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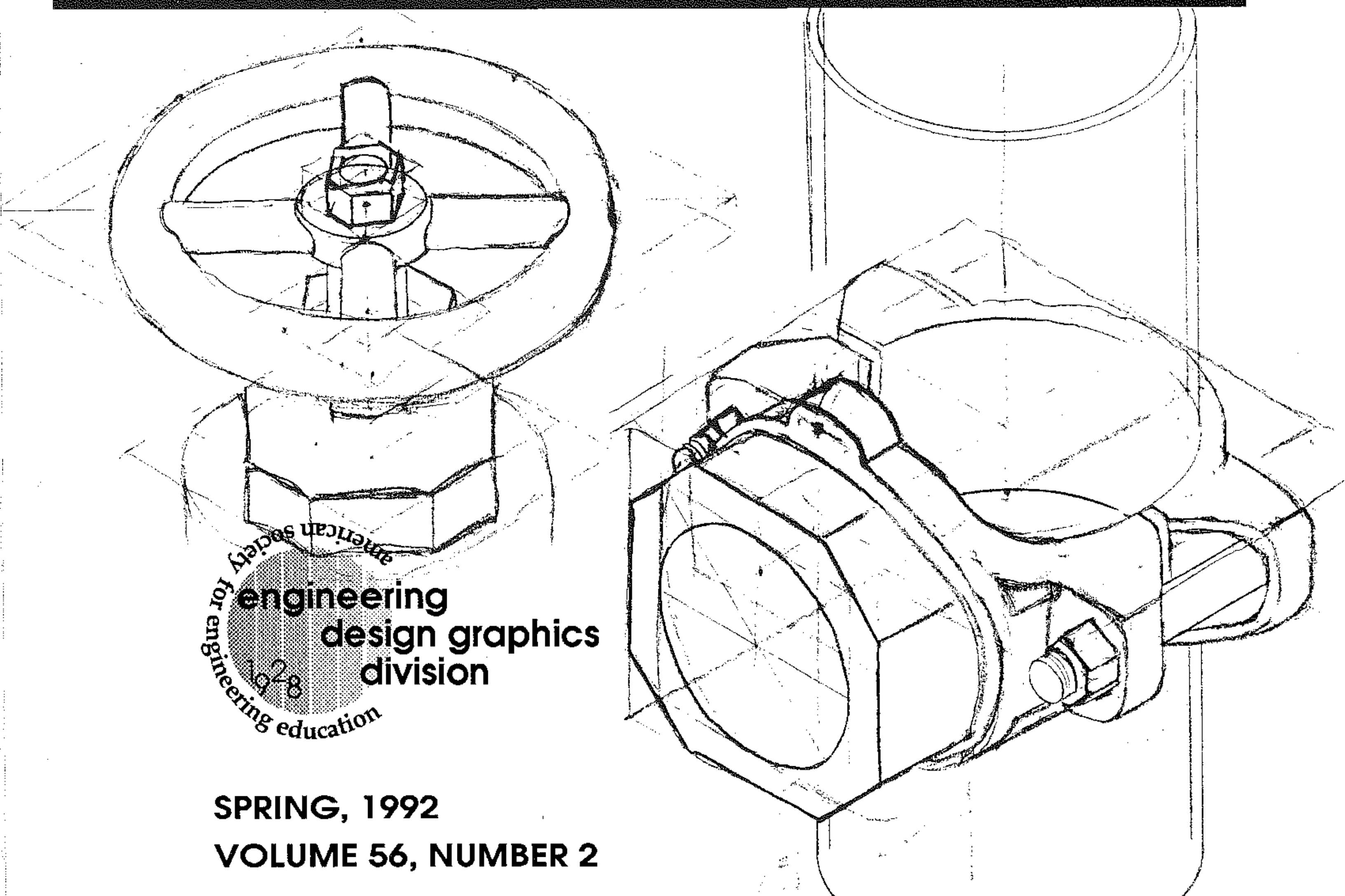

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ENGINEERING DESIGN GRAPHICS DIVISION
AMERICAN SOCIETY FOR ENGINEERING EDUCATION

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In July, 1992, PWS Kent will publish a textbook entitled **Computer Solid Modeling using SilverScreen** by Drs. Bolluyt, Oladipupo and Stewart.

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This textbook will be bundled with a complete copy of the DOS Version of SilverScreen as well as drawing files prepared by the authors. (The SilverScreen software is the commercial version, not a limited student edition.) The software included in the textbook will be licensed for use on one computer for any purpose. In addition, any school adopting the textbook will be automatically licensed at no cost to use SilverScreen on any number of computers required to teach the course using the textbook.

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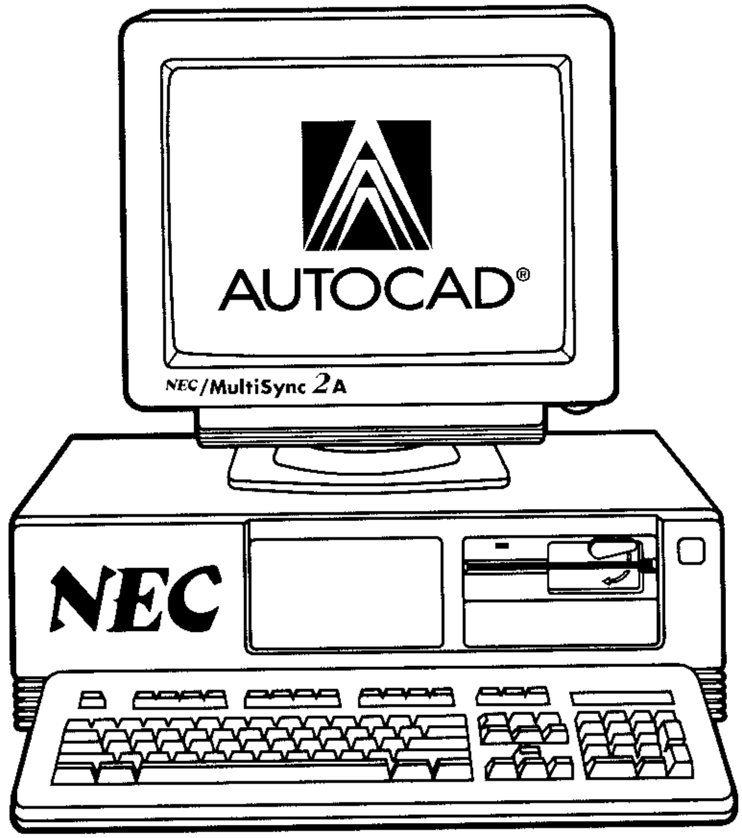
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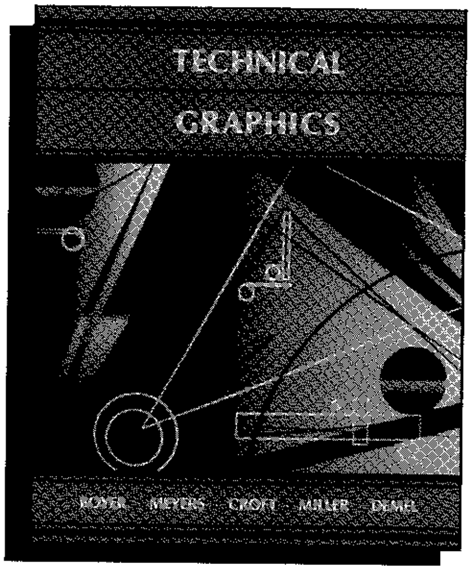

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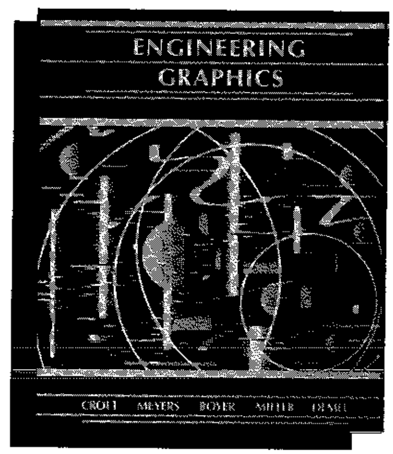

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UTILIZATION OF SOLID MODELING IN ENGINEERING GRAPHICS COURSES

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Abstract

This paper presents a proposed engineering graphics course sequence restructure employing current solid modeling technologies. Rationale given for the course restructure is based upon recent research and publications of the engineering graphics educational community as well as industrial trends in the design-to-manufacture sequence. The proposed course sequence makes use of computer-generated solid modeling geometry to exercise students' visualization capabilities and to emphasize concepts, standards and conventions of creating graphics for engineers.

