Element Analysis (FEA). Kinematic simulations can be run, and checks for clearance and interference can be made directly from the software model. As the design is analyzed and finalized, the resulting data base can communicate directly to numerically controlled manufacturing machines for fabrication. Results of these analyses and simulations can, in turn, communicate a need to modify the geometric model. While design analysis, manufacturing, and construction are not central topics to the EDG curriculum, it is important that the modern EDG process acknowledges and alludes to these applications of geometric modeling, which is the essential component of the EDG Process.

"Most engineers agree that design is a step-by-step, goal-oriented process that starts with a recognition of a problem and concludes with a detailed specification for its solution."

It is recognized that not all of these aforementioned capabilities are currently available in all engineering practices today. Hence, a final artifact of the modern EDG process is the generation of detailed engineering drawings directly from the geometric model. These drawings would include all the

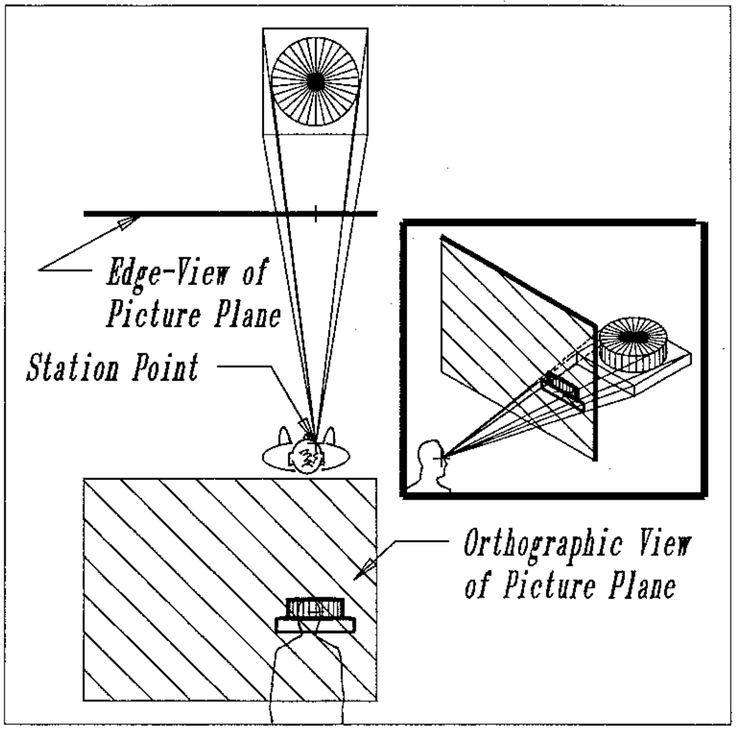

Figure 1

to represent geometry as beheld by the eye he early (first?) represents lines that are parallel in nature as intersecting lines. A century later Filippo Brunelleschi is probably the first to determine the station point and multiple vanishing points in a manner similar to the way we do today. Brunelleschi called his graphical solution: Perspectivi. Leon Battist Alberti's treatises in 1435, *De Pictura and Della Pittura (On Painting)*, codifies his own and Brunelleschi's developments and contains the first written account of one-point perspective. Although artists soon after produced detailed and elegant drawings from every viewpoint, they noticed that there is an anomoly, if, indeed, perspective drawings reproduce the image beheld by the eye. Artists found there is unequivocal distortion at the extremity of a correctly projected perspective drawing and that they must compromise the projection in order to compensate for the distortion.

It was in the the second half of the fifteenth century that Leonardo da Vinci first discovered there is a difference between a Classical Perspective Projection ("Artificial Perspective") image of an object and the object as it is beheld by the eye ("Natural Perspective"). Kepler is credited with enjoying an error discovered in Dürer's analysis of the orthographic projection of an ellipse in an inclined position. Such a projection is, of course, also an ellipse; Dürer mistakenly identifies it as egg shaped (he coined the word: Eierlinie). Because Dürer at the time (a century before Kepler) was also investigating the Artificial Perspective Projection of an inclined circle--which, if constructed by the box-in method (figure 4 and 5), is, indeed, egg shaped--it may be, this to which Dürer was referring. If true, then it is Dürer who first documents this aspect of Perspective Projection that has for so long plagued graphicians: that the Artificial Perspective of an inclined circle, using the box-in method, is not an ellipse. Dürer published his analysis of perspective projection in a mathematical treatise, *Instruction in Measurement with Compass and Ruler in Lines, Planes and Solid Bodies.*

Artificial Perspective Projection

Definition

Artificial Perspective Projection is that branch of projective geometry in which projectors from all points of an object project to one concurrent point ("Station Point") and an image projectively created thereby upon an arbitrarily located plane of projection. There is no restriction on the placement of the plane of projection ("picture-plane") other than it may not contain the concurrent point. The picture plane may incline at any angle with any particular projector, including the centerline of the cone of vision; it may be located between the Station Point and the object, or it may be located otherwise. Figure1 is a typical arrangement.

Distortion

When Brunelleschi developed his approach to Artificial Projection, he, as most after him, did not question whether the (orthographic projection of the) image that is perspectively projected upon the picture plane is the same image of the object as beheld by the eye from the Station Point. Figure 2 illustrates that there is a difference: the object being projected is rotated about the Station Point so the object being projected appears unchanged to the eye; nevertheless, the orthographic projections of the *images from the picture-plane* confirm they are different, and different images cannot simultaneously represent the (one) image beheld by the eye.

The above notwithstanding, there is a circumstance in which both Artificial and Natural Perspective do appear the same to the eye: when the image on the Artificial Perspective picture plane is viewed from space with the eye precisely at the Station Point. At that position the distortion induced by the angles between the eye's lines of sight and the surface of the picture plane exactly compensates for the distortion of the Artificial Projection image itself. To apply this to a drawing: if a Station Point is constructed, say, three inches from the picture plane, then in order for the drawn image to appear the same to the eye as the object itself, the drawing must be viewed with the eye three inches from the paper (and, naturally, also at the corresponding horizontal and vertical positions).

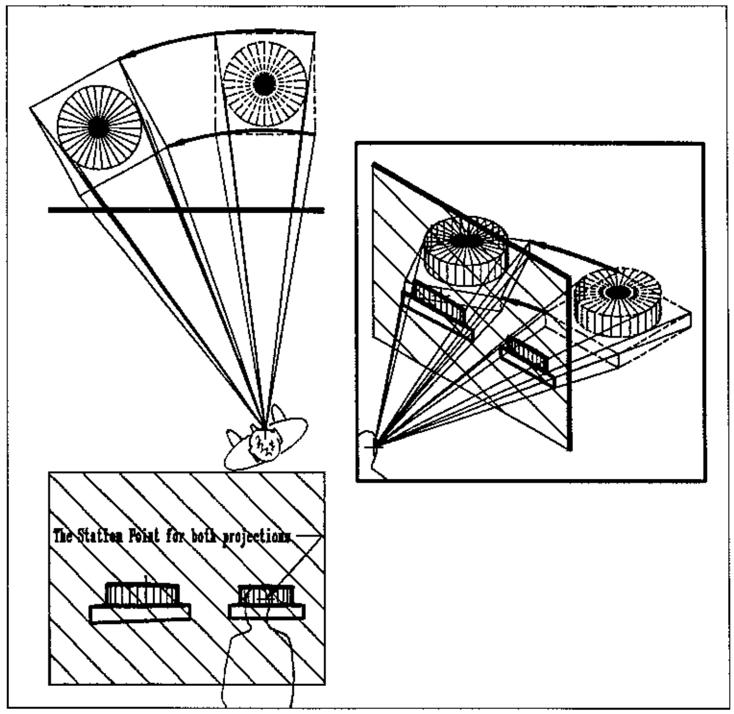

Figure 2

The Nature of he Distortion

To demonstrate the nature of the distortion of Artificial Perspective Projection, a twelve inch triangular scale is perspectively projected onto a picture plane and the image compared with the true shape (Orthographic Projection) of the scale. (See Figure 3) To test for non-linear distortion: corresponding scale divisions of the orthographic and the perspective images are connected, and the connections tested for parallelism. The test reveals that Artificial Perspective Projection distorts the image non-linearly. The nonlineairty is of the second degree because the angles between the connections change at a steady rate (not demonstrated here).

The Circle

To further demonstrate the nature of the distortion, foreshortened inclined and oblique circles are investigated. The perspectives are produced by two techniques: the Boxed-In technique and the Point-Plotting technique.

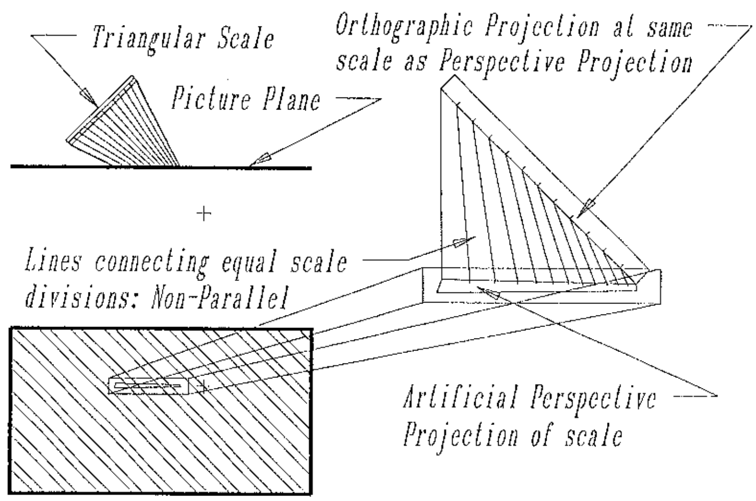

Figure 3

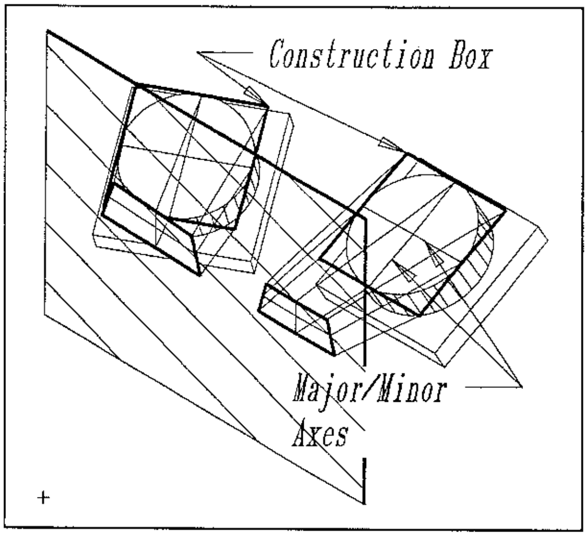

Figure 4

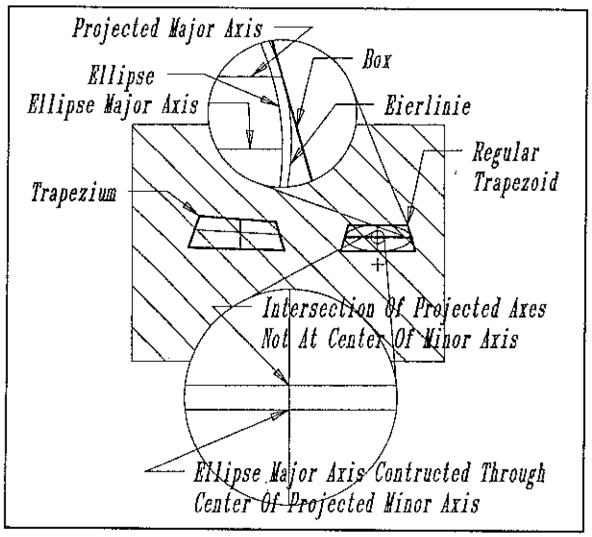

Figure 5

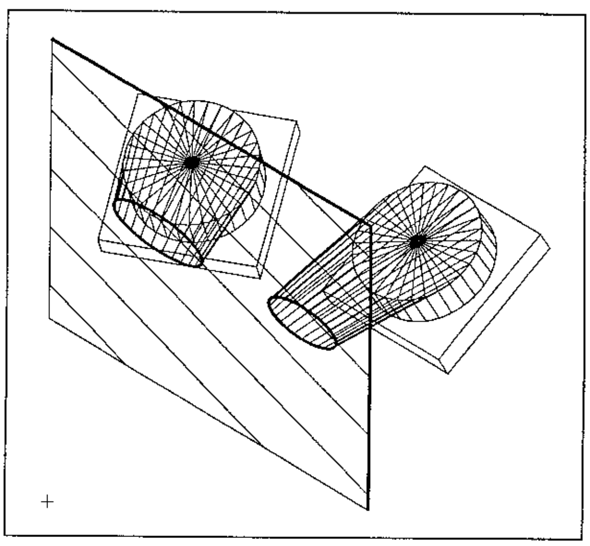

Figure 6

Notice that for the demonstration the objects in Figure 2 are tilted with the horizontal plane so the tops of the cylindrical shapes are visible from the station point.

