THE ENGINEERING DESIGN GRAPHICS

Journal

Winter 1987 Volume 51 Number 1

ENGINEERING DESIGN GRAPHICS DIVISION

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

- Jobs and Conferences
- International Socities
- 1987 Midyear Meeting—Austin, Texas
- A View from Academe
- Microcomputer CAD Review
- Solid Modeling Techniques
- Student Attitudes

ISSN 0046-2012

PUBLICATION BOARD

CALENDAR OF EVENTS

ASEE ANNUAL CONFERENCES

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1988 PORTLAND hosted by Portland State University
1989 NASHVILLE hosted by Vanderbilt University

EDGD MIDYEAR MEETINGS

1987 LOUISVILLE hosted by The University of Louisville
1988 EVANSVILLE hosted by The University of Southern Indiana
1989 TUSCALOOSA hosted by The University of Alabama

The Engineering Design Graphics Journal is published one Volume per year, three Numbers per Volume in Winter, Spring, and Fall by the Engineering Design Graphics Division of the American Society for Engineering Education, for teachers and practitioners of Engineering, Computer, Design, and Technical Graphics. The views and opinions expressed by the individual authors do not necessarily reflect the editorial policy of The Engineering Design Graphics Division or of the American Society for Engineering Education. The editors make a reasonable effort to verify the technical content of the material published; however, the final responsibility for opinions and technical accuracy rests entirely upon the author.

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All fees are payable to the Engineering Design Graphics Journal at: The Engineering Design Graphics Journal, Department of Engineering Graphics, The Ohio State University, 2070 Neil Avenue, Columbus, OH 43210. Back issues are available at single copy rates (prepaid) from the circulation manager and are limited in general to numbers published within the past six years. Subscription expiration date appears in the upper right corner of the mailing label as follows: ASEE/EDGD member is the same month/year as ASEE dues e.g. 6/86; all others last issue paid e.g. W86 for Winter 1986. Claims for missing issues must be submitted to the Circulation Manager within a six-month period following the month of publication: February for Winter, May for Spring, and November for Autumn.

OBJECTIVES OF THE JOURNAL

The objectives of The Journal are:

1. To publish articles of interest to teachers and practitioners of Engineering Graphics, Computer Graphics, and subjects allied to the fundamentals of engineering graphics education and graphic technology.
2. To stimulate the preparation of articles and papers on topics of interest to its membership.
3. To encourage teachers of graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses.
4. To encourage research, development, and refinement of theory and application of engineering graphics for understanding and practice.

DEADLINES

The following are deadlines for submission of articles, announcements, and advertising: FALL-September15; WINTER-December1; SPRING-February 1.

STYLE GUIDE FOR JOURNAL AUTHORS

1. All copy is to be typed, double spaced, on one side only using white paper with black ribbon in standard English. Dot matrix copy is acceptable if high quality.
2. All pages of the manuscript are to be numbered consecutively.
3. TWO copies of each manuscript are required.
4. Refer to all graphics, diagrams, photographs, or illustrations in your text as Figure 1, Table 1, etc. Be sure to identify all material. Illustrations cannot be redrawn. Accordingly, be sure that all linework is black and sharply drawn and that text is large enough to be legible when reduced. Good quality photocopies of sharply drawn illustrations are acceptable.
5. Submit a recent, glossy black and white photograph (head to chest). Make sure that your name and address is on the back. Photographs, illustrations or other submitted materials cannot be returned without postage prepaid.
6. The editorial staff will edit manuscripts for publication after return from the board of review. Galley proofs cannot be returned for author approval. Authors are encouraged to seek editorial comment from their colleagues before submission.
7. Enclose all material, unfolded, in a large envelope. Use heavy

Continued inside back cover.

VOLUME 51 NUMBER 1

THE ENGINEERING DESIGN GRAPHICS

Journal

ENGINEERING DESIGN GRAPHICS DIVISION

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Departments

Features

FROM THE DESK OF THE EDITOR

At the End of the Term, Thoughts About Students

Another semester sets at the big farm and around faculty lunch tables discussion has turned to students and how to deal with them. Every teacher has his/her own thoughts on the matter. Since I am on this side of the computer screen, let me share a few of mine with you.