Introduction

The significance of solid modeling with respect to teaching engineering graphics is twofold. Firstly, the procedure involving the development of a 3-D model as an initial step in the design-analysis-manufacture sequence relegates 2-D documentation drawings to a consequence of the 3-D model. This industrial trend should be reflected in both the content and order of topics in fundamental engineering graphics courses. Secondly, computer-generated 3-D models offer new, more flexible, and possibly more effective means of providing visualization of three-dimensional objects than with past technologies. Visualization is a required element in understanding the body of concepts, standards, and conventions associated with creating graphics for engineers. For these reasons, the authors propose a restructure of the fundamental courses in engineering graphics.

Engineering Graphics as a *Body of Knowledge*

Engineering graphics is believed by graphicians to be a body of knowledge centered around the visualization and communication of 2- and 3-D objects in space. This body of knowledge is characterized by a set of concepts, specific terminology, and industrial standards and conventions specific to the mission of communication and visualization. The specific set of concepts, terminology, and standards is currently undergoing scrutiny, refinement, and definition by the engineering graphics community (Duff, 1990b & c). The premise is that engineering graphics has traditionally been taught as a tool-related activity, but engineering graphics as a body of knowledge is media independent--the graphical concepts are the same whether the graphics have been generated by computer or by other means (Duff, 1990a).

"Among graphic educators, visualization continues to be an issue of study and controversy."

Visualization is an aspect of engineering graphics education which has remained a central issue of the body of knowledge. McGee (1979) defines spatial visualization as: "The ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli" (p. 3). Visualization is a personal attribute which graphics instructors attempt to cultivate in engineering students during the fundamental courses. Among graphic educators, visualization continues to be an issue of study and controversy. It could be argued that today's engineers experienced their greatest personal growth of visualization capabilities via fundamental engineering graphics courses.

Developing solutions for complex technical problems is the primary responsibility of the engineer. Engineering design solutions are a product of skilled left-brain deductive reasoning functions and intuitive right-brain functions (Sadowski, 1989). Visualization is, unlike other topics in the engineering curriculum, a non-quantitative, right-brain function. Visualization, like design, should be practiced through the engineering curriculum like a thread tying together separate elements. This is similar to the way in which writing as a subject is practiced through a curriculum (Duff, 1990b). Yet, visualization and design are somewhat intangible due to their non-quantitative, right-brain nature, thus becoming lost elements in the engineering curriculum (Bertoline et al., 1990). We should actually be thankful that EAC/ABET (Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology) insists on requiring that a minimum number of design credits be included in each engineering discipline's curriculum.

"Solid modeling brings a new capacity to engineering graphics education that enhances our capability of instruction for visualization."

Reflect back on personal experiences with engineering graphics. You probably first remember the constant attention to instruments and line quality (tool-related skills), as well as procedures for geometric constructions. You should also remember knowledge related to standards and conventions of engineering drawings. These procedures and structures are primarily left-brain functions. Putting this aside, it may be hard to pinpoint what other ability you developed. It was the ability to visualize: to make mental manipulations of 3-dimensional objects in space and to read a 2-D drawing or sketch and visualize a 3-D object--a right brain function. Visualization, like the ability to design, is a necessary proficiency of the engineer but is not achieved by chance. High visualization ability must be nurtured and developed in stages through planned and unplanned experiences (Bertoline, et al., 1990). Visualization abilities of engineering students must be developed through organized engineering graphics course work.

The Effect of Solid Modeling on Visualization and Fundamental Engineering Graphics Courses

Solid modeling brings a new capacity to engineering graphics education that enhances our capability of instruction for visualization. The solid model database contains not only the information needed to analyze, fabricate, test, and document the final design, but also the geometric features and dimensions of the model. The model can be dynamically displayed and manipulated interactively until a complete mental description of the object is realized.

The typical instructional approach to strengthening visualization has been in the form of lectures on orthographic theory or pictorial representations followed by application problems. At best, an actual 3-D wooden or plastic model or a Goss Box could be used to demonstrate orthographic concepts. The student would then be assigned a pictorial drawing and asked to construct three views of the object. Practice in multiview and isometric transformations has been the primary vehicle for developing students' visualization capabilities; however, this method often resulted in frustration and confusion for the student. Hence, a new approach to developing visualization is possible utilizing solid modeling technology.

We propose to utilize solid modeling supplemented by sketching exercises to develop visualization abilities. This effort is accomplished through both demonstrations and hands-on exercises involving dynamic rotations and translations of solid models and the formation of orthographic views from appropriate positioning of viewing angles. The student can interactively manipulate the solid model to determine the "views" for a multiview drawing and to support understanding of orthographic theory much the same way as one would handle the actual object or a model to understand its spatial description. Display of a computer model, however, can be presented in both parallel and varying degrees of perspective projection, which could be instrumental in illustrating these concepts. Compared to a physical model, the computer model offers the instructor more convenience and flexibility in construction, alteration, presentation, and storage. The authors believe that this idea is somewhat simple and utilizes only a fraction of the potential of a 3-D database; however, utilizing this technology can have far-reaching effects on developing young engineering students' spatial visualization capabilities. Some variations of this instructional technique have been shown by graphics educators (Pleck, 1990); however, little research indicating the effectiveness of these techniques has been published to date. Other graphics educators have targeted the development of visualization capabilities using solid modeling as a primary goal for new curriculum development (Barr, 1989).

Solid modeling offers another possible positive application to the engineering graphics curriculum. Solid modeling demonstrates the design of complex objects based upon combinations of simpler geometries and functions. Constructive Solid Geometry (CSG) and Boolean operations make 3-D solid modeling concepts simple enough to introduce in a fundamental course without teaching the full range of software-related (primarily 2-D) skills. We propose demonstrations and hands-on experience in solid modeling to serve primarily as an instructional aid in developing concepts (concept-oriented material) and secondarily as an introduction to CAD operation (tool-related skills).

The ability to understand the spatial description of a solid model, however, is not the same as the ability to create or read a conventional engineering drawing. Graphical standards and conventions as well as tool-related skills first must be known. Standard graphical formats provide engineers with a means to communicate with other engineers, designers, and manufacturers, similar to the way computers need standard formats for data file exchange. Therefore, course work in visualization and 3-D modeling must be followed by course work in engineering graphical standards and conventions (primarily 2-D work), as well as the tool-related hardware and software skills.

Documentation Drawings from the 3-D Model

With the integration of computer technologies into the design process, the method and sequence in which engineering drawings are developed has changed. CAD adds nothing to the content of engineering drawings other than accuracy, but it does allow us latitude in the way we design and document. We can now construct a 3-D model as an initial step in the design-to-product sequence and utilize the 3-D database throughout the analysis, testing and manufacturing process. In this light, 2-D drawings truly become documentation drawings. The drawings themselves are not the real products--they only facilitate the manufacture or construction of real products (Wright, 1990). The advantage to modeling is that documentation drawings can be generated as a consequence of the 3-D database. After all, the generated orthographic drawings are simply defined views of the 3-D model.

"The ability to understand the spatial description of a solid model, however, is not the same as the ability to create or read a conventional engineering drawing."

Some engineers may design using orthographic drawings, others may conceive through freehand pictorial sketches, and some may prefer to initiate ideas with the help of a 3-D engineering workstation. Regardless of the method used, good designers think in three dimensions. The question is: when do we build the 3-D model, before or after 2-D? The 3-D model should be an initial step and should dominate the design process (Wright, 1990). Some graphics educators have indicated instructional methods reflecting this sequence (Juricic, 1990).