Box-In Technique

This technique involves a construction box in the plane of and tangent to the circle. The construction box is projected to the picture-plane and a French curve fitted within the resulting trapezium shape to represent the foreshortened circle. The shape of the trapezium depends upon whether the plane of the circle is oblique or inclined, and upon the direction of the cone of vision relative to the picture-plane. The resulting curve is either a free form type of curve or an egg shaped line (eierlinie). In neither case is it an ellipse. Note that if the centerlines of the circle are projected to become the major and minor ellipse axes, the major axis does not project to intersect at the midpoint of the minor axis. (See Figures 4 and 5)

Point-Plotting Technique

This technique involves projecting points of the circle onto the picture plane. Note that the projectors from the object define an elliptical cone to the station point; this elliptical cone of vision is cut by the picture plane; therefore, the resulting image is, indeed, an ellipse. As it is with all Artificial Perspectives, the ellipse does not appear the same as the ellipse beheld by the eye unless viewed from the station point. (See Figure 6)

The Horizon Line

Another source of distortion is with the line that represents the horizon of the earth. It is commonly assumed to appear at eye level. (See Figure 7)

This error becomes apparent as the horizon evolves into a circle as one travels into space. (See Figure 8) The source of the error: the wrong horizon is considered. *(Where the paper speaks of horizon, it refers to the abstract limit of an infinite plane. As is demonstrated below, a geometric line may realistically - not merely, theoretically - represent this limit to our eyes. Therefore, horizon may or may not imply a line. Where this paper speaks of horizon line, it refers to the geometric line that represents the limit of an infinite plane to our eyes.)*

Consider the following thought experiment:

Imagine that you are standing on the earth, i.e., a bald sphere, and looking at the earth horizon. It seems at eye level. Then imagine there is an infinite plane tangent to the earth at the point you are standing. (See Figure 9) It is the horizon of this plane that appears at eye level and which remains so at any position of the universe as you travel perpendicularly to the plane. (From this, it follows that parallel infinite planes appear to have the same horizon.) When standing on the earth, the earth horizon line appears slightly below eye level, i.e., slightly below the infinite plane horizon line. (See Figure 10) For practical purposes this displacement is insignificant, especially compared to the inherent distortions mentioned earlier.

It is interesting to speculate if an infinite plane has a horizon (line). This paper suggests that it appears to our eyes too. By the same argument that the sum of an infinite series can be determined, so too the apparent limit which an infinite plane approaches asymptotically can be determined for our eyes. If, then, the plane is considered opaque, the plane horizon becomes apparent for our eyes. Further, the aparent horizon line of any plane in space can be determined: merely draw two non-parallel sets of parallel lines on the surface; stand back, and eye-ball align a straight edge to appear to coincide with one parallel line; repeat with another line parallel to the first line. Where the two alignments appear to intersect is a point on the horizon of the (infinite) plane. If the plane happens to be horizontal, the horizon line will be horizontal through the point. If the plane is not horizontal, repeat the process with the remaining set of parallel lines to determine a second point on the horizon. The two points define the horizon line.

In space, each horizon line is determined by its infinite plane. The only reasons

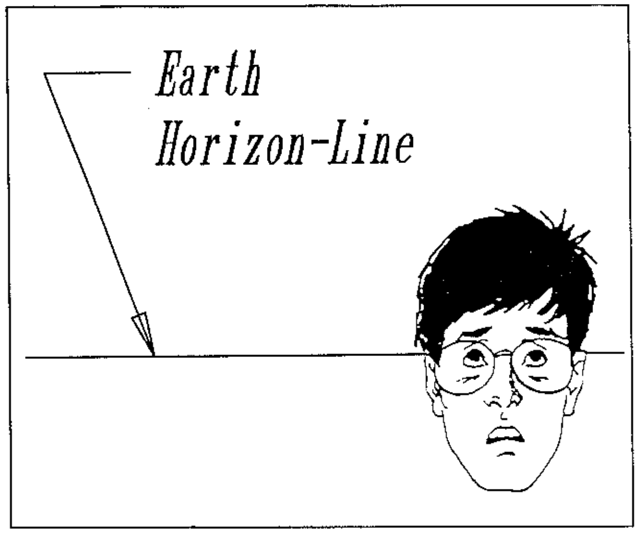

Figure 7

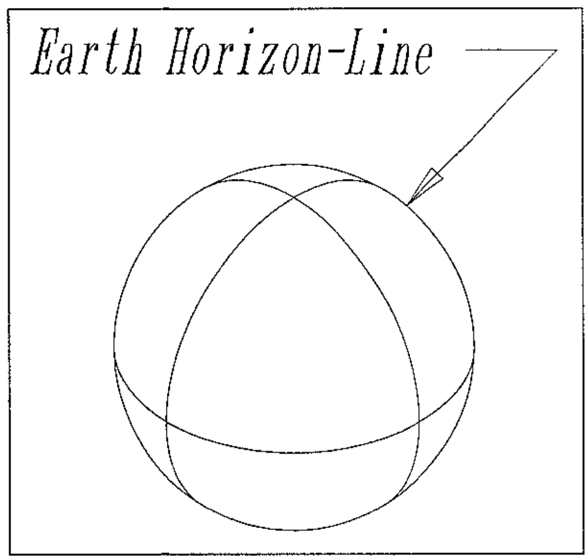

Figure 8

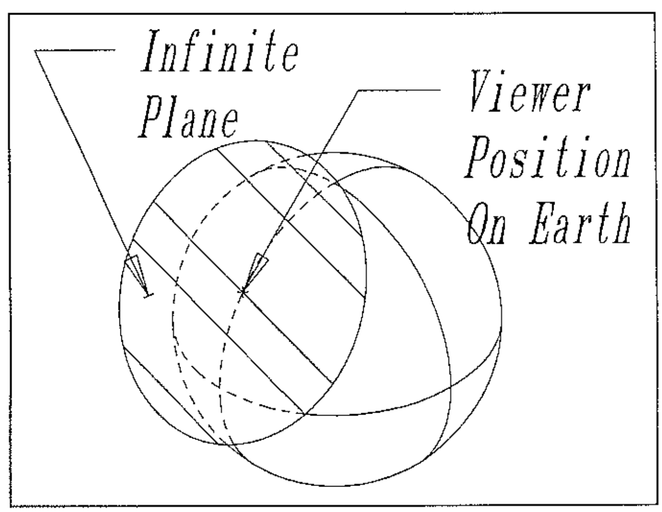

Figure 9

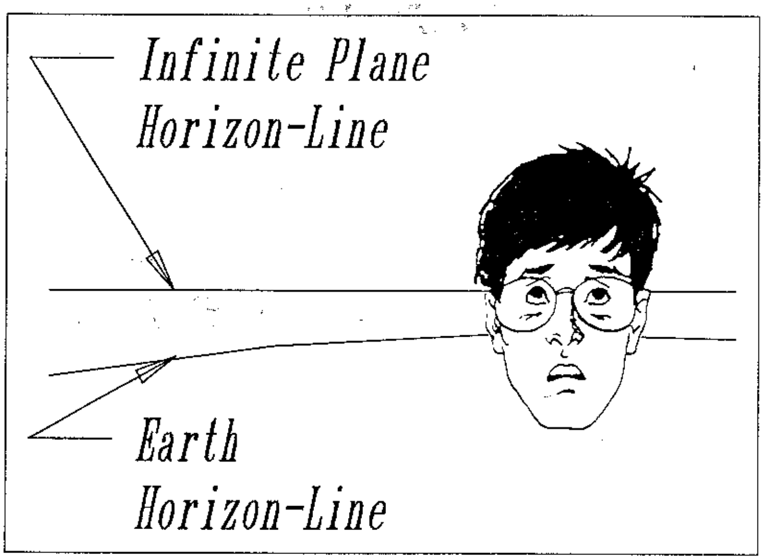

Figure 10

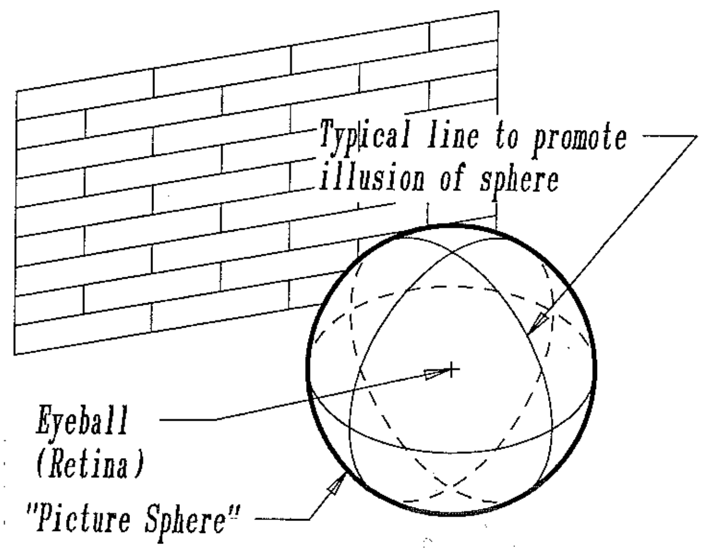

Figure 11

that the earth's horizon is useful are:

1. because from our vantage near to the earth the earth horizon is a good approximation of the horizon of the tangent plane, and

2. because of the many lines (usually architectural) on planes parallel to the earth, i.e., parallel to the tangent plane.

Vertical planes also have their horizon lines. A "Three-Point Perspective" is an accommodation to a vertical plane in combination with a horizontal plane. But there is no reason there should not be a "Zillion-Point Perspective" if there are a zillion non-parallel planes in a perspective projection.

NATURAL PERSPECTIVE PROJECTION

Definition

Natural Perspective Projection is the image of spatial geometry as it is beheld by the eye.

Distortion

That there is distortion in the image beheld by the eye is not immediately apparent on a day-to-day basis because we experience nothing else visually throughout our lives, but on reflection there is an obvious contradiction that has not been fully explained: Why do straight parallel lines in space appear to intersect **twice**? The following thought experiment illustrates the contradiction:

> Imagine that on an infinite plane there is an infinitely long and infinitely straight railroad and that you are standing between the parallel rails. As you peer down the track in one direction the rails appear concurrent. As you peer in the opposite direction they again appear concurrent. You look at your feet and the rails are far apart. It logically follows that one or both of the rails are curved. To determine which, you put your eye onto one rail and sight down it. You discover it is straight in the sighted direction. You then sight down the same rail in the opposite direction. You discover it is straight also in the opposite direction. It logically follows, then, that the other rail must be curved. You similarly test the other rail and discover it too is straight. How can this happen?

The explanation lies in an extension of Alhazen's discovery: the conical (concurrent) projections of spatially parallel straight lines create concurrent straight line images on surfaces of projection. (The exception: if both the surface of projection is planar and the spatially parallel lines are parallel to the plane of projeciton.) However, for the spatially parallel lines to appear straight and also to appear to intersect twice, the surface of projection must be spherical. (Be reminded that (a) perspective projections of straight lines in space, through the center of a sphere, projectively create great circles on the picture sphere, and (b) that the great circles appear as straight lines when viewed from the center of their sphere. This is the reason why the Natural Perspective Projection of the rails of our thought experiment are actualy circular yet appear straight. That this is consistent with our normal vision implies that the retina functions as though it is spherical shape, if, indeed, it is not actually spherical shape. Therefore, to produce the image that the retina beholds using projective geometry techniques, substitute a **spherical** surface of projection for the **plane** of projection, i. e., use a "picture sphere" rather than a "picture plane." Place the eye or "station point" at the center of the picture sphere. (See Figure 11)

Figure 12 shows that the perspective projection of the horizontal top line of a wall intersects at the retina (actually, at the focal point in front of the retina). The intersecting lines define a plane that intersects the sphere of projection in a great circle.

Figure 13 shows the projection of the horizontal bottom line of the wall and its great circle of intersection.

Figure 14 shows that the two great circles of intersection intersect. The two points of intersection are two (vanishing) points on the horizon line of the plane of the wall as seen from the center of the picture sphere. The points of intersection are analogous to the two points of intersection as one peers down a railroad track **in both directions**.

Observe at this stage that a horizon line of the wall is not yet determined. It is demonstrated below that a horizon line is determined by vanishing points only.