Egalitarian education is a difficult concept to handle in an institution interested in scholarly activity and excellence in teaching and research. In a community college it is an admirable end. However, I find I spend 90% of my time dealing with the problems of 10% of my students. Fine. I guess it's what I'm paid, at least partly, to do. But I'm sure that each of you has experienced the cold chill that accompanies the realization that you are no longer teaching, rather you are subtly counseling the student into another line of work. You know the telltale signs: dialated pupils, blank stare, rhythmic nodding—all followed by a total inability to understand the problem at hand. What do you do? After the lecture, after drawing dyn-o-mite illustrations on the board, after sitting down at the student's desk (terminal?) and showing them how to move their hands, after doing all this what is left when the student laments "but this lab sheet isn't anything like that!" What's going on here? As a teacher, how long can you hear this and keep your sanity?

Obviously there is little synthesis going on inside that student's head. The certain indicator is when you have to repeat the lecture 22 additional times as you circulate around the room.

> *"...your brain has been transformed into grey clay."*

I have come up with the "Graphics Litmus Test of Subject Matter Applicability," (GRALTSMA, for short). If you find that you have to teach the specifics of a problem for the majority of the students to complete the lab sheet (substitute computer program or design exercise if you like), then the GRALTSMA index indicates that if you continue to do this, your brain will turn to silly putty within 3 years. If the only way that your students can work lab sheet 56.2.3 is by *you* working 56.2.3 in front of them, something is terribly wrong with a) your teaching, b) the students' ability, c) the students' preparation, d) the appropriateness of the lab sheet, or e) all of the above.

A parallel indicator to the GRALTSMA scale is the "Variable Comprehension Index," (VARCOMPDEX for short). This index measures when a problem becomes so difficult that a majority of students can't work it. The calibration here reveals a *GO-NO-GO* situation. Students will scoff that the problems are "cake" or "trivial." Let's say that 100% of your students are able to successfully complete the assignment. Make it a little more challenging, you say. Add one more variable to the problem and the VARCOMPDEX of 90% of the students goes off the scale. Worse, the GRALTSMA indicator buzzes again, signaling that more of your brain cells have been transformed into grey clay. That same student whose unblinking eyes had looked like bottomless black pools, who had convinced you to abandon concepts and theory and cut directly to the bone of 56.2.3 (don't teach me theory, how do I finish this sheet?"), who still needed that little extra hand-holding to determine visibility and label points, is lost again. What's going on here?

From the Engineering Technology Division

Since many of us who teach graphics must by necessity straddle the engineering-engineering technology fence, news from the Engineering Technology Division (ETD) is of

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chairman

A MESSAGE FROM THE CHAIRMAN

Engineering curricula are designed to provide the basis for 40 - 50 years of service in the profession. We, as educators, are charged with the responsibility of providing the necessary knowledge and skills to enable graduating engineers to move smoothly into entry level positions, to contribute positively to the goals of the engineering profession and to stay abreast of the changing technology. In one sense, we must "teach" our students to be lifelong learners because we certainly cannot accurately predict the technology changes that are going to occur in the future.

Technology advances are so rapid today that significant changes will take place during the 4-5 years the engineering student is pursuing a degree. Curricula structure, laboratory equipment and textbooks cannot be upgraded at the same rate as advancements in technology. Instead, curricula must emphasize those fundamentals which serve as the building blocks for learning and applying new technology. It is easy to overlook these fundamentals in light of the many new and exciting technological advances we feel would benefit our students.

Consider for a moment oral, written, and graphical communication in engineering. The beginning engineering student generally has an extensive background in oral and written communication. These skills are further developed during the engineering education process with emphasis on technical applications. Changing technology has not significantly altered the <u>fundamentals</u> of oral and written communication, but technology certainly has affected the <u>methods</u> of producing and delivering these forms.

Entering engineering students have little if any experience with graphical communication. In past years, engineering students took two or more graphics courses and continued to develop graphical communication skills in engineering analysis and design courses. Most likely their first position in industry involved work on the drawing board to further sharpen their skills. Today, most engineering programs require one course at best in graphics and there is very little requirement for <u>drawing</u> skills beyond the first graphics course. Whether this is appropriate or not is something that needs to be collectively decided by the engineering profession. I will express <u>my</u> opinion here.