The sequence of 3-D design to 2-D documentation should be reflected in the way in which we teach engineering graphics. Students should have the latitude and capability to utilize 3-D modeling and to generate orthographic views from the 3-D database. The authors estimate that currently in most engineering schools 3-D modeling is seen only as an advanced topic or course. This is not surprising since, until recently, solid modeling required the high-powered capability of engineering workstations.

Today, however, software for solid modeling (complete with B-rep, CSG, and Boolean operations) is available for DOS 386 platforms. Also, prices for diskless UNIX-based workstations rival those of top-of-the-line DOS machines. Thus, the authors, among others in the engineering graphics community (Barr, 1990), propose to utilize these current technologies to introduce solid modeling concepts and viewing capabilities in fundamental engineering graphics courses.

Proposed Topic Outlines of Engineering Graphics Courses

The following is a proposal for restructuring the current fundamental engineering graphics courses at the University of Louisville to reflect the sequence of topics (concepts and tool-related skills) utilizing solid modeling technologies. Two courses, EG 105 and EG 214, are required courses for all engineering disciplines and are involved in the restructure. The first course, EG 105, is primarily concept-based and focuses on developing visualization and orthographic theory. The second required course, EG 214, centers around standards and conventions for documentation drawings and related tool-based skills. Two other courses, covering descriptive geometry principles, advanced features of production drawings, and advanced CAD topics, utilize 3-dimensional CAD capabilities but are not included here as part of the fundamental course restructuring.

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Table 1. EG 105 Fundamentals of Engineering Graphics I
(1 cr) (required)

A conceptual approach to the fundamentals of engineering graphics featuring visualization and communication, and examining multiview projection and pictorial representation. Media: freehand sketching, instrumental drawing, CAD.

TOPICS	INSTRUCTIONAL EMPHASIS
Introduction to CAD	Concept oriented•
3-Dimensional geometry	Concept oriented
Fundamentals of CSG modeling	Concept oriented
Viewing and dynamic viewing	Concept and tool-based•
CSG command syntax	Tool-based
Orthographic projection theory	Concept oriented
Pictorial representation theory	Concept oriented
Freehand sketching	Tool-based
Multiview sketching	Concept and tool-based
Pictorial sketching	Concept and tool-based

- Concept oriented - instruction focusing on concepts or theories; student work centering on texts, illustrations, and demonstrations with little to no tool-related practice.
- Tool-based - instruction focusing on tool usage, techniques, and manipulative skills; student work centering on practice with or problem solving utilizing freehand sketching, instrumental drawing, or CAD.

In this course, instruction on the fundamentals of 3-dimensional geometry and Constructive Solid Geometry (creating complex solid models from primitives and Boolean operations) and viewing of these solid models is given first in concept and then in practice. The intent is to then utilize simple computer-generated solid models (viewing and dynamic viewing with parallel and varying degrees of perspective projection) as an instructional aid when introducing orthographic projection theory and pictorial representation concepts. The computer models will be manipulated to assist the students in making the mental transformation from a 3-dimensional object to the conventional 2-dimensional representation in much the same way as wooden or clay models have traditionally been used. Conventional 2-dimensional representations (multiview and pictorial drawings) are initially sketched freehand or on grids, then later constructed by instrumental drawing methods.

Table 2. EG 214 Fundamentals of Engineering Graphics II
(1 cr) prerequisite: EG 105 (required)

Communication of 2- and 3-dimensional objects emphasizing standards and conventions of 2- and 3-dimensional engineering graphics. Increased application of tool-based skills and problem-solving exercises. Media: CAD, freehand sketching.

TOPICS	INSTRUCTIONAL EMPHASIS
CSG modeling	Tool-based
Documentation drawings from solid models	Concept oriented, then tool-based•
2-Dimensional constructions	Tool-based
Conventions of multiview projection	Concept oriented, then tool-based
Dimensioning	Concept oriented, then tool-based
Geometric tolerancing	Concept oriented, then tool-based
Sectional views	Concept oriented, then tool-based
Auxiliary views	Concept oriented, then tool-based
Pictorial representation	Tool-based
3-Dimensional presentations	Concept oriented, then tool-based

• Instruction giving concepts and theories followed by necessary tool-related operations; student work begins with study of concepts (via texts, illustrations, demonstrations) followed by problem-solving exercises that test and practice the understanding of concept material and the application of tool-based skills. Instrumental drawing is not used in this course.

This second required course builds on the concepts (geometric modeling, orthographic projection, pictorial presen-tation) and tool usage skills (CAD, freehand sketching) of the first course. The emphasis is the generation of 2-dimensional documen-tation drawings from a 3-dimensional database practicing accepted engineering standards and conventions.

On Teaching Computer Aided Design Concepts to Industrial Engineers

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ABSTRACT

The Industrial Engineering Department, University of Pittsburgh, has designed and offered a course in Computer-Aided Design (CAD). Now in its sixth year, this course is required for junior industrial engineering students and is an elective for students from other departments. Unique aspects of the course include the emphasis placed on learning how CAD can facilitate design, and understanding and utilizing its graphical database. Design skills are developed through the completion of a series of unstructured problems. Students learn to manipulate the graphical database, extract information from it, and export that information to other software for further applications.

This paper describes the evolution of the course content over its history and also discusses how a knowledge of computer graphics and CAD system capabilities can be used to address a diverse range of industrial engineering applications. The relevance of computer graphics and CAD to other courses within the modern industrial engineering curriculum is also discussed. Finally, the application of these CAD concepts by industrial engineering students to two senior-level design problems is presented.

INTRODUCTION

Industrial Engineering (IE) is concerned with the design, installation, maintenance, and improvement of integrated systems of people, material, information, equipment and energy. It draws upon specialized knowledge and skills from the mathematical, physical and social sciences, together with the principles and methods of engineering analysis and design in order to specify, model, predict, and/or create such systems. Although a relatively new discipline, industrial engineering has moved substantially beyond the early successes of Fredrick Taylor and the Gilbreths through productivity improvement and into its current emphasis on areas such as total quality management and concurrent engineering (Emerson and Naehring, 1988).

The low cost availability of computer graphics hardware and software is an especially attractive and invaluable tool to help industrial engineers solve systems level problems in a multitude of engineering environments. This paper details the value of including computer graphics and computer-aided design as part of an undergraduate industrial engineering program. It also describes a strategy used to teach undergraduate industrial engineering students these concepts as a three-credit junior level course within a specific IE program. This course is taught with a focus on using CAD to facilitate the systems design process with an emphasis on the information contained in

CAD databases. The student learns how information can be extracted and used for problem solving.

THE NATURE OF INDUSTRIAL ENGINEERING AND ITS RELEVANCE TO COMPUTER GRAPHICS

Industrial engineers (IEs) apply their repertoire of problem-solving skills to a diverse spectrum of problems typically involving either the production of goods or services. Today, industrial engineers can be found in almost every type of industry including manufacturing, distribution, consulting, banking, health care delivery, social services, transportation, construction, information processing, electronics and energy. For example, an industrial engineer may be involved in long range planning and facilities design for a transportation facility, be responsible for implementing robots in an automotive assembly plant, or be required to develop a more effective patient flow pattern within a major hospital. Despite the diverse nature of the industrial engineer's work environment, the same tools can be applied to all such settings. Computer graphics and computer-aided design are among these tools, but their applications are as varied as the work of the IEs.

> "The major difference between the appropriate computer based tools and other traditional problem-solving techniques is that the computer-based tools are interactive problem-solving media."

The most obvious benefit of CAD and computer graphics is as an aid in problem visualization. Specifically, CAD's major contribution may be as a communications tool. Engineering design graphics are fundamentally useful during the ideation phase of engineering design. Here the engineer explores and develops new approaches to a specified design problem. Graphics aids the industrial engineer in the visualization, design, and solution to a problem (Wiley, 1990). Engineers have historically communicated their design through some form of graphics. Until recently, this communication has taken the form of drawings. By the 1970s, CAD packages had become available for mainframe and mini-computers. However, the combined cost of the hardware, software, operation and maintenance, restricted their educational use to selected universities, and then typically only at the graduate level. With the widescale introduction of personal computers with graphical capabilities in the early 1980s, a major instructional medium for engineering education emerged. By 1985, there were several commercially available personal computer-based CAD systems, thus enabling engineering curricula to introduce serious coursework in this rapidly evolving media. The major difference between the appropriate computer-based tools and other traditional problem-solving techniques is that the computer- based tools are interactive problem-solving media.