Note

It is fundamental to Artificial Perspective that spatially parallel lines project to appear concurrent. This paper has so far demonstrated (1) that Artificial Perspective

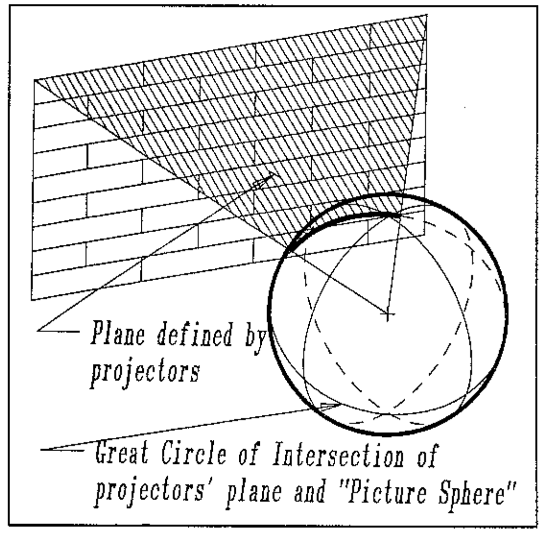

Figure 12

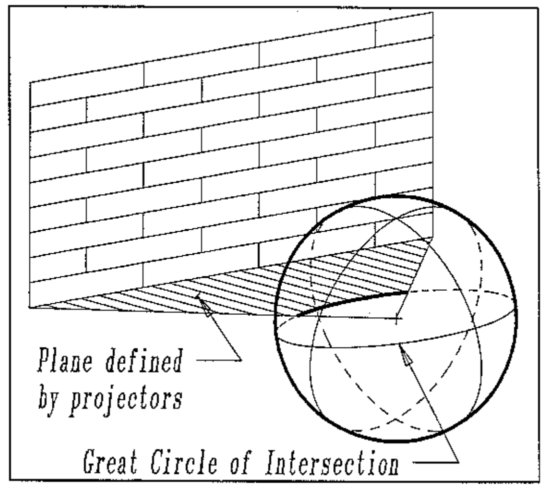

Figure 13

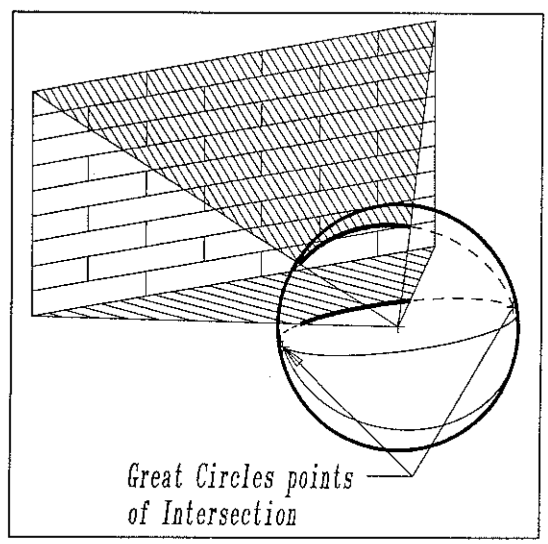

Figure 14

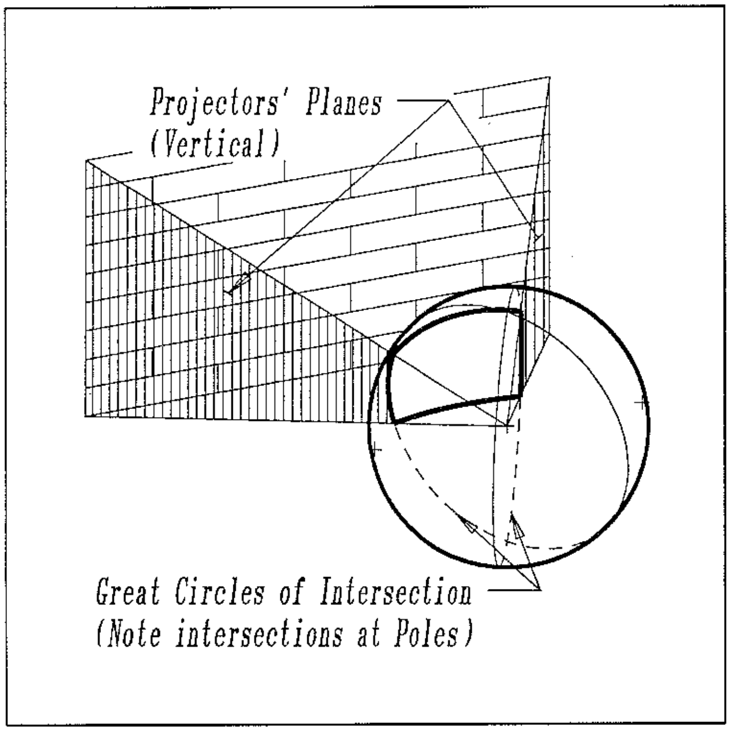

Figure 15

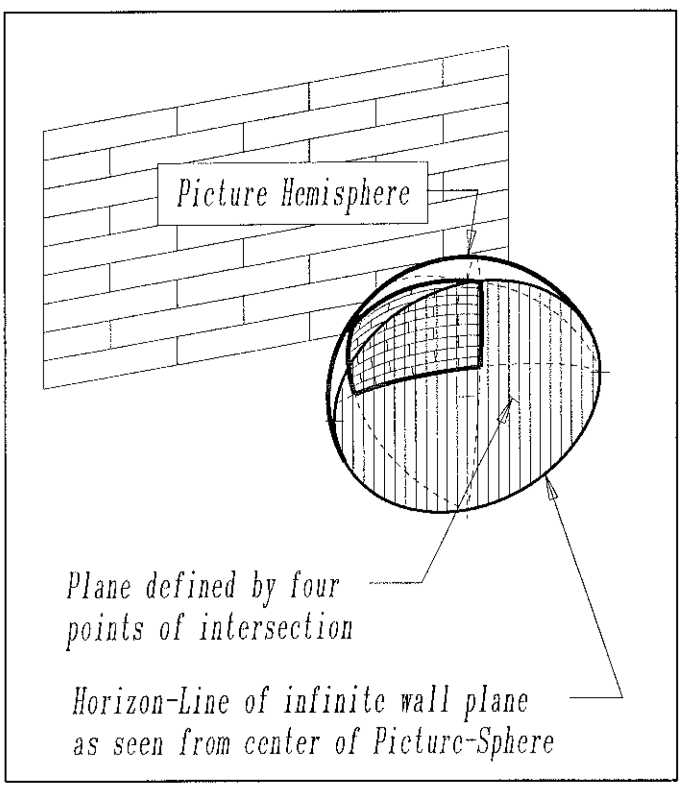

Figure 16

Projection distorts non-linearly and (2) that Natural Perspective projects spatially parallel lines (a) to appear straight and (b) to intersect in two places.

Figure 15 shows the perspective projection of the two vertical ends of the wall and their two great circles of intersection. Note that the two great circles intersect at the north and south poles of the picture sphere. These two points create two more (vanishing) points on the horizon of the plane of the wall.

Figure 16 shows the circle of intersection between (1) the plane defined by the four vanishing points of the plane of the wall and (2) the picture sphere. The circle is the horizon of the plane of the wall as seen from the center of the picture sphere.

Note

Horizontal and vertical lines are used in the illustrations. In fact any two sets of parallel lines on the wall could be used; the same circle of intersection, i.e., the same horizon line, is defined.

The Nature of the Distortion

That the Natural Perspective also produces non-linear distortion may be inferred from our thought experiment with the railroad: if the railroad has equally spaced crossties, the equal spaces appear smaller at an uneven rate as the horizon is approached. That the uneven rate of change seems to accelerate as the horizon is approached suggests a third or higher degree of non-linearity.

The graphical proof of this is not as straghtforward as with Artificial Perspective because it is impossible to replicate on a plane the image beheld by the eye (unless the spatial eye position from which to view the plane is also specified). The suggested procedure is to link in (virtual) space the crosstie images that are on the picture-sphere with their corresponding ties on the railroad in space and determine if the rate of change of the adjacent angles varies.

The reason it is impossible to accurately produce Natural Perspective Projection on a plane surface (page) because it is impossible to accurately develop a sphere into a plane. (Similarly, a photograph can never accurately reproduce the image beheld by the eye because the photosensitive film surface is

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Effect on Spatial Visualization: Introducing Basic Engineering Graphic Concepts Using 3D CAD Technology

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Abstract

Computer Aided Design technology has revolutionized the way geometry is conceptualized and described. Yet, instructional strategies in engineering graphics have not taken advantage and/or kept pace with this technological revolution. This study attempted to evaluate Computer Aided Design technology's 3D wireframe modeling capability in fostering spatial visualization abilities while introducing basic projection theory to beginning level engineering graphics students.

Introduction

The principle goal of courses in engineering graphics is to help students develop abilities in spatial visualization. Horton suggests a definition for visual thinking which also defines spatial visualization and captures the essence of the principle goal of engineering graphics: "it is the ability to create images in our minds to help store information, make decisions and solve problems" (Horton, 1982 p. 23). Yet, students in engineering and technology have little prior training in visualization using graphics (Sommer, 1978, p.54). The only exposure to graphics many of these students receive in their higher education experience is one or possibly two courses in engineering graphics. With so little time to expose students to the power that spatial visualization offers, it is imperative that spatial visualization instruction be as efficient as possible. The author's experience using 3D CAD in advanced graphics courses indicated the potential of 3D CAD as an instructional tool for fostering visualization abilities in beginning level engineering graphic courses. However, simply incorporating 3D CAD technology in a graphics curriculum does not guarantee that students will reap its inherent benefits. Instructional materials and methods must be properly developed and tested to ensure that 3D CAD will be integrated in an effective and efficient manner.

3D CAD's potential as an instructional tool for fostering spatial visualization abilities and the belief that instructional methods in engineering graphics have not kept pace with the rapid changes in this technology, were driving forces for this research. However, it was the following statement by Victor Wright, Vice President of engineering for VBM Corporation, that convinced this author that such research was urgently needed.

I [Victor Wright] submit that 3D modeling is one of the most important facilities that CAD has to offer for precisely the reason that too many designers do not think in three dimensions, but in two. For them, drafting is not a matter of transposing a 3D model into 2D orthographic views, but an iterative process of creating and cross-checking 2D models. At best, their drawings are littered with unnecessary sections and auxiliary views; at worst, the required views are inconsistent. Nor can they clarify their three-view drawings with 3D models, because they have no prototype mental 3D model (MicroCAD News, August, 1990, p. 34).

Spatial Visualization: What Is It? and Can it be Taught?

The difficulty researchers have had and are still having in determining the exact nature of spatial visualization is reflected by the comments of Linn and Petersen who wrote "it is generally agreed that spatial ability is an important component of intellectual ability, yet its nature remains to be clarified" (1985, p.1479). Despite the lack of a unanimous consensus, there appears to be sufficient agreement in research to justify the acceptance of two basic factors of spatial visualization (Ekstom, French, and Harman, 1976; Guilford, Frutcher, and Zimmerman, 1952; McGee, 1979; Thurstone, 1938). McGee uses the terms spatial visualization and spatial orientation to describe these two factors. He defines spatial visualization as "the ability to mentally rotate, manipulate, and twist two- and three-dimensional stimulus objects" and spatial orientation as "the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude to remain unconfused by the changing orientations in which a spatial configuration may be presented, and an ability to determine a spatial orientation with respect to one's body" (1979, p.909). The existence of two factors of spatial visualization warranted the use of two tests in this research, one designed to measure each of the factors.

Another important issue which directly effected this study was the question of whether spatial visualization ability is: 1) a factor that can be learned and enhanced through direct training; 2) an innate ability which can be developed through training; or 3) an innate ability with a fixed degree of proficiency. Research findings on this issue are mixed. Some research has found no significant improvement of spatial visualization due to training as measured by spatial tests such as the Surface Development Test (Churchill, Curtis, Coombs, and Harrell, 1942; Faubion, Cleveland, and Harrell, 1942). Yet others have found that training specifically directed at improving spatial visualization abilities has resulted in significant improvements in spatial visualization ability (Brinkmann, 1966; Lord, 1985; Dorval and Pepin, 1986; Kyllonen, Lohnman, and Snow, 1984). Although the above research results are mixed, there appears to be sufficient evidence to conclude that it is possible to improve spatial visualization ability if: 1) the training is appropriately designed and 2) implemented for an adequate length of time.

". . . it is generally agreed that spatial ability is an important component of intellectual ability, yet its nature remains to be clarified."

Problem Statement

The study compared two fundamentally different instructional approaches for teaching beginning level engineering drawing. The new instructional approach abandoned the traditional methods of introducing orthographic projection in favor of a three dimensional computer aided drafting (3D CAD) approach. The traditional method emphasized third angle projection, the "glass box" paradigm, planes of projection, folding lines, a changing of the position of the observer to obtain different views, and the belief that 2D CAD must be a prerequisite to using 3D CAD. The nontraditional 3D CAD approach purposely avoided such traditional concepts and methods. Instead, basic graphic concepts, particularly orthographic projection, were introduced through the development and manipulation of 3D CAD wireframe models. The 3D wireframe model acted as the focal point around which all other engineering graphics concepts were introduced. The study was an attempt to discover if a 3D CAD instructional approach would be more effective in improving students' spatial visualization ability than traditional instructional methods used in engineering graphics.