"We must teach our students to be life-long learners"

In my estimation spending a high percentage of a very limited amount of time in an engineering graphics course on drawing skills is not an efficient use of the time. Engineers must possess the ability to sketch and letter in a consistent, accurate manner; however, capability to produce complex geometric constructions and blueprint-quality design drawings should not be high on the priority list for graphics instruction because it is inherently time consuming and is not required in later engineering analysis and design courses.

The engineering workstation and computer-aided-design and drafting (CADD) software appears to be a light at the end of the tunnel for engineering graphics. However, training students to use the sophisticated packages to generate complex geometries and design drawings has to come <u>after</u> a thorough grounding in the description of geometries for engineering design. Multiview representation, sectioning and dimensioning are <u>fundamental</u> to describing and communicating geometries.

Continued on next page

CHAIRMAN'S MESSAGE

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When I look at an item of software for possible inclusion in the engineering graphics course at Iowa State, I study it in light of the existing goals of the course.

Thus, advances in the capabilities of the software are measured against well-established course objectives and not vice-versa.

Only in this manner can a strong graphics course be developed and maintained while taking optimal advantage of the potential of computer graphics.

We all need to think about fundamentals as we contemplate changes in our engineering graphics courses. What is "right" for the engineering student today must be a decision of the engineering faculty at each institution. Experience that you gain from your classroom activities and other professional activities must be input to the decision-making mechanism or you may not be happy with the final outcome.

In the spring issue, I will pass along additional thoughts regarding geometric modeling and analysis.

Rollie Jenison
Chairman, EDGD

division

NEWS OF THE ENGINEERING DESIGN GRAPHICS DIVISION

Call for Papers

VIENNA 1988

The Third International Conference on Engineering Graphics and Descriptive Geometry will be held July 11-16, 1988 in Vienna, Austria. The conference will be hosted by the Technical University Vienna and co-sponsored by ASEE/EDGD, the Institutes and Departments of Geometry of Austrian Universities at Graz, Innsbruck, Leoben, and Vienna, and the Austrian Working Group on Descriptive Geometry (AGDG).

Papers dealing with the following topics are solicited:

1. *Theoretical graphics, descriptive geometry, Kinematic Geometry, and other applications of geometry.*

2. *Engineering Computer Graphics, Computer Aided Design, Computer Aided Geometric Design, and Computerized Descriptive Geometry.*

3. *Graphics Teaching Techniques, Graphics Exercises, and Computers in Engineering Graphics Education.*

Deadlines:

April 1, 1987: Pre-registration forms
October 1, 1987 : 500-word abstract
February 1, 1988: Full Papers

Send Correspondence to:

Professor Steve M. Slaby
Civil Engineering Department
Princeton University
Princeton, NJ 08540 (609) 452-4654

Editor's Page

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particular interest. Several items from the latest ETD Newsletter piqued my own interest.

A *World Congress on Education in Engineering and Engineering Technology* had been planned to be held prior to the ASEE national in Portland in 1988 but has fallen through with a vote from the ASEE Board of Directors not to support the effort. Generally it was felt that ASEE and ETD would be over-extended with the QEEP study and ASEE reorganization. Also noted in the newsletter was a column by Dr. King Osborne (University of Central Florida, Orlando FL 32816) concerning a "National Computer Applications SIG." If you have interest in this, drop him a line. The last point of interest was the ETD treasurer's report. Those of you who have been involved in the EDGJ know that we operate essentially on a shoe string. There has been concern lately about the level of advertising in the EDGJ, and it *would* be better if we could have 4-6 advertisers each issue. If you havn't seen the Journal of Engineering Technology (JET) try to get a copy. This is a two-times a year journal that is heavily supported with advertising. The ETD should be congratulated on a fine publication. But the bottom line is that each copy of the JET costs their division 3-1/2 times what ours costs. It points out that if we want to do things that way (and several of you have mentioned to me "why doesn't the EDGJ look more like the JET?), the level of advertising and *paid services* would increase dramatically. They assist their editors up to $2400 per year (travel, per diem, equipment costs?). When I think about it, it is commendable that the EDGJ has 50+ years of continuous publication.