THE EVOLUTION OF A COURSE THAT TEACHES CAD CONCEPTS TO INDUSTRIAL ENGINEERS

Early coursework in IE was based on tools for productivity improvement and efficiency. These included work design, work measurement, and time studies. As the original concepts of industrial engineering were refined, new technologies were developed and innovative concepts uncovered. The original topics were expanded to include aspects of manufacturing, engineering economics, production planning and inventory control, statistical quality control, human factors, systems management and operations research. This growth of topics led to the present diversity of tools required by the industrial engineers to function effectively in the modern work place.

As microcomputers were introduced into the undergraduate curriculum, they have had an irrevocable effect on both course offerings and content. Students now have access to a wealth of "canned" algorithms and software packages that can facilitate problem solution. The use of packaged software for such computational and data intensive topics as linear programming, work measurement, and statistical analysis, is becoming the accepted norm. While the challenge remains to teach the student the underlying principles, more realistic problems can now be addressed, modeled and solved by student engineers. New topics such as "Computer Graphics," "Computer-Aided Design," and "Computer-Aided Manufacturing" have become an integral part of the curriculum.

In the mid 1980s when the personal computer "explosion" was at hand, the School of Engineering at the University of Pittsburgh committed to developing a CAD teaching laboratory that could be shared by its various departments. With the laboratory in place, an IE CAD course emerged, and, over the past few years has been extended to address a broad range of applications. This course was designed to develop the student's knowledge of computer graphics while focusing on the interface of CAD packages with other computer- based problem solving tools.

CAD LABORATORY FACILITIES

The desire to offer courses in Computer Graphics and Computer-Aided Design gave rise a variety of laboratory needs. These included the need to provide students with useful hands-on experience in Computer-Aided Design that emphasized the principles of computer graphics rather than devoting large amounts of time to learning a complex CAD system. Further it was felt that formal class time should be dedicated to learning the underlying principles of CAD, design, database structure, etc., with the laboratory sessions reserved for learning the particular CAD software. Specifically, the goal was to teach basic CAD concepts common to all systems, rather than the intricate details of a particular software package.

If students understand the basic functions of a CAD system, then they should be able to learn with relative ease how to use a specific system in the work place. In order for the CAD laboratory experience to be useful, it was felt that students would need at least ten hours per week of laboratory time. Further, while some of this time would have to be part of a regularly scheduled laboratory session, the remainder would be unstructured time devoted to completing the assigned problems. Since the number of computer stations would be limited, a system would have to be developed which enabled each student to have a fair opportunity to obtain an appropriate amount of laboratory time.

Hardware and software costs in the mid 1980s precluded the School from obtaining a mini-computer based CAD system and then being forced to purchase expensive maintenance contracts for both hardware and software. Clearly, the concept required that hardware be serviced by the school's technicians and software be reasonably priced to facilitate acquisition and updating of a sufficient number of copies. Thus, a microcomputer based system was required. These systems would allow the greatest number of students to obtain the required hands-on instruction and thus return a larger benefit for the cost incurred. The original system selected was based on the IBM 286 machine, then emerging as a system of choice. At that time, the 286 system offered sufficient speed combined with enhanced graphics capability and color. A 20-workstation lab was created; the software chosen was AutoCAD™, then a relatively new product. The first twenty copies were obtained as part of a grant program from Autodesk, Inc.; an additional four copies were purchased for use by faculty and teaching assistants (Bidanda and Wolfe, 1988). The original machines were upgraded to 80386 models in 1991 and linked to a file server through a LAN. AutoCAD™ has been upgraded to Release 11.

"As microcomputers were introduced into the undergraduate curriculum, they have had an irrevocable effect on both course offerings and content."

COURSE TOPICS AND CONTENT

The resultant three-credit-hour course consisted of two 50-minute lectures and a two-hour recitation in the CAD laboratory. Students are encouraged to sign-up for additional laboratory time under a system that facilitates equal access. The laboratory is open approximately 14 hours per day and is shared by the Civil, Industrial and Mechanical Engineering (ME) Departments. The laboratory accommodates 50 to 60 IE students and approximately 120 ME students during the Fall Term through careful scheduling and coordination of assignments. During the Spring Term approximately 50 Civil Engineering students also utilize this facility. Students who are registered for

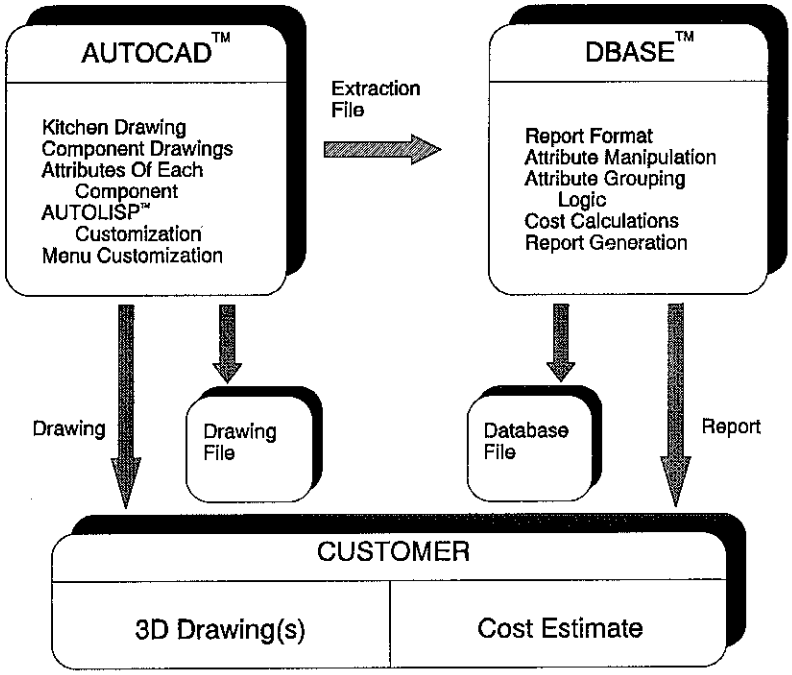


Figure 1. Program Structure

Development of Quick Cost Estimates in Home Remodeling

This project involved the design of a kitchen cabinet ordering system for use at a building supply center (Crew et al., 1989). Typically, a prospective customer meets with a design associate at the store who helps the customer to layout the kitchen. Traditionally, everything had been done manually. Each kitchen plan may draw upon a multitude of shelving, counter tops, and other standard fixtures. For each kitchen scheme, the cost must also be computed manually by the associate, taking approximately 30 minutes (during which time the customer usually waits). The final design is generally developed iteratively, after many such designs have been proposed and their associated costs have been manually calculated.

After several meetings between the student group and associates at the store, the student team decided to create an alternative system using an AutoCAD™ based system with AutoLISP™ written routines including an interface with dBase III™. The four main work packages were: icon creation, customization with AutoLISP macros, custom menu creation, and dBase III™ programming and integration. The program structure is shown in Figure 1.

As noted, the final product provided both three-dimensional views of the proposed kitchen and a cost estimate. This system provided visual feedback, had memory capability, was a reliable cost system, reduced customer waiting time, and most of all, was easy for the design associate to use. Figure 2 shows a sample kitchen drawing. An associated cost estimate is also printed. This contains the following information for each item in the drawing: Item Code, Quantity, Weight, Volume, Base Price. The total cost of the kitchen and pricing/estimate policy are also part of the cost estimate printout.