Sampling

The sample was drawn from the population of undergraduate male students enrolled at Ohio University in the College of Engineering and Technology during the fall 1990 and winter 1991 quarters. The subjects majored in one of the following disciplines: electrical engineering, civil engineering, industrial and systems engineering, mechanical engineering, or industrial technology. In each of the fall and winter quarters, two sections out of a possible six sections of IT 101 Engineering Drawing I were selected. The two sections chosen for fall 1990 made up the control (traditional) group while the two sections chosen in winter 1991 made-up the experimental (3D CAD) group. The total number of subjects was 40 for the control group and 31 for the experimental group.

IT 101 Engineering Drawing I is a required course for all the majors mentioned above. Students in IT 101 Engineering Drawing I were chosen as the population because IT 101 has no prerequisites and the majority of students taking this course have had no prior experience in engineering graphics. Although females do take IT 101, sufficient data upon which to make any judgement regarding the influence of a subject's sex on the dependent variables could not be obtained due to the small number of females enrolled per section. To avoid suspicion of special treatment, the females enrolled in IT 101 were pre and posttested but the data collected from the females were not included in the analysis.

Treatment

Both the control and the experimental groups were instructed by the author to help ensure consistent treatment as no other engineering graphics instructor had sufficient experience using the 3D CAD database approach for teaching basic engineering graphics concepts.

The control group completed approximately seventy percent of its drawings manually and thirty percent on 2D CAD, while the experimental group completed all its drawing assignments on 2D and 3D CAD. It is important to point out that the 2D CAD assignments for the experimental group were designed to introduce students to the CAD software commands and intentionally avoided any instruction on the basic concepts of engineering graphics and projection theory. Concepts of engineering graphics were introduced using 3D CAD wireframe models.

A major difference between the treatment of the control and experimental groups was the manner in which the topic of orthographic projection theory was introduced. Projection theory was introduced to the control group using the very traditional approach found in every major engineering graphics text i.e. third angle projection, folding lines, and the paradigm of the "glass box". The "traditional" method of introducing projection theory was supported by the use of the text Engineering Graphics (1987) 5th Ed. by Giesecke, Mitchel, Spencer, Hill , and Dygon. Projection theory for the experimental group was introduced by the creation and manip-

1.

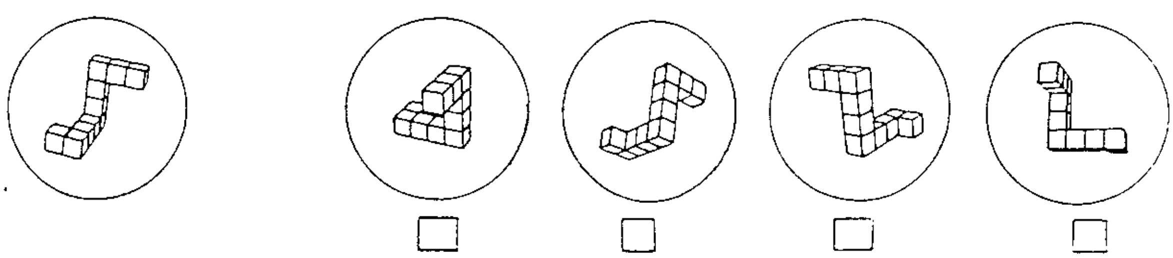

Figure 1. Example of a Mental Rotation Test question used to measure the factor of spatial visualization. (Vandenberg and Kuse,1971)

ulation of a 3D wireframe model using CADKEY Educational Version 1.42E software. To avoid having the subjects become prejudiced by traditional approaches, the experimental group used the text Concepts of Technical Graphics by Jon M. Duff. Duff's approach to introducing projection theory supports the abilities of 3D CAD software and compliments the manner of presentation used with the experimental group.

Instrumentation

Achievement measures such as exams, drawing plates, CAD assignments, or standardized drafting achievement tests were deemed inappropriate in testing an increase in spatial visualization abilities. Such measures typically concentrate on drawing proficiency and understanding of technical knowledge. To assess the two factors of spatial visualization and spatial orientation in the pretest and posttest, two measures were used: 1) the Mental Rotation Test [MRT] (1971) by S.G. Vandenberg and A. R. Kuse was used to measure the spatial visualization factor, and 2) the Guilford-Zimmerman Aptitude Survey Part V Spatial Orientation [GZ] (1947) by J. P. Guilford and W. S. Zimmerman was used to measure the spatial orientation factor.

The MRT consists of twenty items in a visual multiple choice format (Figure 1). Each question presents a criterion figure to the left which is a pictorial view of ten assembled opaque cubes. The examinee must choose two correct alternatives from four possible answers on the right. The correct alternatives have the identical configuration as the criterion figure, but have been rotated about a vertical axis resulting in a different view of the given criterion figure. The distracters are either a mirrored image of the given criterion figure or are a set of cubes assembled in a different configuration.

The reliability of the MRT is .88 using Kuder-Richardson formula 20 based on a "n" of 3268 adults and adolescents. Validity was demonstrated by calculating Pearson correlations with a variety of other spatial tests with results ranging from r = .31 to .68. These correlations and additional testing show "that the Mental Rotation Test compares well with other tests of spatial ability, especially tests of spatial visualization" (Vandenberg and Kuse, 1978, p. 602).

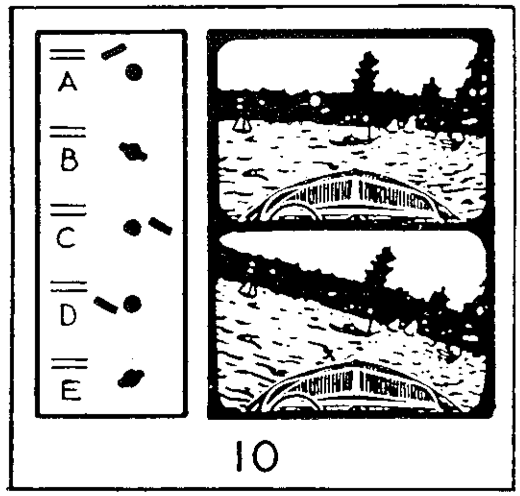

Figure 2. Example of a Guilford-Zimmerman Aptitude Survey Part V Spatial Orientation question used to measure the factor of spatial orientation. (Guilford and Zimmerman, 1947)

The Guilford-Zimmerman Aptitude Survey Part V Spatial Orientation consists of sixty questions (Figure 2). Each question consists of two pictures positioned vertically one over the other. The top picture gives a view as one is standing in a boat looking out over the bow of the boat at a distant scene. The bottom picture is similar to the top picture except that the boat has moved, resulting in a new view as one looks out over the bow of the boat. The objective is to determine, from five possible answers, the direction the boat has moved in order for the resulting view to be possible.

The reliability for the GZ is .89 using Kuder-Richardson 21 formula based on a "n" of between 2,617 to 2,728 college men. A factor validity measure of .58 is reported based on a sample of 500 male college students [a factor loading of .60 and above is considered good for a factor test] (Consulting Psychologists Press, 1981, p.9).

The attitude of the participants toward the subject matter of the IT 101 Engineering Drawing I course was ascertained using the Gable-Richardsons Attitude Toward School Subjects [GRASS] (Gable, 1983). The reliability of the GRASS reported by stating the alpha reliability of the three subdivisions of the questionnaire: General Interest (11 questions) .94, Usefulness (5 questions) .70, and Relevance (3 questions) .59.

Research Design

A quasi-experimental design was used for the present study as true random sampling of subjects and random assignment to treatments was not possible. The design is based on the Nonequivalent Control Group Design No. Ten suggested by Campbell and Stanley (1963). Figure 3. illustrates the basic design where O represents the taking of measurements of the dependent variables, X the experimental treatment, and the line indicates that the comparison groups are not equated by random assignment.

Basic Research Design

Experimental	O	X	O
Control	O		O

Figure 3. Basic Research Design (Campbell and Stanley, 1963, p.47)

The top row represents the experimental group which was pretested before any instruction took place. Instruction, based on the experimental instructional method discussed above, proceeded for the ten week quarter followed by posttesting. The bottom row represents the control group which was pretested before any instruction took place. The control group then received instruction in a traditional manner followed by posttesting at the end of the ten week quarter.

Data Analysis

For the analysis of the data a two-way multivariate analysis of covariance (two way MANCOVA) was utilized. The first independent variable was the method of instruction having two treatment levels: 1) manual / 2D CAD traditional instructional method, and 2) 3D CAD non-traditional instructional method. The second independent variable was the student's major, having two treatment levels: 1) mechanical engineering major, and 2) non-mechanical engineering majors . The study included the two levels for the independent variable, student major, because research by Blade and Watson (1955) showed that mechanical engineering students scored consistently higher on measures of spatial visualization than non-mechanical engineering students. The two dependent variables were the resulting score from the: 1) MRT Posttest and 2) the GZ Posttest.

Method of Instruction

Student's Major	Traditional	3D CAD
Non-mechanical	MRT/GZ	MRT/GZ
Mechanical	MRT/GZ	MRT/GZ

Figure 4.
Structure of the Variables and Treatment Levels.

The MRT and GZ Pretests were used as covariates to help control any initial differences in visualization abilities between the control and experimental groups. Two other factors were evaluated as possible covariates: 1) experience in a spatially oriented course such as art, blueprint reading, or mechanical drawing as determined by a demographic survey, and 2) students' attitude toward the subject of engineering graphics ascertained by the GRASS survey. Figure 4 provides an illustration of the structure of the basic analysis.

The statistical hypotheses tested were:

Ho1 : There is no significant difference between the measure of spatial visualization in engineering graphics students taught using manual/2D CAD traditional methods and 3D CAD non-traditional methods.

Ho2 : There is no significant difference between the measure of spatial visualization in engineering graphics students majoring in mechanical engineering and non-mechanical engineering students.

Ho3 : There is no significant interaction between an engineering graphics student's major and the type of instructional method.

Correlation tests indicated that there was no significant correlation between prior experience and the dependent measures of the MRT Posttest ($r = .02$) or GZ Posttest ($r = .04$). It was therefore decided not to include prior experience as a covariate. Correlation tests indicated that student's attitudes toward the subject matter of drafting as determined by the GRASS survey were not correlated with the dependent measures of the MRT Posttest ($r = .29$) or GZ Posttest (r = .13). It was therefore decided not to include attitude toward school subject as a covariate.

The collected mean scores for the MRT and GZ Posttests are given in Table 1 displaying both the observed means and the adjusted means. The adjusted means are a result of the effect of the covariates MRT and GZ Pretests. It should be noted that the adjusted means do differ from the observed means indicating that the covariates had some, though minor, effects.

The MANCOVA analysis was performed using the collected data to determine if there was a significant difference in the means in order to accept or reject Ho1: There is no significant difference between the measure of spatial visualization in engineering graphics students taught using manual/2D CAD traditional methods versus 3D CAD non-traditional methods. The results of the MANCOVA statistical analysis are given in Table 2. Using a level of significance of p .05, there was no significant difference in the means of the two teaching methods, Traditional and 3D CAD, and therefore Ho1 could not be rejected.

The MANCOVA analysis was performed using the collected data to determine if there was a significant difference in the means in order to accept or reject Ho2 : There is no significant difference between the measure of spatial visualization in engineering graphics students majoring in mechanical engineering versus non-mechanical engineering students. The results of the statistical analysis are given in Table 3. Using the level of significance p .05, there was no significant difference in the means of the two levels of Student's Major, Non-mechanical and Mechanical, and therefore Ho2 could not be rejected.

The MANCOVA analysis was performed using the collected data to determine if there was a significant difference in the means to determine to accept or reject Ho3: There is no significant interaction between a engineering graphics student's major and

MRT and GZ Posttest Cell Means

Student's Major		Traditional		3D CAD	
		Observed Mean	Adjusted Mean	Observed Mean	Adjusted Mean
Non-mechanical	MRT	28.31	26.94	24.72	26.6
	GZ	32.52	31.64	26.8	28.35
Mechanical	MRT	28.55	26.76	29.83	31.11
	GZ	28	27.96	31.17	30.59

Table 1.

Statistical Results of the Main Effects on Teaching Method

Test Name	Value	Approx. F	Hypoth. DF	Error DF	p
Pillais	.02671	.87822	2.00	64.00	.42
Hotellings	.02744	.87822	2.00	64.00	.42
Wilks	.97329	.87822	2.00	64.00	.42

Table 2.

Statistical Results of the Main Effects on Student's Major

Test Name	Value	Approx. F	Hypoth. DF	Error DF	p
Pillais	.034460	1.14213	2.00	64.00	.326
Hotellings	.035690	1.14213	2.00	64.00	.326
Wilks	.966554	1.14213	2.00	64.00	.326

Table 3.