-ed

The Japan Society of Graphic Science

Japanese Professor Brings the EDGD News of His Association

An Introduction to the Japan Society for Graphic Science

Professor Kazuhiko Takeyama
Dr. of Engineering
Kobe University

The Japan Society for Graphic Science (JSGS) was established in May of 1967 for advancing the research and education of graphic science as well as for the diffusion of knowledge in the field. It is a young organization which will mark its 20th anniversary this next May. It currently has about 300 members and is enrolled in the Science Council of Japan. The member's fields of training and academic background are of a wide variety including fine art, graphic design, architecture, city planning, civil engineering, mechanical engineering, optics, psychology, physics, and mathematics although architecture and mechanical engineering account for a higher proportion of members. Most members are university teachers, and the number of practitioner-members is limited.

The major activities of the **JSGS** are:

1. *Meetings*
   - Annual Conference: paper sessions and an annual general meeting held usually in May
   - Symposium in Tokyo, usually held in November
   - Study meetings organized by each of four local branches (Tohoku, Chubu, Kinki, and Kyushyu)

2. *Publications*
   - The Journal of Graphic Science, published twice a year (March, September), consisting mostly of research papers. The published papers can be classified into categories of education, plane descriptive geometry , solid descriptive geometrty, axonometry, perspective projection, drafting, paintings, and computer graphics. On the occasion of the 20th anniversary, a complete index of the journal will be published.
   - A newsletter, published quarterly (February April, June, November).
   - Two books have been edited by the **JSGS**:

     Computer Automated Drafting Systems: Nikkan -kougyo Shinbunsh a, 1975

     Handbook of Graphic Science: Morikita Shuppan, 1980.

Besides the above mentioned activities, the committees for standardization and terminology, the committee for reviewing literature, and the research group on education in computer graphics take an active part in **JSGS**. Our members have participated in the International Conference on Descriptive Geometry (ICDG) in Vancouver in 1978 and the International Conference on Engineering and Computer Graphics (ICEDG) in Beijing in 1984. We well recognize that both conferences were sponsored by the EDGD of ASEE.

The president's term in our society is two years. The current president is Dr. Shiro Odaka, Professor Emeritus of Kobe University. For membership application, a recommendation of a current member and a registration fee of 1,000 yen are required. The yearly membership is 7000 yen (153 yen=1 dollar).

—— continued on next page ——

Fall National Design Show a Hit !

NY Exposition Scheduled Again for Sept. 29-Oct.1, 1987

The 1st Annual Design Engineering Show and Conference held at the Jacob K. Javits Convention Center in New York City concluded with high marks from both vendors and conferees alike. Over 10,200 East Coast design engineers were able to view what over 500 leading suppliers had to offer in the way of new products and services. The reviews were so favorable that 76% of the vendors have renewed for 1987.

Some companies sent entire design teams to the show, feeling that as a group they could cover more ground and allow some of the group to attend conference sessions. Afterward, they could discuss what they've seen while everything is fresh in their minds.

The vendor list was a who's who in the CAD/CAM/CIM/CAE. Giving away samples was a popular traffic generator and, of course, there were contests. One interesting feature of the show was a Hands-on-Center, located right on the main floor. This allowed designers to find out what the systems "felt" like out of the selling environment. The 1987 Design Engineering Show and Conference should be even bigger than the first, making it an attractive educational attraction for engineering professionals and teachers.-*ed*

jobs

Engineering Faculty
Department of Mechanical and Industrial Engineering
Louisiana Tech University

Graphics faculty with knowledge of FORTRAN—This position is at entry level, but some experience is desirable.