Facility Design at the Buhl Science Center

The Buhl Science Center in Pittsburgh was in the midst of a major expansion project with the construction of a new Science Center. This expansion represented not only a large increase in area, but also a large staff increase (Wertman and Pajak, 1990). The facility under construction needed to house between 80 to 100 staff workers in approximately 60 offices. Space requirements varied depending on each person's position and work performed. The goal of the project was to quantify a staff person's equipment and space requirements in order to better plan the new office facility. The project used AutoCAD™ and dBase III™ to evaluate various office layouts in order to find one that was aesthetically pleasing, efficient and cost effective.

Questionnaires were designed to establish a current inventory of office equipment and survey department heads in order to assess future requirements for each department. These results were entered into a database and served as a planning aid in designing the new office layouts. Blueprints of the office area were interpreted and an AutoCAD™ drawing file was created. Symbols representing various pieces of office equipment were then created. A customized, user friendly menu was also developed. This allowed the staff to design their own office layout with their existing and anticipated new furniture. The CAD system allowed visualization of office and equipment needs, and allowed the administration to compile a list of needed and existing furniture, by extracting attribute information from AutoCAD™ and linking it to dBase III™. With this system, the Buhl Science Center could compare prices and discounts by hav-

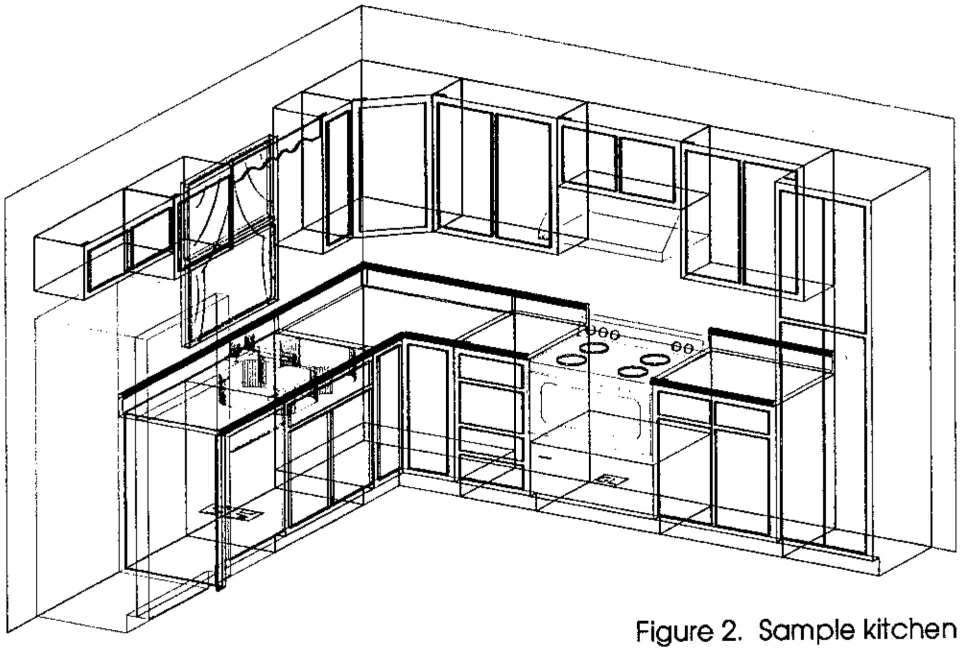


Figure 2. Sample kitchen drawing

ing ready-made lists of anticipated equipment purchases. The system is currently being used as a planning tool at the Science Center.

These and other projects have proven to be successful. A great deal of this success can be attributed to the knowledge gained from the student's Computer Graphics and CAD class.

INTEGRATION OF CAD WITH OTHER IE COURSES

Computer Graphics is treated as an integral part of a modern information system. In this format, it can be best viewed in the context of the other industrial engineering courses in the curriculum. The course also serves to integrate knowledge gained from other courses in the IE curriculum. The following sample exercises, in conjunction with the examples already presented, illustrate the integrative aspect of the Computer Graphics and CAD course:

1. Design of an ergonomically suitable computer keyboard. The design of keyboards is an active area of research in the field of ergonomics. Students analyze the keyboards presently used, identify areas for improvement, and use their creativity and knowledge of ergonomics to develop a better design. Upon completion of the assignment, students better appreciate the utility of CAD for producing designs.

2. Layout cutout patterns on sheets to minimize scrap. The students are given several shapes, e.g., the patterns for producing a metal jug. They then lay out the patterns on a fixed size of sheet metal allowing for machining tolerances, and optimizing the layout to minimize scrap percentage. This is analogous to the "cutting stock" problem in Operations Research.

3. Design of a factory layout to minimize material handling costs. Material processing routes through different types of machines for a particular product are supplied in the assignment. The machine capacities are also provided. Students design a factory layout with the objective of minimizing material handling costs. They are also required to write an AutoLISP™ program to calculate the material handling cost for a particular product routing.

FUTURE WORK AND CONCLUSIONS

The course has now been taught once a year for the past six years. Four different faculty members have been involved with its design and continued evolution. Students have found the course challenging and

Profile and Practices of Contributors to the Engineering Design Graphics Journal

Robert A. Chin
Department of Construction Management
East Carolina University

Table 1

Number of Articles Published in the EDGJ by Affiliation of First Authors

Affiliation	n
Ohio State	33
Texas A & M	19
Israel Institute of Technology	17
Iowa State	16
Northeastern	11
VPI & SU	10
Illinois at Chicago Circle	9
Louisiana Tech	9
Miami (Ohio)	9
North Carolina State	9
Purdue	9
Melbourne, Australia	8
Texas at Austin	8
Louisiana State	7
Pennsylvania State	7
Cincinnati	5
Clemson	5
Rhode Island School of Design	5
Wisconsin-Madison	5
Federal City College	4
Kansas	4
Marquette	4
Mississippi State	4
Princeton	4
Queen's, Canada	4
Virginia	4
Appalachian State	3
Arizona State	3
Central Michigan	3
Delaware	3
E. I. DuPont	3
Georgia Institute of Technology	3
Machine Design (trade journal)	3
Miami-Hamilton	3
New York	3
Tufts	3
U. S. Naval Academy	3
Wisconsin-Milwaukee	3
Total	265

editors note: Table 1 from page 23 of Vol. 55 NO. 3 of the Autumn 1991 Issue of *The Engineering Design Graphics Journal* was incorrect. The correct version of that table is printed here along with the corrected text which refers to Table 1.

Page 24, paragraphs 2 & 3

While the list features 27% (n=38) of the population, the total number of feature articles associated with these organizations represents 66% (n=265) of all the feature articles published in the *EDGJ*.

The organizations with which 10 or more feature articles were associated were responsible for 26% of the feature articles published. That is, individuals affiliated with 4% (n=6) of the 141 organizations were responsible for over a quarter (n=106) of the feature articles published in the *EDGJ* during this time frame. It should be pointed out that these data, however, do not take into consideration the size of the organization, budget, etc. that may play a role in an organization's ability to support research.

Page 26, Paragraph 2

3. Two-thirds of the articles published in the *EDGJ* were contributed by authors who were affiliated with less than one-third of the organizations conducting engineering design graphics research. More dramatic is the fact that authors affiliated with four percent of the organizations conducting engineering design graphics research were responsible for over a quarter of the articles published.

Bylaws for the Engineering Design Graphics Division (EDGD) of the American Society for Engineering Education (ASEE)

Article I: NAME AND OBJECTIVES

Section 1. The name of this Division of the American Society for Engineering Education (the Society shall be the Engineering Design Graphics Division (the Division).

Section 2. The objectives of the Division shall be to:

a. Provide leadership and guidance for those engaged in the teaching of conceptual design and graphical analysis and their use in industry.

b. Investigate matters relating to engineering graphics and to inform the membership of current developments.

c. Encourage the early participation of engineering students in the areas of graphics and design.

d. Promote, stimulate and provide opportunities for the professional interchange of ideas among the membership.

Article II: MEMBERSHIP

The membership of the Division shall consist of all members of the Society who have indicated an interest in the Division and paid the annual Division dues. Division dues are billed, due and payable with the Society dues on the anniversary of the date on which a member joined the Society. Division dues are deposited by the Society to the account of the Division and disbursed upon request of the Division Chair or Secretary-Treasurer. Dues fund Division publications sent to each member.