Statistical Results of the Interaction Effects of the MANCOVA

Test Name	Value	Approx. F	Hypoth. DF	Error DF	p
Pillais	.05706	1.93635	2.00	64.00	.153
Hotellings	.06051	1.93635	2.00	64.00	.153
Wilks	.94294	1.93635	2.00	64.00	.153

Table 4.

the type of instructional method with respect to spatial visualization ability. The results of the statistical analysis are given in Table 4. Using a level of significance of p .05, there was no significant interaction between a engineering graphics student's major and the type of instructional method , and therefore Ho3 could not be rejected.

The statistical analysis showed that the MRT Pretest and the MRT Posttest were significantly correlated with an r = .74 and the GZ Pretest and the GZ Posttest were significantly correlated with an r = .52 (both values were significant at a .001 level of significance). The need for using both the MRT and the GZ to insure a measure of both factors of spatial visualization and spatial orientation is questionable.

Discussion

The statistical tests performed on the data collected found no significant differences in students' mean scores of spatial visualization measures regardless of the method of instruction i.e. traditional or 3D CAD. Although this indicates that the new 3D CAD instructional approach did not prove to be more effective in increasing the visualization ability of students over the more traditional approach, it can be concluded that the 3D CAD method was as effective as the traditional approach. These findings should help instructors feel comfortable about using the 3D wireframe model capability of CAD technology to introduce basic graphical concepts in a beginning level course in engineering graphics.

"Postponing the use of 3D CAD will only reduce the amount of exposure a student receives to industries' design and production tool of the present and future."

Using the 3D CAD approach forces the instructor to set priorities and clearly state goals and objectives. This task must be performed because some traditional material, concepts, and/or methods of teaching engineering graphics will need to be changed due to the nature of 3D CAD technology.

The 3D capacity of CAD systems are often considered advanced concepts and techniques that should follow after students have acquired a command of traditional 2D concepts and 2D CAD. The findings of the present study indicate that this belief is not accurate. The 3D CAD group had all graphics concepts introduced utilizing 3D wireframe models, and performed equally well on all evaluation instruments. Postponing the use of 3D CAD will only reduce the amount of exposure a student receives to industries' design and production tool of the present and future. It may appear contradictory that the 3D CAD group spent the first two weeks (20% of instructional time) using 2D CAD, but it should be emphasized that the objective was to make students comfortable using computers and become familiar with the nature of the software. All concepts of engineering graphics were introduced using 3D technology.

Recommendations

The following recommendations are the result of the planning, execution, evaluation, and observations made in the process of performing this research study.

1. If replicated, the researcher would be justified in using only one measure of spatial visualization as the MRT and the GZ were significantly correlated.

2. Research is needed to evaluate new developments in CAD technology and incorporate effective and efficient ideas into the instructional strategies used to teach engineering graphics.

3. There is a need to design the curriculum to: a) reduce student anxiety by planning time for students to become familiar with the CAD software before introducing concepts of engineering graphics, b) avoid introducing too many CAD commands in a single assignment, and c) avoid introducing too many engineering graphics concepts and CAD commands in a single assignment.

4. Encourage textbook authors to include explanations of engineering graphics concepts which utilize the power of 3D CAD software and the paradigm of the 3D model.

5. Allocate more time in engineering graphics courses to the following: a) methods of generating and manipulating 3D geometry, b) assignments using 3D CAD to solve actual problems which illustrate the power 3D CAD offers as a problem solving and

analysis tool, c) generic applications of 3D CAD which are not dependent on the understanding of specific areas of technology such as mechanical engineering.

6. Additional research is needed to assess the correlation between the factors spatial visualization and spatial orientation, and also to determine what implications these findings would have on instructional strategies for beginning level engineering drawing courses.

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Division News and Notes

Chairman's Message by Vera Anand

The success of the 5th International Conference on Engineering Computer Graphics and Descriptive Geometry in Melbourne, Australia, brings to mind the need for a dialogue at the international level, relating to issues of graphics education and research. The newly formed International Society for Geometry and Graphics (ISGG) will provide a forum for these discussions and will certainly focus on issues of interest to graphics educators and researchers in the international arena.

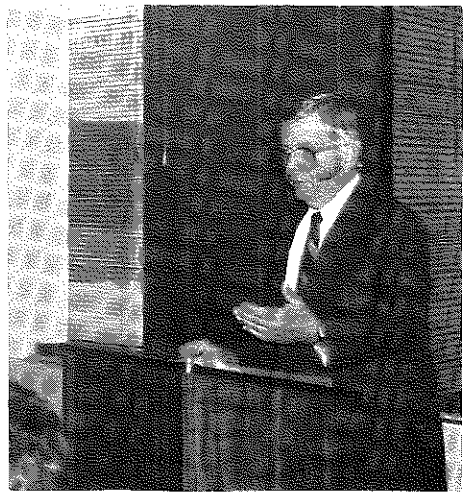
It might be worthwhile at this time to think about these issues from the point of view of engineering needs. Various efforts have been under way in the U.S. throughout the last few years, funded by the National Science Foundation, to reform the engineering design graphics curriculum. Also, NSF Engineering Education Coalition funding has been used for restructuring the engineering curricula, including the area of design graphics. Studies within all of these programs have indicated a weakness in the process of engineering design education, at all levels of the undergraduate curriculum. Should the role and importance of graphics in this design process be more thoroughly evaluated, focused and strengthened? This may be the key element that will enhance the creative process associated with design. All areas in which graphics affects the engineering design process, be it scientific data visualization, two-dimensional layout, three-dimensional modeling, or any others, need be carefully reevaluated as to their importance in the engineering design curriculum.

Have our international partners in Europe, Asia and elsewhere done this more efficiently than we have? How can we gain from the experience of countries like Germany and Japan, prominent in today's world economy? Maybe through the efforts of groups like the newly formed ISGG, an exchange of ideas can occur that will benefit all concerned. The involvement of our division in this type of dialogue should help in promoting engineering design graphics education and avoid a fragmentation of views within our own ranks.

1992 Distinguished Service Award

Presented to
Larry Goss

June 23, 1992
Toledo, Ohio
ASEE Annual Conference



Introduction by Frank Croft

I've known this gentleman for nearly twenty years. He introduced me to this group several years ago. He's been a member of this division since 1967 which, if my math is correct, is twenty-five years. He has served the division very nobly over those twenty-five years as Director of Technical and Professional activities, Vice-chair, Chair, and has served as Division Editor of the journal. If you haven't guessed by now, this person is Larry D. Goss of the University of Southern Indiana.

Larry is a born and bred Hoosier. He grew up on a farm near Fort Wayne, Indiana. He attended Purdue University from 1955 to 1957. He majored in mechanical engineering at that time. He transferred to Illinois Institute of Technology and graduated in 1960 with a BS in Product Design. After that, he enlisted in the Air National Guard (1960-1966) and had active duty during the Berlin Crisis in 1961-62. With this degree in product design, he also had minors in education and human factors engineering. He later returned to Purdue and received a MS in Household Equipment Design in 1966.

Larry began his teaching career before he completed his bachelor's degree in 1958. He was an adjunct faculty member at the University of Chicago where he taught shop processes. While a graduate student at Purdue, he was an instructor in Engineering Graphics. After completing his master's degree, he became assistant professor of Mechanical Engineering at Oklahoma State University in Stillwater. He stayed at Oklahoma State until 1971 when he went to West Virginia Institute of Technology to become chairman of the Drafting and Design Department. He then took the position that he currently has at Indiana State University, Evansville, that later became the University of Southern Indiana. He is now a full professor of engineering technology and director of the Master's of Industrial Management program.

Larry became active in the division immediately, and also with ASEE. He has attended all but two annual meetings and all but four mid-year meetings since joining ASEE. He has also attended every international conference on Engineering and Computer Graphics in Vancouver, Beijing, Vienna, and Miami. He was a presenter at each of those conferences, and is also a presenter at the next international conference in Melbourne this August. He has won the Oppenheimer award, and was the Dow Outstanding Young Faculty Award recipient from the Midwest Section in 1971.

Larry has been a rather unique individual. He's willing to take chances not only with controversy within the division, but also with teaching innovations. What he did may not seem to be significant, but when you think of the timeframe we're dealing with it puts them into perspective. He introduced design at the freshman year in 1966. He introduced computer graphics at the freshman level as well, in 1967. In 1969, Larry introduced us to an "Orthographic Projection Simulator." That is a long name for "The Goss Box." He really gave us that and it really was a significant contribution.

I've known Larry and his wife Rena for the past 20 years. I walked into their house back in 1973 and entered their family room. The first thing that I noticed was a symbol of their marriage. In a prominent place on coffee table there is a little sculpture. On one side of the sculpture you see a clarinet, and on the other side a cam shaft. That's what Larry Goss is all about. I am forever grateful that Larry gave me the opportunity to get into this wonderful career of teaching. I owe him a great deal for that. With that, I'd like to present this award to Larry.

The inscription reads:

Distinguished Service Award. Larry Dean Goss is hereby recognized by the Engineering Design Graphics division of the American Society for Engineering Education for his outstanding contributions to the division and to engineering education. He has served the division in many capacities including director of Technical and Professional Activities, vice-chair, and chair. He has willingly given his time and his talent to the division in many unofficial capacities as well. He is a teaching innovator who gave us the "Goss Box" that has helped many engineering and engineering technology students understand orthographic projection concepts. This award is the highest that can be presented by the division to one of its members. Larry Dean Goss has been selected for this honor by his colleagues for his outstanding career as an educator, scholar, and innovator. Presented this day June 23, 1992, at the ASEE annual conference, Toledo, Ohio. [Signed by] John Demel, chairman.

Remarks by Larry Goss

I have some formal remarks, but I also have some informal remarks that I want to start with because Frank left some things open that you might find interesting.

The Goss Box. The largest Goss box that was ever built, was a twelve-foot cube in the Industrial Engineering Department at Mississippi State. They used it for motion and time studies. It is large enough that you can put an entire work cell inside of it and photograph it to get coordinated orthographic views of the activity. The most Goss boxes ever built were by Abe Rotenburg in Australia. Abe saw the article that appeared in the journal and wrote to me and said, "I like it. I want both the model two and the model three." (You see, there never was a model one. Well, there really was, but it had to stay where I originally invented it out in Oklahoma. It was built with university funds and had to stay there when I left.) Abe said, "I need to have first angle projection as well." So as a result, I drew up the plans for Abe and he built four different Goss boxes.

It took me many years to realize what a unique childhood I had. What you heard about me is the result of that childhood. My father was the first designer that I ever knew. I see things all the time that remind me of him and his life. He graduated from the University of Colorado in 1927 with a degree in Electrical Engineering. He immediately left with his bride of one year for Fort Wayne, Indiana, and the General Electric Company. He was put on a four-man design team for refrigeration. Their objective was to come up with an hermetically sealed refrigeration unit. The result of that was the monitor top refrigerator. I saw one last night at Tony Packo's. Every one of those I've ever come across is still working. My father's patent on that, one year out of school, was the permanent lubrication of the motor. He was the first person to use a sintered bronze bushing, impregnate it with oil, and put an oil soaked felt collar around it with a lifetime supply of oil. We had a tradition at our house that every New Years we traveled around the entire farm and oiled every motor. On those that were sealed, my dad very deftly took a breast drill and drilled a one-sixteenth inch hole through the casing. I said, "Why are you doing that, it's permanently lubricated." He looked at me with one of those withering looks that a father gives to a wayward son and said, "I know. I invented it. So I know there is no such thing." That was the beginning of a number of patents that my dad got while he was working at General Electric. We had the third domestic freezer in the State of Indiana. He built it. It was about 64 cubic feet. Five by nine by two-and-a-half feet. The thing I remember specifically about it is that it would hold a five gallon ice cream freezer can upright. That was in the summer of 1941. My mother got anxious right away about how to fix frozen foods. She called up the county agent and he said, "I don't know." He called Purdue. Purdue said, "We don't know. We've got two freezers down here and to our knowledge they're the only ones in the state." As a result our family has always felt we were probably number three. That freezer that my father built from scratch lasted better than twenty years, until we finally got tired of the thing and tore it out.

I suddenly realized one day that I lived with prototypes. In the bottom of your refrigerator, besides the hermetically sealed unit, there is a small circulating fan. That fan was developed by my father in 1932. After the motor had gone through "test," it was sent out to the salvage yard. My father recovered it, brought it home, and we used it around the farm for years. I still have that fan. I use it in my garage during the summer when I'm working at my work bench. I rode in the first air-conditioned automobile. General Electric decided not to put that air-conditioning unit into production, but many fall-out products came from the design team that worked on it. My father was in charge of providing the power for the compressor. It was obvious early in the design that a six-volt power supply was inadequate to run the compressor, and space restrictions in the engine compartment precluded using large D.C. generators. My father's solution was to develop an alternator and rectifiers to power the entire automotive electrical system. The first one was installed in a 1948 Buick, and now it is impossible to buy a car that does not have an alternator for the charging circuit.