Article III: OFFICERS AND DUTIES

Section 1. The Division shall be administered by an Executive Committee consisting of the following elected officers plus the immediate past chair: *(See Art. VI)*

Chair	1 year
Vice Chair	1 year
Secretary-Treasurer	3 years
Directors (5)	3 years

Terms of office shall conform with the Society-year, beginning in June following the Annual Conference of the calendar-year in which elected *(See Art. IV, Sec. 1f)*.

Section 2. The duties of the Division officers shall be those usually associated with the respective office and described as follows:

2a. CHAIR

2a(1). The Chair is the chief executive officer of the Division and of the Executive Committee and an ex officio member of all Division committees. The Chair presides at all business meetings of the Division and the Executive Committee.

2a(2). The Chair is the senior member of the Division on the Executive Board of the ASEE Council for Professional and Technical Education.

2a(3). The Chair shall review the annual Division budget as prepared by the Secretary-Treasurer [*See Art. III, Sec. 2c(6)*]. The Vice-Chair shall be consulted during this review. If necessary, adjustments to the budget will be made and discussed with the Secretary-Treasurer. When finalized, the budget shall be presented by the Chair to the Executive Committee. Upon approval, the budget shall be submitted to the Executive Director of the Society.

2a(4). The Chair shall prepare a written report, including budget expenditures, for the term of office just completed and transmit, not later than thirty (30) days following completion of the term of office, copies to the Secretary-Treasurer.

2a(5). The Chair shall keep the Vice-Chair informed of all Division activities during the term of office, and transmit to the Vice-Chair at the end of the term all material needed to maintain continuity.

2a(6). The Chair shall appoint all bylaw committees *(See ART. VII)* except the Nominating and Elections Committees, designating the chair of each committee except where the chair is specified by the bylaws.

2a(7). The Chair shall appoint the chairs and, at his discretion, members of committees not specified by the bylaws but considered necessary for the adequate administration operation of the Division, and assign such committees to the Vice-Chair or appropriate Director for Administrative control.

2a(8). The Chair shall review and approve the composition of all committees.

2a(9). The Chair shall assure the effective operation of the Division by revoking the appointment of any appointee who is not satisfactorily performing the duties of the position to which appointed.

2a(10). The Chair shall, with the advice and consent of the Executive Committee, request the resignation of any officer of the Division who is not satisfactorily performing the duties of the office to which elected, and shall appoint another member of the Division to that office for the remainder of the unexpired term. If the officer refuses to resign or does not respond to the resignation request within thirty (30) days, the Chair shall relieve that office by executive fiat and appoint a replacement to serve the remainder of the unexpired term *(see ART. IV, Sec. 1g)*.

2a(11). The Chair is responsible for all meetings of the Division and of the Executive Committee.

2a(12). The Chair shall arrange for a letter of welcome containing information about the Division and its objectives to be sent to each new member of the Society who has indicated an interest in the Division.

2b. VICE-CHAIR

2b(1). The term of office of the Vice-Chair begins with the Society-year beginning in June following the Annual Conference of the calendar-year in which elected *(SeeART. III, Sec. 1)*.

2b(2). The Vice-Chair succeeds to the Chair of the Division at the beginning of the Society-year following the term as Vice-Chair.

2b(3). In the event that the Chair is unable to perform the duties of the office, the Vice-Chair shall assume the Chair.

2b(4). In the absence of the Chair, the Vice-Chair shall preside at all business meetings of the Division and of the Executive Committee.

2b(5). The Vice-Chair shall be the junior member of the Division on the executive board of the ASEE Council for Professional and Technical Education.

2b(6). The Vice-Chair shall assist the Chair in the administration and operation of the Division.

2b(7). To provide continuity, the Vice-Chair shall, through communication with the Chair, keep informed on all current activities and become familiar with the Division's operational procedures.

2b(8). The Vice-Chair shall appoint the Nominating and Elections Committees *(See ART. VII, Secs. 1a and 1b)* subject to the approval of the Executive Committee.

2b(9). The Vice-Chair is the chair of the Elections Committee, and with the aid of the other members of the Elections Committee, counts the election ballots and submits a confidential report of the results of the election to the Chair of the Division.

2b(10). The Vice-Chair shall prepare a list of committees for the following year for presentation to the Division. Printed copies of this list shall be made available to the Executive Committee and provided to all persons attending the annual business meeting of the Division.

2b(11). The Vice-Chair is responsible for the functioning and performance of the following Bylaws Committees: Nominating, Elections and Distinguished Service Award. The duties and composition of these committees are defined in Art. VII, Sec. 1.

2c. SECRETARY-TREASURER (S-T)

2c(1). The Secretary-Treasurer is Secretary-Treasurer of the Division and of the Executive Committee.

2c(2). The S-T shall keep complete records of all meetings of the Division and of the Executive Committee and within sixty (60) days following each meeting or group of meetings shall provide copies of the minutes to all members of the Executive Committee and proxies. The S-T shall distribute copies of the minutes of the previous annual and mid-year business meetings to all members in attendance at the annual business meeting in June.

2c(3). The S-T shall receive and preserve copies of all reports and papers presented at the meetings of the Division and of the Executive Committee.

2c(4). The S-T shall transmit to the Director: Publications *(See ART. VIII, Sec. 1a)*, the Division archivist, all archival records (minutes, proceedings, lists, etc.).

2c(5). When changes are made to these Bylaws, the S-T shall, within sixty (60) days following the annual conference at which the changes become effective, provide each Division officer with a copy of the (revised) Bylaws.

2c(6). The S-T shall prepare an annual budget and submit it to the Division Chair for review prior to presentation to the Executive Committee for final approval or revision.

2c(7). The S-T shall receive any Division money excluding Division dues and other funds under control of the Publications Committee. Such money shall promptly be placed on deposit in a suitable account in a federally-insured financial institution under the name of the EDGD-ASEE with signatures of both the S-T and Chair on file, with either having access to the account.

2c(8). The S-T shall be the disbursing agent for the Division, and will disburse funds upon approval of the Division Chair.

2c(9). The S-T shall submit an annual financial report at the annual business meeting and an interim report at the mid-year meeting.

2d. DIRECTORS

2d(1). There shall be five Directors, each elected to serve for a three-year term. No more than two (2) directors shall be elected for any Society-year. Each Director shall be responsible for all committees in one of the following categories:

A. Liaison
B. Professional and Technical
C. Programs
D. Publications
E. Zones Activities

2d(2). GENERAL DUTIES OF DIRECTORS

Directors are responsible for establishing functions and guidelines for the operations of each of their assigned committees. Each year, prior to the Annual Conference, they shall recommend to the incoming Chair names of suggested committee chairs and members of committees under the Director's jurisdiction. A Director whose term is ending should consult with the elected replacement as to the committee composition. The actual appointments should not be made until approved by the Executive Committee and the Division Chair as described in ART. III, Sec. 2a(8). Directors shall maintain contact with the chairs of their assigned committees to ensure timely performance of the committees' functions. Directors are responsible for the presentation of reports on the activities of their assigned committees at the Executive Committee meetings during the Annual and Mid-Year

(b) Improvement of the tools of, and conditions for teaching. Evidence of such achievement may consist of subject matter (textbooks, etc.), courses of curricula, diagrams and models, laboratory and other teaching equipment, and other similar activities.

(c) Improvements of teaching to include: the development of teachers in a department or in other schools, testing or guidance programs, promotion of cooperation with other types of educational institutions or industry, development of testing and guidance programs, and the coordination of fields of subject matter.

(d) Scholarly contributions to literature, significant honors, etc.

(e) Service to the Engineering Design Graphics Division of ASEE as evidenced:

- By regular attendance at its meetings as an indication of interest in the improvement of teaching.

- Service on its committees or an officer with a record of definite achievement.

- Contribution to its publications or summer shcool programs.

1d(4). Nominations. Nominations may be made by any member or group of members of the Division except members of this Awards Committee.

1d(5). Nomination Form. A nomination form shall be prepared by the Distinguished Service Aware Committee which will outline the qualifications and will provide space for a brief description of a nominee's performance in each category. This form shall accompany the election ballot *(See ART. IV, Sec. 1d).*

1d(6). The report of this Committee shall be made at the appropriate time and place.

1d(7). Nominees from the previous three years may also be considered for the award by this committee. A list of names of those individuals, and all supporting information, shall be passed on to the incoming chair of the Committee by the outgoing chair.

Section 2. NON-BYLAW COMMITTEES
Non-Bylaw committees shall be assigned to one of the following described categories under the supervision of the appropriate Director. They may be appointed by the Division Chair or by the Executive Committee when such a committee is deemed necessary for the proper functioning of the Division. Some special-purpose committees may be assigned under the control of the Chair or Vice-Chair.

2a(1). LIAISON
Committees in this category are those whose purpose is to provide a connection between the Division and other related or interested groups both within and without the Society.

2a(2). PROFESSIONAL AND TECHNICAL
The purpose of committees within this category is the advancement of knowledge in the many areas encompassed by the Division.
The Director: Professional and Technical Committees shall recommend, as required, an ANSI Committee to act for the Division to consider and approve or disapprove any American National Standards Institute (ANSI) Drafting Standards submitted to it in accordance with ASEE policy.

2a(3). PROGRAMS
Committees in this category are responsible for planning and implementing the ongoing programs of the Division. There shall be an Ad Hoc Program Committee for each Annual and Mid-Year Conference, and it shall be responsible for all conference sessions sponsored totally or jointly by the Division during that conference. Each program committee shall be appointed at the conference occurring approximately 18 months prior to the conference for which it is responsible, and shall cease to exist following the conference for which it was formed. A Program Committee shall generally consist of the Division Vice-Chair, the Director: Programs, a Program Chair, and at least one other person closely allied with, or especially qualified to represent and act as liaison for, the institution or area in which the particular conference is to be held. This person may also be the Program Chair.

2a(4). ZONE ACTIVITIES
Committees in this category are to increase and promote Section and local activities of Division members within the various zones. There shall be a committee from each of the sections in the particular zone.

Section 3. COMMITTEE CHAIRS
Committee chairs are responsible for following the guidelines established by their Director and for keeping the appropriate Director informed of the activities of their committee. The chair directs the activities of the committee members within the constraints of those guidelines. The committee chair may suggest to the appropriate Director such additional activities as deemed necessary for the committee's proper functioning. Each chair shall prepare and submit reports to the appropriate Director in time for the reports required of the Director to be prepared. Required reports are interim for presentation at Mid-Year Conference and annual for presentation at the Annual Conference.

3a. PROGRAM CHAIR
Each Program Chair shall submit proposed programs to the Director: Programs for approval. The Director will in turn submit the proposal to the Division Chair and Executive Committee for their approval. The Program Chair for an Annual Conference and the Division Chair shall attend the ASEE planning meeting for that particular conference. The Program Chair, with the assistance of the Program Committee, determines the number, type and specifics of all national events, including participants and session moderators. Although it is the Director's responsibility to pass on to the Program Chair all available papers, abstracts, program suggestions and other pertinent information, it shall be the responsibility of the Program Chair to select and schedule the actual events and participants after the program has been approved by the Director: Programs and the Executive Committee.

The Program Chair shall also be responsible for preparing feature articles or announcements publicizing the program in the appropriate journal (s) and in other ways assist in the proper advertising and promotion of the program.

Article VIII PUBLICATIONS

Section 1. PUBLICATIONS COMMITTEE.
The Publications Committee shall be composed of the Director-Editor *(See ART. III, Sec. 2d (3d))*, the Circulation Manager-Treasurer, the Advertising Manager, and such Assistant Editors as are deemed necessary by the Director-Editor.

1a. The Publications Committee shall be responsible for the timely publication of the Engineering Design Graphics Journal, and any other Division publications, as authorized or directed by the Executive Committee. A minimum of three issues of the Journal shall be published each year.

Section 2. SELECTION OF THE PUBLICATIONS COMMITTEE

2a. The Director: Publications shall be elected for a three-year term as described in Article IV.

2b. CIRCULATION MANAGER-TREASURER
The Circulation Manager-Treasurer shall be appointed by the Director: Publications, subject to the approval of the Executive Committee. The term of appointment shall be indefinite and continue for so long as: it is mutually agreeable with the appointee, the supporting institution, and the Director: Publications and the responsibilities of the office are properly served. The appointment may be terminated by resignation or death, by request from the supporting institution, or for cause by action of the Executive Committee. A recommendation to terminate the appointment may be made to the Executive Committee by the Director: Publications or may be initiated by the Executive Committee after suitable notice to the Director: Publications. Termination, for whatever reason, shall consider the best interests of the Division and be handled in such a manner as to ensure continuity of the operations of this office.

2c. The Advertising Manager shall be appointed by the Director: Publications and serve a concurrent term with and at the pleasure of Director: Publications.

Chairman's Message by John T. Demel

A Time of Change

Many things are happening in higher education. Decreases in funding. Increases in work load. Some hollow talk about quality. Few of us are able to continue business as usual.

Should higher education be exempt from the economic pressures facing the rest of our country? Probably not.

Can the proper use of technology and methodology help us face these pressures? Can such things help our students learn and keep our loads reasonable? We know that good teaching occurs in a variety of ways. Good lectures with dialog. One to one with students during labs or in the office. Are there new things that we should be considering?

Computer Aided Instruction (CAI) – I have a colleague here at Ohio State in another department who has developed successful CAI materials for landscape architecture. Now that we have affordable multimedia PCs and Macs, he is having a ball creating material for his students. I asked him how long it took to create a course using Authorware software on a Mac. He smiled and said, "I could tell you three months or fourteen years." What he was saying is that there will be a big investment of time to create new materials. He could produce a course in three months because he had spent fourteen years organizing the materials for a number of different systems that had shown promise.

However large the investment, these software modules free him to spend more time with his students on a one-to-one basis. These students are missing his stirring, entertaining lectures but are they getting as much or more from his CAI software and one-to-one contact?

Video – Most of us have experienced video both for entertainment and instruction. I don't like it because I can't ask questions. CAI incorporating video segments allows us to answer the typical questions once for many people. Where do expert systems play a role in this arena? Could I capture Ron Barr on Modeling? Del Bowers on Visualization? Larry Goss on Dimensioning?

We have a tremendous body of knowledge about engineering graphics in this Division. Is there a way in which we can capitalize on this knowledge base to create better learning environments? What would it take to get the people in this Division to work together on a project that would cover pictorials, dimensioning, modeling, detailing, drawing storage and exchange, sections, conventions, illustration? I don't think that any one of us could afford the time to develop all of these materials but we could if we would work together.

This would be a long term investment in the face of changing technology. Our country has not shown much patience for long term investments. We tend to like competition better than cooperation. Can we in education be smarter than our colleagues in industry? Let's discuss what such a project might be worth to us, to our students, and to industry as we meet, talk, and send e-mail.

1992 ASEE Design Graphics Division Annual Conference

University of Toledo Seagate Center

Toledo, Ohio June 21 - 24, 1992

The Glass Capitol of the World and the home of the Mud Hens, Toledo, Ohio, is the site of the 1992 ASEE Annual Conference. Currently in the planning stages, the EDGD program will include five technical sessions, the annual business luncheon, and the annual awards banquet. Come, participate, and enjoy.

Program Chair:
J. Douglas Frampton
Engineering & Science Technology Division
The University of Akron
120 Shrank Hall South
Akron, Ohio 44325-6104

SEMINARS

• **Saturday, June 20**
12:30 - 4:30 **Session #0038**

ASEE/SDRC
Using *I-DEAS Solid Modeling Workshop*

Instructors:
Dr. Robert Mabrey
Tennessee Technological University

Mark Lawry, Technical Support Mgr.,
SDRC University Consortium

SHAPING OUR WORLD – CENTURY II

• **Saturday, June 20**
12:30 - 4:30 **Session #0099**
• **Sunday, June 21**
8:00 - 12:00 **Session #0138**

ASEE/EDGD
Geometric Dimensioning & Tolerancing

Instructor:
Patrick J. McCuistion
Ohio University

This workshop focuses on a basic understanding of geometric dimensioning and tolerancing as a means of specifying engineering design requirements with respect to the actual "function" and "relationship" of part features. Overhead transparencies and actual parts are used to explain the different geometric characteristics relative to their functional tolerance zones.