Do any of you golf? Do you ride an electric golf cart? The motor in that was my father's design. My father designed D.C. control motors for many of the jet aircraft. One of the last designs he had with the General Electric Company was the redesign of the telechron clock motor. He turned the motor inside out, putting the magnets on the inside as part of the rotor, and used metallic fingers on the gear frame to establish the rotating magnetic field. This brought the cost of building the motor down to twelve cents.

The last design he worked on was the development of thrust meters for jet engines. That thrust meter can be retrofit to all jet aircraft engines. It is on all commercial aircraft engines, and all navy aircraft. For some reason, the air force and the army never bought it. I thought of that this spring when the Army C-130 crashed in Evansville.

That's the unique design life I lived before I went to school for any formal training.

Those are the informal comments I wanted to make. Let me talk to you about what I really wanted to say tonight which is that because I know there are a lot of new members in the division, many of us do not know who the former recipients of the Distinguished Service Award are. The question many of us have is, "Who are these guys?"

Who are These Guys?

The distinguished service award has been bestowed by this division since 1950. Many of the early members are no longer with us, and to many of our newer members some are only names. Geiseke, Rising, Spencer, Paffenbarger, Wellman; Who are they? Why do we honor them? What makes these people special?

In looking through this list, I realize that over half of these people are my personal friends. Allow me to reminisce with you and relate a few of the things that make them important to me.

George Hood, 1952. University of Kansas. He wrote the first graphics textbook entirely in third angle projection.

William E. Street, 1961. The oral historian of the division. The eloquence with which he recounted the 50-year history of our group in 1978 is still fresh in my mind.

Theodore T. Aakhus, 1963. Although I never met Ted, I feel a kind of kinship with him because his nephew, Michael, is a colleague at the University of Southern Indiana.

Warren J. Luzadder, 1964. When I started my engineering education at Purdue, the very first professor that I had on the very first day of class was Warren Luzadder. When I started to teach engineering graphics at Purdue, he became a colleague and friend. Many years after that, I became a coauthor on his workbooks with Ken Botkin. Ken, by the way, was the first laboratory instructor I had as a freshman at Purdue.

Ivan L. Hill, 1967. I first met Ivan in 1957. I was a student in the Institute of Design at IIT, and he was the department chairman of Engineering Graphics. I had heard that they also taught a product design course in his department, so one day I climbed the stairs to the fifth floor of Old Main to see what they were doing. I was disappointed in the concepts of design as they were envisioned in his department. I'm sure Ivan never remembered our having met on that early occasion, and the difference in design concepts between his department and the Institute of Design under Jay Doblin kept us philosophically separated.

J. Howard Porsch, 1970. Del Bowers and I were working at the Cambridge, Ohio, plant of RCA. We happened to find out that we had similar educational backgrounds and we started comparing notes about our futures with the company (which in our estimation was about to close down). He asked me what I was going to do and I said I had written to Purdue seeking a teaching position and that Howard Porsch had responded favorably to me. Del said, "Remember me." I started at Purdue in September of 1963, and Del came with us the next semester. That started a number of memorable events between Del, Jerry Smith, and me. For those who are media freaks, you might find an incident that Del and I had to be a little enlightening. We had noticed that there was a monstrous old Beseler overhead projector in the supply room that we thought would be helpful in the technical illustration classes. We approached Gale Seaton, the store man, about using it and he referred us to Howard. Howard listened to our plea to use overhead transparencies in our lectures and then said abruptly, "No, we tried it once and didn't find it very helpful."

I asked Howard to sponsor my membership in ASEE in 1965. He looked at me and said, "No, that organization is just for deans and department heads." I believed him, so it was with more than a little surprise and gratification that when I started teaching at Oklahoma State University, I was actively recruited for ASEE membership by Karl Reid. Not only that, but there was a dedicated overhead projector in every engineering classroom.

"Geiseke, Rising, Spencer, Paffenbarger, Wellman; Who are they? Why do we honor them? What makes these people special?"

Eugene G. Pare, 1976. Gene has always reminded me in very subtle ways to be more ecumenical and open-minded in my hiring practices. Hank Gerdom, whom some of you at Purdue remember when he was near retirement, was my first office mate. Hank was the senior faculty member, so he had about 80% of the office, and I had one little corner. He came back from a committee meeting one day all worked up because things were in their usual turmoil. The committee had been charged with revising the descriptive geometry course to improve its content and delivery. They put forth their proposal with the best syllabus and the best teaching materials they could find and had been shot down. They had committed the unpardonable sin of recommending a text book from an off-campus author. Their choice had been "Descriptive Geometry " by Pare, Loving, and Hill.

Percy H. Hill, 1977. I miss Percy at these meetings. He and I saw eye-to-eye on a lot of things regarding design and how it should be taught. I adopted his design graphics worksheets in 1968 and lamented to him years later that he had not seen fit to publish a second edition. His response was that unfortunately I was one of the few people who had adopted the series. My whole family still uses the toothbrushes that he designed and the special injection molded travel cases that go with them.

C. Gordon Sanders, 1978. The poet laureate of our division. We haven't had much good poetry (or bad poetry for that matter) published in the Journal or read at our meetings since he retired.

William B. Rogers, 1979. An officer and a gentleman. We have served on many committees together in this division and each experience has been a delight because of his attention to detail and his keen sense of humor.

Mary Plumb Blade, 1980. I first met Mary in 1978 at the first international conference in Vancouver. I attended her tensegrity structures workshop at that conference and was bowled over by the fact that she was teaching about a whole class of structures that had either been overlooked or ignored by Buckminster Fuller. She stopped by my table to see how I was progressing with tensegrity structure design and I proceeded to describe to her ideas I had for super lightweight beams constructed of tensegrity modules. Finally she said, "Why don't you stop talking about it and just do it?"

Robert D. Larue, 1981. I don't remember when I first met Bob, but we became well acquainted when I spent a sabbatical at Ohio State University. We share common interests in bargain hunting, handbell ringing, and N-gauge railroading. I passed on to him one day that I had come to a realization of a different level of meaning for the phrase "publish or perish." I observed that this phrase has particular meaning for colleges and universities themselves. An educational institution without resident authors in a field has no authority in that discipline. We have an imperative to write, not just for personal gain and reputation, but for the visibility and authority of our departments within the profession.

James H. Earle, 1982. I shared a seat with Jim on a bus while riding back from the EDG business luncheon to Bancroft Hall at the Naval Academy in 1971. The division had just gone through argument concerning its new name -- Engineering Design Graphics. Jim was feeling glum and looked despondent about what we had just gone through and he said to me, "Well, I guess it's time I stepped aside and let some of you young bucks take over the leadership of the division." I was shocked. Here was a young man in the prime of his career ready to pass the baton of leadership. He was right of course. It helps the health and vigor of an organization to have a smooth and timely transition of leadership.

Steven M. Slaby, 1983. Steve is our goodwill ambassador for multidimensional geometry. He has more recognition among our international colleagues than any half dozen of the rest of us. Tom Thomas of the Royal Institute of Technology contacted me for recommendations concerning seating at the head table for the International conference in Melbourne. I told him that the selection should be based on how much space he has for people. If he only has room for one, that person should be Steve Slaby.

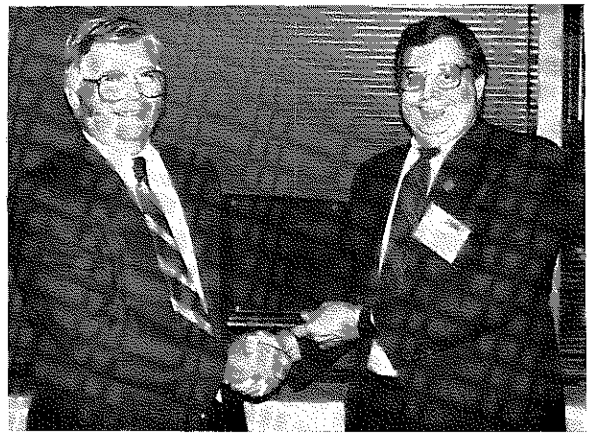
Amogene F. Devaney, 1984. Amogene is our Texas Rose from Amarillo. She was always concerned about testing and student evaluation, and shared many of her testing ideas with me. She was also most encouraging to me in Vancouver after I had given one of the worst presentations imaginable at the international conference. Fortunately, I don't think anyone currently active in the division was there to hear it.

Klaus E. Kroner, 1985. Klaus was a pioneer among us in computer graphics. He ran short courses, seminars, and workshops for us at a time when computer graphics was in its infancy and when almost no programs were transportable between systems. We look back on the things we did then as trivial by today's standards, but they were significant at the time.

Claude Z. Westfall, 1986. Our "down easter" from Orono, Maine. He delighted in exotic and unusual drafting equipment and vigorously pursued locating things like railroad pens to give to members of the division.

Clarence E. Hall, 1987. Clarence headed the international committee of this division for many years. It was primarily through his efforts along with Amogene Devaney, Jack Brown, and others that the first international conference took place. He begged us year after year to actively seek out faculty from two-year and community colleges for membership in this division.

Paul S. DeJong, 1988. A trusted friend and colleague. Paul is a man who delights us continuously with the new things he is doing; from programming stadium scoreboards, to exploration of fractal geometry, to designing the centennial logo for ASEE.



Larry Goss & Frank Croft

Frank Oppenheimer, 1989. Frank was a salesman. He was, and in my way of thinking still is, Gramercy. He stopped in to see me once when I was teaching at Purdue, but he started visiting me two to three times a year when I taught in Oklahoma. Rena and I invited him out to the house for dinner on one occasion and he spent nearly an hour down on the floor playing with our children. When we visited the Oppenheimers in Denver several years later, he once again played with the children. He is a delightful man whose avocation is reader's theater and whose true profession is that of classical musician.

Clyde Kearns, 1990. A quiet, reserved, and steadfast individual who has provided leadership for this division in the most self-effacing ways imaginable. He shuns the spotlight and almost grudgingly accepts the honor and respect we owe him for his many years of unselfish service.

Robert Foster, 1991. Another of our super-service individuals. I first met Bob in 1971 at Annapolis. I remember thinking at the time, "I need to know that man." Since then we all have come to know him as our secretary-treasurer on several occasions, as our chairman, as an author, and as a collector of antique O-gauge trains.

That's who these guys are to me. They are our authors, our mentors, our senior statesmen, our friends and colleagues.

Now, you have seen fit to add my name to this list. It is an honor and a very humbling privilege. I hope I can be for you the mentor, friend, and guide that these and others have been for me.

Thank you very much.

Calendar of Events

Prepared by Dennis R. Short

Association for Experiential Education
20th Annual Conference
Banff, Canada
October 8-1, 1992
For further information:
Karen Hirl
3407 - 54 Ave. SW
Calgary, Alberta, CANADA
T2E5H3
(403) 242-5702 (home)
(402) 240-8969 (fax)

CHISIG Annual Conference
Interface Technology: Advancing Human - Computer Communication
November 26-27, 1992
Gold Coast, Queensland Australia
For further information:
OZCHI 92 Secretariat, School of Information & Computing Sciences, Bond University, Gold Coast, Qld 4229
AUSTRALIA
+61 (0)75 953324
+61 (0)75 953320 (fax)
E-mail: ozchi92@bu . oz . au

ICCG93
International Conference on Computer Graphics: Interaction, Design, Modeling, and Visualization
February 22-26, 1993
Bombay, India
For further information:
ICCG93 Secretariat
National Centre for Software Technology
Gulmohar Cross Road No. 9
Juhu, Bombay, 400 049, INDIA

Society for Information Display (SID)
International Symposium, Seminar and Exhibition
May 16-21, 1993
Washington State Convention Center
Seattle, Washington, USA
For details contact:
Todd Reed
EE Dept. - UC Davis
Davis, CA 95616
(916) 752-4720
(916) 752-8428 (fax)
E-mail: reedt@eecs . ucdavis . com

Ninth Annual ACM Symposium on
COMPUTATIONAL GEOMETRY
May 18-21, 1993
San Diego, California
Program Committee Chair:
Mark Overmars
Department of Computer Science
Utrecht University
P.O. Box 80.089
3508 TB Utrecht, the Netherlands

CALL FOR VIDEOS
2nd Annual Video Review of Computational Geometry
Authors are requested to send one copy of a videotape to the organizers by February 2, 1993. The videotape should be at most five to eight minutes long.
For further information:
John Hershberger
E-mail: johnh@src . dec . com,
(415) 853-2242
DEC Systems Research Center
130 Lytton Ave.
Palo Alto, CA 94301
(415) 324-4873 (fax)