Fee: $50 (Covers both sessions and can be paid at the registration desk at check-in.)

Technical Sessions

• MONDAY, JUNE 22

8:30 - 10:15 am Session #1238

Visualization/Solid Modeling: Past, Present, Future
Moderator: Ed Galbraith, Cal. Poly, Pamona.

Presenters

Dennis R. Stevenson, University of Wisconsin-Parkside. *Effect of Instruction in Solid Modeling Upon Scores in Orthographic Projection Problems.*

Craig Miller, Purdue University. *Clair V. Mann: The Father of Research and Visualization Studies in Engineering Graphics.*

Gary Bertoline & William A. Ross, Purdue University. *Teaching Solid Modeling Using Sketches and Computers.*

Ronald E. Barr, University of Texas at Austin. *Southern Coalition for Modern Engineering Design Graphics at Two Year Institutions.*

12:30 - 2:00 pm Session #1438

Engineering Graphics: Curriculum Issues I

Moderator: Tim Sexton, Ohio University

Presenters

Judith A. Birchman, Purdue University. *Graphics Instructional Materials: A Design Strategy.*

Lia N. Brillhart, Triton College. *Using an Engineering Graphics Course to Improve Retention.*

Rollie Jenison, Iowa State University. *The Role of Engineering Design Graphics in Engineering Curricula of the 21st Century.*

D. E. Calkins, University of Washington. *Excel-Freshman Engineering Design at the University of Washington.*

Del Bowers, Colorado School of Mines. *Imaging Science: An Emerging Discipline.*

6:00 - 8:00 pm Session #1838

Engineering Design Graphics Division Executive Committee Meeting
Chair: John T. Demel,
The Ohio State University.

8:15 - 9:15 pm Session #1899

Standards Committee Meeting
Chair: Edward W. Knoblock,
University of Wisconsin-Milwaukee.

• TUESDAY, JUNE 23

8:30 - 10:15 Session #2238

Engineering Design Graphics: Teaching Design Strategies

Moderator: C. Wayne White, Purdue University.

Presenters

Karl J. Zimmer, Villanova University. *Villanova University's Space Shuttle Experiments Program.*

Edward E. McDonald, The University of Akron. *Mechanical Design: An Early Approach.*

Eric Bell, Triton College. *An Honors Engineering Graphics Project at the Community College Level.*

Alfredo V. Soeiro, Dept. Engineering Civil-FEUP. *Using Computer Graphics in Structural Engineering Education.*

D. E. Calkins, University of Washington. *SAE Formula Car Competition: A Study in 'Systems Engineering.'*

12:30 - 2:00 pm Session #2438
Engineering Graphics:
Curriculum Issues II

Moderator: Richard W. Parkinson, The Ohio State University

Presenters:

Dan D. Sharp, The University of Dayton.
Ansi Standard Y14.5M at the University of Dayton.

Jon M. Duff, Purdue University.
The Impact of Just in Time Manufacturing on CADD Course Content.

Patrick J. McCuistion, Ohio University.
Dimensional Management: A Holistic Approach.

6:30 - 8:00 pm Session 2638
Engineering Design Graphics Division
Annual Awards Banquet

Chair: John T. Demel,
The Ohio State University.

• Wednesday, June 24

12 noon - 2 pm Session #3428
Engineering Design Graphics Division
Business Luncheon

Chair: John T. Demel,
The Ohio State University.

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 paper printed in the *EDG Journal*. The rate i determined by the status of the first autho listed on the paper at the time the paper i received by the Editor. The rates are as fol lows:

$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 hel offset the increasing costs of publication. Pag charges are due upon notification by the Edi tor and are payable to the Engineering Desig 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.

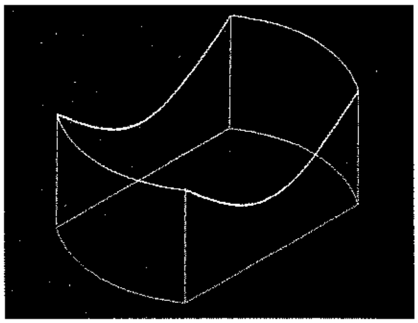
Article copies and 16, 35, and 105 mm microfiche are available from:

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

Computer Illustration
Bradley S. DeForest
Spring Garden College

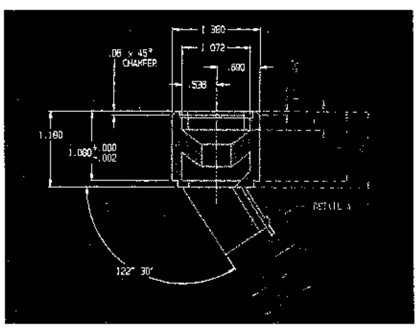
While our competition relies on its *name* to sell products, we rely on our products.

You might think that the 3-D CADD system with the biggest "name" in the business is also the best. But look closely at how well they handle *real* 3-D CADD problems. Then look at CADKEY.®



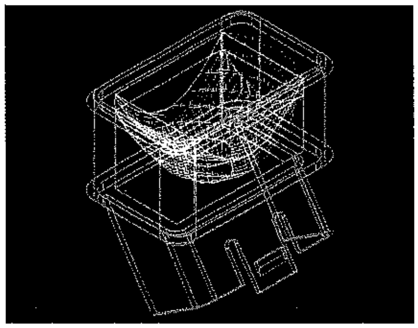
Problem #1

Problem #1: How do you translate your "bright idea" into a form others can understand? CADKEY gives you *all the tools you'll need —from wire-frame to CADKEY SOLIDS®*—to create complex designs quickly and easily. The parabolic curve pictured above may look simple, but it's a design our competition *can't* handle. Ask them.



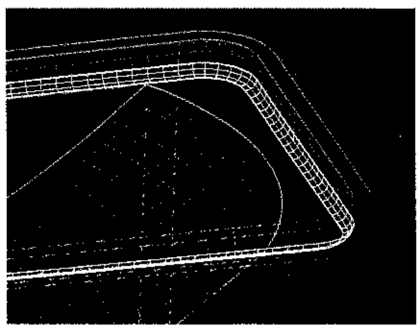
Problem #2

Problem #2: Need to convey your idea to engineers in Zurich and CNC machinists in Seoul . . . with accuracy in the *ten thousandths?* CADKEY'S ANSI, ISO, DIN and JIS compliance assures clarity and reliability *anywhere in the world.*



Problem #3

Problem #3: Want to make design changes? With CADKEY'S *transformation, editing, and detailing functions,* adjustments are no problem. Details and dimensions are *simultaneously and automatically updated.*

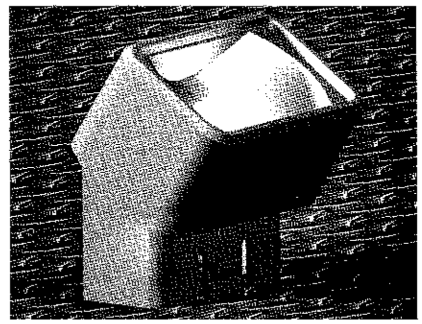


Problem #4

Problem #4: Will the design work? CADKEY goes way beyond simple polygon meshing to *true surface definition.* Ask our competition if they can handle variable radius fillet blends or surface intersections.

Need more illumination on the subject?
Send for your copy of the CADKEY 4 and AutoCAD® 11 technical comparison, and the name of the dealer nearest you. Write us or call CADKEY at 1-800-654-3413.

Problem #5: Do you see red when the sales manager asks for blue? With CADKEY RENDER® you can look at options and generate photorealistic soft prototypes *before* going into production. Change colors, even materials, without tooling a single machine!



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