SOLID MODELING '93
Second ACM/IEEE Symposium on Solid Modeling and Applications
Montreal, Canada
May 19-21, 1993
This symposium provides on international forum for the exchange of recent research and practical results in all areas and applications of solid modeling. Emphasis is on the impact of solid modeling in design and manufacturing.
For further information:
Mary Johnson
Design Research Center, CLL 7015
Rensselaer Polytechnic Institute
Troy, NY 12180-3590
(518) 276-6751
(518) 276-2702 (fax)
E-mail: mjohnson@rdrc . rpi . edu

PACIFIC GRAPHICS '93
The First Pacific Conference
on Computer Graphics and Applications
Seoul, Korea
August 30 - September 2, 1993
Pacific Graphics is an international conference on computer graphics and applications. The conference brings all computer graphics people to discuss and exchange their researches for promoting computer graphics in the East in cooperation with international professional societies.
For further information:
Sung Yong Shin
Computer Science Department
Korea Advanced Institute of Science and Technology
373-1 Kusung-dong, Yusung-ku
Daejon 305-701, Korea
+82-42-869-3528
+82-42-869-3510 (fax)
E-mail: syshin@cs . kaist . ac . kr

The EUROGRAPHICS '93
International Conference
Barcelona, Spain
September 6-10, 1993
EG '93 will highlight three major threads of R&D and four application areas in Computer Graphics, Advanced Interaction Cooperative Working Visualization in Computer-Aided Design, Animation, Electronic Publishing, Geographical Information Systems.
EUROGRAPHICS '93
Palau de Congressos
Dept. de Convencions
Fira de Barcelona
Avda Reina Maria Cristina s/n
08004 BARCELONA
+34-3-423-3101
+34-3-426-2845 (fax)
Telex 53117 FOIMB-E
E-mail: eg93@lsi . upc . es

POSITION VACANCY

GRAPHIC COMMUNICATIONS

NORTH CAROLINA STATE UNIVERSITY

GRAPHICS/ENGINEERING and TECHNICAL: North Carolina State University has a tenure-track position available in the Graphic Communications Program with employment to begin in August of 1993. Applicants must have an earned doctorate, demonstrated teaching skills and proficiencies in engineering/technical graphics, computer graphics and CADD. Activity in relevant professional organizations and a record of publication is desired. Industrial experience in the area would be helpful.

The Graphic Communications Program at NCSU currently offers a 15-hour minor and provides nine service and/or elective courses in engineering graphics, technical graphics, descriptive geometry, furniture graphics, 2D and 3D computer graphics, desktop publishing and visual thinking. Approximately 900 to 1000 students are served each semester by 9 full-time faculty and 5 part-time faculty.

Review of applications will begin February 1, 1993 and will continue until the position has been filled. Applicants should send cover application letter, current resume, transcripts, current placement papers and three current references to:

Dr. William J. VanderWall
Graphic Communications
North Carolina State University
Box 7801
Raleigh, North Carolina 27695-7801
Phone (919) 515-2234.

North Carolina State University is an equal opportunity, affirmative action employer.

Product Review

Digital Design Media

Van Nostrand Reinhold, New York. 1991. 439pp with color plates

by Jon M. Duff

The professor curls up in the chair on Friday night, steaming cup of Earl Gray near by. Quiet time. Reading time. Is it Tony Hillerman? Lawrence Sanders? Clive Barker? Elmore Leonard? No, something much more satisfying, much more exciting. Tonight the professor will get close to William Mitchell and Malcolm McCullough.

William Mitchell and Malcolm McCullough? Of course, the professor teaches graphics and finds, beyond traditional literary interests, that Digital Design Media is about as exciting reading as one could imagine.

This reference text, although aimed at architecture, is the best mixture of theory, application, and explanation available as of this reading. It's as if Foley and Van Dam met James Michener to make sense of difficult graphical and spatial concepts. Unlike other landmark texts in this area, Digital Design Media is appropriate reading for undergraduates, more of a technological treatment than a computer science orientation as one might expect from the design school background of the Harvard authors. This book is appropriate for engineers, technologists, industrial designers, animators, and architects. Technical background in mathematics, vector theory, and graphic data structures is presented at a level appropriate for those who will plan, evaluate, and use graphic tools in the design process.

Some of Digital Design Media may be marginally of interest (text, sound, hypermedia) but these sections are still good reading—especially if, as many graphics teachers find, their background is devoid of such subjects.

The book is divided pedagogically into sections treating one-, two-, three-, and multi-dimensional media. This makes for orderly progression and progressively complex concepts and applications. It also makes the book easy to use as a reference. The illustrations are of highest quality. Line illustrations are sharp and explain underlying relationships in step-wise fashion. Screen captures are publication-quality halftones that show applications of the theory in such a way that theory and application are tied together nicely. There is not one substandard illustration in the book. Color plates in an eight-page folio are both informative and eye-catching.

One section that should be required reading is that on "Design Database Management." In this section, models of relational data bases are shown and discussed as is the linking of graphic and relational databases. Other topics presented are version control, consistency, horizontal and vertical integration, and archiving. If you (or your students) need to understand two- or three-dimensional graphic theory or how design information is extracted from drawings, read Digital Design Media first.

EDITOR'S NOTE:

If you would like to review a book, or product pertinent to the graphics field and interesting to our readers, please contact me. You will find my address on page 62.

Kenneth E. Botkin

Kenneth E. Botkin, former Technical Graphics department head, died August 4th, 1992 in Lafayette. He had been in failing health for several years but had kept his keen interest in community and university activities.

Ken stepped down in 1982 after 12 years of leading the department. He continued to serve the School of Technology as Building Deputy until he retired in 1988. Ken's tenure as Department Head saw the growth of the AAS program and the early planning of the BS degree. He was active in professional graphics associations, serving as EDGD Chairman in 1973-74, and was instrumental in the careers of many engineering and technical graphics faculty members around the country. Ken will be remembered as leader during the time that graphics at Purdue assumed it own identity.

Mid-Year Meeting

San Francisco

January 9 - 11

1993

Saturday, Jan. 9: all-day workshops

- *Design Analysis and Optimization*

  Instructor: Mike Wheeler.
  Technical Director
  Rasna Corporation
  Silicon Valley
  San Jose, California

For those interested in enineering design

- *Animation and Video*
  Instructor: Vijey Patel
  Director
  Cogswell College
  Silicon Valley
  Cupertino, California

For those interested in Technical Graphics, multi-media, animation and video.

- *Advanced 3D construction with AutoCAD R12, AME (Solid Modeling), and Solution 3000 (Surface Modeling)*
  Instructor: Dieter Schlaepfer
  Training Specialist

For those interested in teaching CADD with or without solid modeling using AutoCAD R12, AME and possibly 3D Studio.

Sunday, Jan. 10

8:00 am - 9:00 am Registration

1:00 pm - 9:00 am Registration

2:00 - 6:00 pm: Committee Meetings

Sunday Evening:
Evening 6:00 - 7:00 pm Social hour
7:00 - 9:30 pm Opening Technical Session

Graphics from Myth to Virtual Reality

Bill Ross, Purdue University, & Steve Aukstakalnis, Matrix Technical Services
Walter Rodrígues, Georgia Tech
D. K. Lieu & A. M. Okamura, U. C., Berkeley

Monday, Jan. 11
7:45 - 10:00 am Technical Session

New Curriculum Strategies for CAD

Del Bowers, Colorado School of Mines
Gary Bertoline, Purdue University
John Demel & Michael Miller, The Ohio State University
Jon M. Duff, Purdue University
Joe Tallerico, California School System

10:20 am - Noon Technical Session

Real World Applications of CAD

Ron Barr & Davor Juricic, University of Texas, Austin
Frederick D. Meyers, The Ohio State University
Patrick McCuistion, Ohio University
Kenneth D. Perry & William T. Peters, Dana Corporation and Indiana University-Purdue University at Fort Wayne
Dave Alpert, Ranch Santiago College, Houston

1:00 - 3:15 pm Technical Session

Future Directions of CAD

Len Rand, VP-AutoCAD Division, Autodesk
Paul Teicholz, Director-CIFE, Stanford University
Davor Juricic & Ron Barr,
University of Texas, Austin
Vera B. Anand & Linda C. Cleveland,
Clemson University
Michael Stewart,
University of Arkansas at Little Rock

6:30 - 10:00 Evening in San Francisco

Tuesday, Jan. 12

7:45 - 10:00 am Technical Session

Instructional Strategies for CAD

Mike Pleck,University of Illinois at
Urbana-Champaign
Timothy J. Sexton, Ohio University
Craig L. Miller, Purdue University
Frank M. Croft, Jr., Ohio State University
Robert Chin, East Carolina University

10:20 am - Noon Technical Session

Implementing CAD in University and College Programs

C. E. Teske, Virginia Polytechnic Institute
Terry Burton & Scott Wiley, Purdue University
Billy Wood, University of Texas, Austin
Niaz Latif, Northern Kentucky University
C. Wayne White, Purdue University
Nadim M. Aziz & Mukund Rajagopalan,
Clemson University

12:00 - 1:30 - Business Luncheon

2:00 - 4:15 pm Technical Session

Advanced Applications of CAD

Mike Wheeler, Rasna Corporation
Laneda Barr & Davor Juricic,
University of Texas, Austin
D. K. Lieu & N. H. Talbot, U. C. Berkeley
Steven Howell, Northern Arizona University

5:30-6:30 - Cocktail Hour

6:30 pm - Awards Banquet

General Chair:
Ronald C. Pare
University of Houston

Program Chair:
Jimm Meloy
Autodesk

Registration Chair:
Wes Stelter
Hewlett-Packard

This was received from Michail Zgurovsky, Rector of Kiev Polytechnic Institure.

Dear Sir:

We have the honor to let you know that Kiev Polytechnic Institute has implemented the first IBM Computer Integrated Manufacturing (CIM) Center in the former Soviet Union, thanks to the support and the sponsorship of the ALTER Corporation and the VEMA Trading House.

We are very pleased to invite you to the inauguration of the KPI/IBM Computer Integrated Manufacturing (CIM) Center on November 18, 1992. You will find attached more information about the content and the mission of this CIM Center which is one of the best equipped in Europe.

We believe that this represents a major step in our move to a "Market Economy" and in the use of modern technology and management tools to improve the productivity and the quality of our industry.

This Center will mainly be used to improve the qualifications of engineers and managers from the Industrial Sector.

KPI wants to become a center of expertise in the practical implementation of the New Information Technologies and in the installation and maintenance of IBM hardware and software, as well as in the development of application software.

We are kindly asking you to help us in our effort by making us visible to your collaborators and business acquaintances by circulating the attached text to them.

Thanking you in advance for your effective and much needed support, we remain

Yours faithfully,

Michail Zgurovsky

Rector of KPI

Kiev Polytechnic Institute (Ukraine) Opens First IBM Computer Integrated Manufacturing (CIM) Center In Former Soviet Union To Improve Qualification of the Engineering Community and Productivity of the Ukrainian Industry.

On November 18, 1992, the Kiev Polytechnic Institute (KPI), Ukraine, will inaugurate its KPI/IBM CIM (Computer Integrated Manufacturing) Center. KPI has 18 Faculties, 3 Research Institutes, 28,600 Students and a staff of 3,542 people of which 1,873 are Professors and Assistants.

The center is equipped with up-to-date technology and software including: one IBM Enterprise System/9000, seven RISC Systems/6000, 13 High Precision Graphic Work stations and CATIA software for Computer Assisted Design, Manufacturing and Engineering. It is the first Center of this size in the former Soviet Union and one of the best equipped in Europe. It is the result of close cooperation between the Ministry of Education, Ukrainian Industry, KPI and IBM.

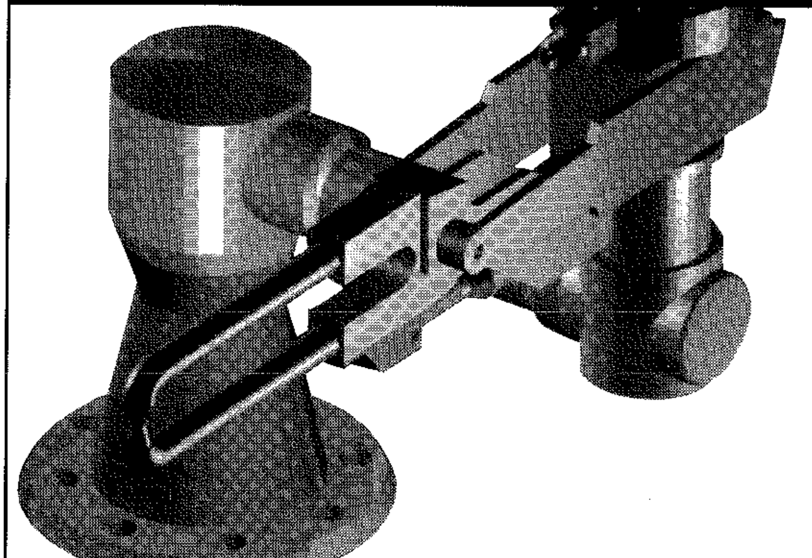
It has been made possible thanks to the sponsorship of the ALTER Corporation and the VEMA Trading House. This Center is part of a large IBM Education Project which is active in the 15 Republics since June 1990. It will mainly by used to improve the qualification of engineers and managers from the Industrial Sector and to implement cooperation and exchange of information with other countries.

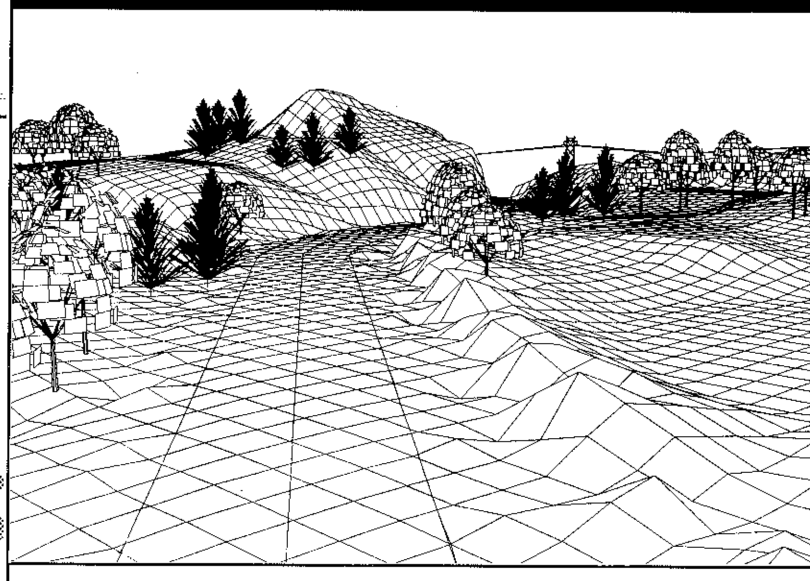
KPI wants to become a center of expertise in the use of the New Information Technologies (NIT) in the engineering, research and manufacturing areas, in management development, in the development of software (CASE) and in data engineering and image processing. CIM (Computer Integrated Manufac-turing) is a concept, a technique and a set of tools using Information Technology and computers to improve and optimize the work flow of a Manufac-turing Enterprise.

It addresses each of the major functional areas of the enterprise • Marketing • Engineering and Research, • Production Planning, • Plant Operations, • Physical Distribution, • Business Management.

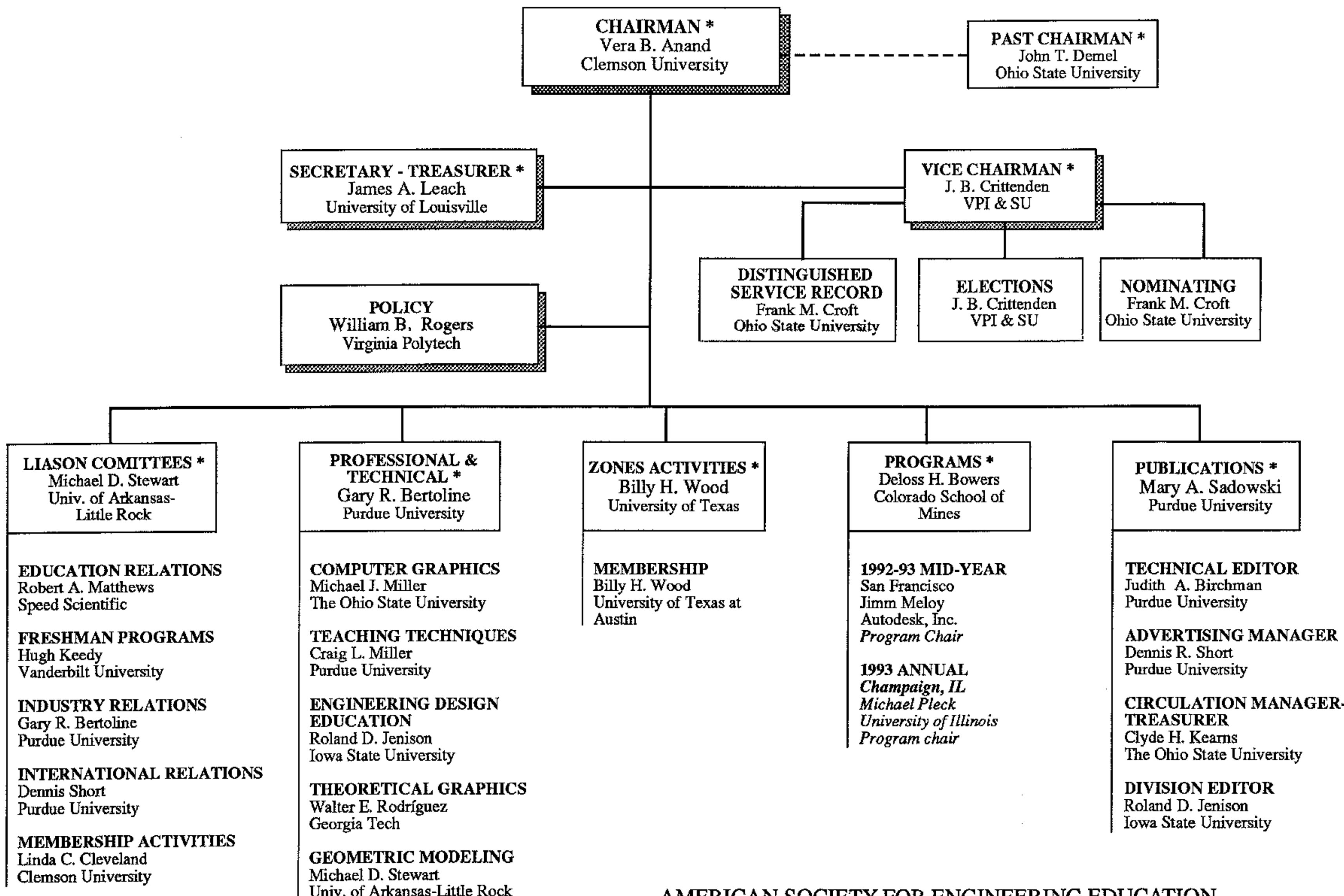
For further information, please contact:

CIM Center, Kiev Polytechnic Institute,
Peremogy Avenue 37, 25205 Kiev, Ukraine.
Phone: 7/044/441-90-95, 441-39-87
Telex: 131434 GOR SU
Fax:7/044/274-39-87,274-09-54





ENGINEERING DESIGN GRAPHICS DIVISION



AMERICAN SOCIETY FOR ENGINEERING EDUCATION
ORGANIZATION CHART 1992 - 1993

* **Executive Committee member**

ASEE NATIONAL CONFERENCE

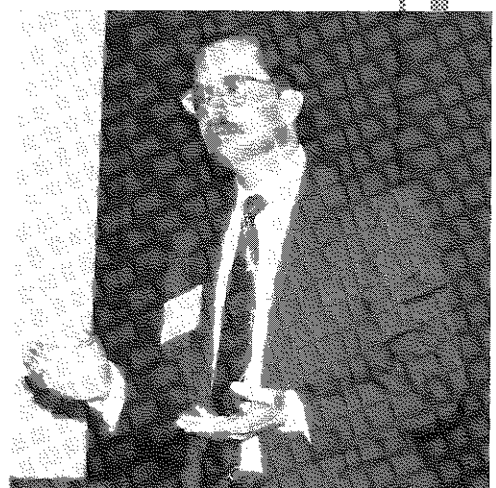
Theme: ASEE's 100th Anniversary

University of Illinois at Urbana-Champaign

June 20 - 24, 1993

Chairman John Demel and his wife, Marge enjoy converstion and wine with Dennis Short prior to the 1992 banquet meal.

PatMcQuiston discusses dimensional management



The EDG Journal Review Board meets for an update by editor Mary Sadowski

Submission of Papers and Articles for the *Engineering Design Graphics Journal*

Submit papers, including an abstract of no more than 200 words, 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
Technical Graphics/Knoy Hall
Purdue University
West Lafayette, IN 47907-1419

Use standard 8-1/2 x 11 inch paper only, with pages numbered consecutively. Clearly identify all figures, graphs, tables, etc. All figures, graphs, tables, etc. must be accompanied by a caption. Illustrations will not be redrawn. All line work must be black and sharply drawn and all text must be large enough to be legible if reduced to single or double column size. The editorial staff may edit manuscripts for publication after return from the Board of Review. Galley proofs may not be returned for author approval.

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 members who are not members of EDGD
$50 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 at:

Mary A. Sadowski
Editor, EDGD Journal
Technical Graphics/Knoy Hall
Purdue University
West Lafayette, IN 47907-1419

FAX: 317-494-0486
PH: 317-494-8206

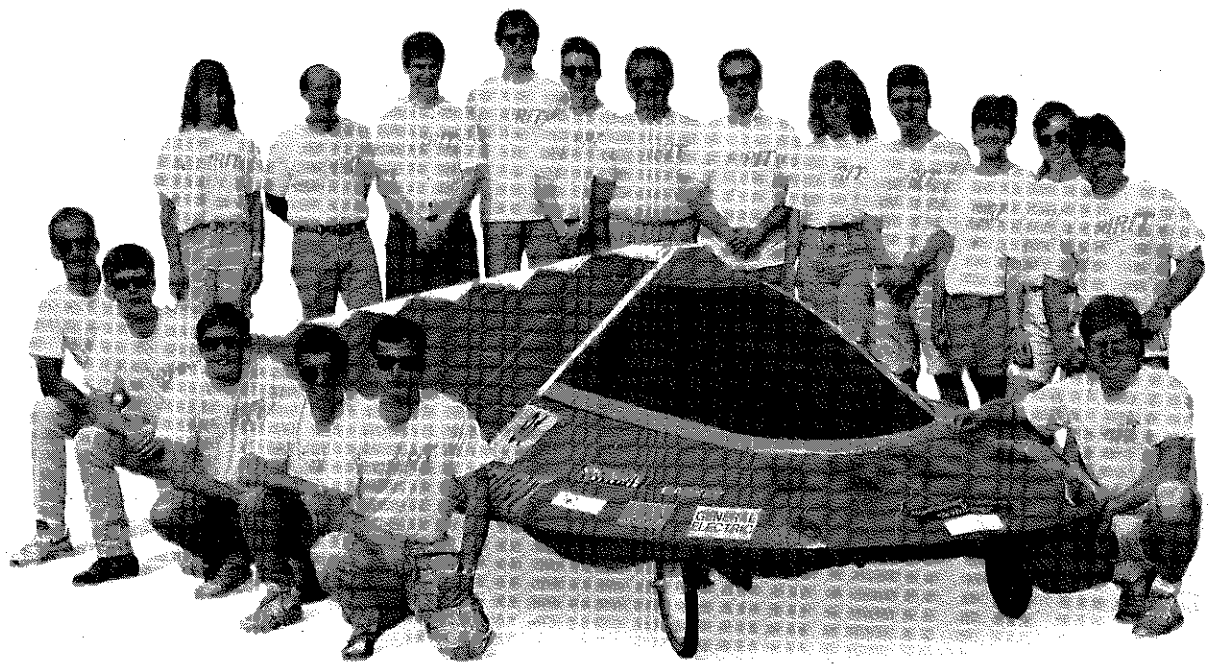
The EDG Journal is entered into the ERIC (Educational Resources Information Center), Science, Mathematics, and Environmental Education/SE at:

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

In the race to invent the future, this RIT team chose CADKEY.®



When Rochester Institute of Technology engineering students decided to enter a GM-sponsored solar powered competition they only had two problems: No car, and very little time to build one.

But when SPIRIT, a 435 pound powerhouse, rolled onto the track for the first time, skeptics asked: "How?" The answer: CADKEY.

CADKEY's desktop 3-D design and drafting software enabled several teams to work concurrently. Hundreds of files had to be designed and shared. Changes had to be made quickly and easily. And because design, analysis and manufacturing are all part of CADKEY, going from concept to finished part was a breeze.

As thousands of schools have discovered, teaching CADKEY as part of a comprehensive mechanical engineering curriculum — whether at the high school, vocational or college level — enables students to spend MORE time learning and designing, thus maximizing classroom productivity. School administrators like CADKEY because it's affordable. And, it's so easy to learn and use.

Best of all, CADKEY is "real world" CAD — as hundreds of thousands of students know — with strong links to analysis and machining.

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The Ohio State University
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Columbus, OH 43210-1275 USA

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