Dr. R.O. Warrington, Head
Mech & Ind Engr Department
PO Box 10348
Ruston, LA 71272-0046

The Rumor Mill:

Heard on the street, but not confirmed through specific job announcements:

- Northeastern University—contact Prof. Bob Lang
- Ohio State University—contact Prof. John Demel
- Purdue University—contact Prof. Jerry Smith
- University of New Orleans—contact Prof. Bill Janna

JAPAN SOCIETY

Continued from page 7

The postal address of the JSGS Secretariat is:

JSGS Secretariat
Department of Graphic Science
College of General Education
Tokyo University
3-8-1 Komaba, Meguro-ku
Tokyo, 153
Japan

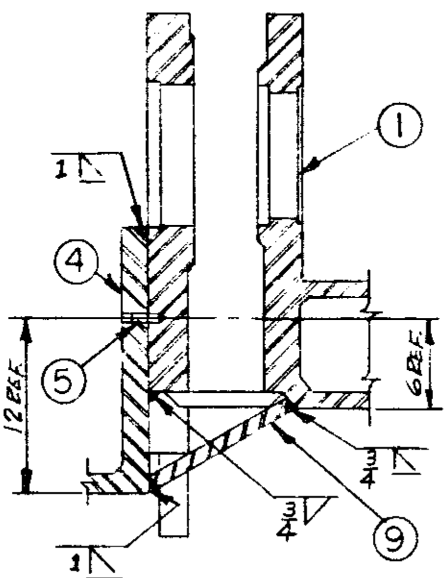
The current problem of the **JSGS** is that the number of members has not been growing in the past years because, I think, the **JSGS** is a science-oriented society. We have to consider how we deal with the technological aspects of graphics. Another problem lies in the current tendency in schools that the weight in the curriculum has moved from descriptive geometry to computer graphics. I believe that learning descriptive geometry is a more efficient way to cultivate graphic thinking and in its turn human intellectual creativity than learning computer graphics for its shortsighted usefulness. We would be glad if members in the EDGD would share with us their experiences and suggestions in this matter. Finally, I would like to thank Professor Jon M. Duff for giving me an opportunity to write this introduction of the **JSGS**.

ASEE/EDGD MIDYEAR MEETING

Industry Leaders Address Austin EDGD

How Much CADD, Traditional Subjects Discussed

Those who were able to attend the 1987 ASEE/EDGD Midyear Meeting January 6-9, 1987 were treated to an informative industrial roundtable hosted by the immediate past EDGD Chairman, Bob Foster of Penn State University. Speaking during the two-hour session were **Tom Oetjens** of General Motors, **Jeff O'Dell** of Motorola, **Ronald Garcia** from the Air Force Logistics Command, **J.J. Walker** of Lockheed, and **Chris Byrd** of Hughes Tool.



SECTION J-J

The speakers were chosen for their direct involvement in the training and supervision of design, drafting, and CADD activities. All of the speakers agreed that a strong background in the fundamentals of geometry, drafting standards, and manufacturing methods was important though there was interesting debate among the audience on whether or not this is best accomplished through traditional methods or by direct exposure to CADD. Mr. Oetjens from General Motors felt that there was no further need for manual instruction, as was reflected in the "futurist" nature of his presentation. The other speakers felt that at least some facility in manual drawing was desirable.

" forget about the equipment and get to the task at hand.."

On the question of what level of CADD should be taught in schools, the general concensus was that engineering and technology students should understand 2 and 3-D concepts and how CADD systems *in general* manipulate geometry. Hands-on experience on a particular CADD system was felt to be a bonus. Mr. Walker felt that at Lockheed, too much knowledge might be a disadvantage. Specific knowledge of applications and systems software may cause the engineer to be more involved with the technology (the "hacker" mentality) than on using the tools available to solve the problem at hand. All of the speakers agreed that an ability to recognize the limitations of a CADD system is important.

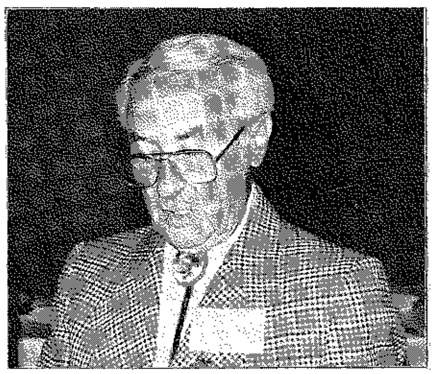
Most of the industrial representatives felt that in the near future the majority, if not all engineering drawings, will be produced on CADD systems. However, they also stressed that most engineers will be *casual* users of CADD programs. All agreed that manufacturing design is the area where CADD has made the greatest impact and that it is the area of engineering analysis that the greatest improvement needs to be made.

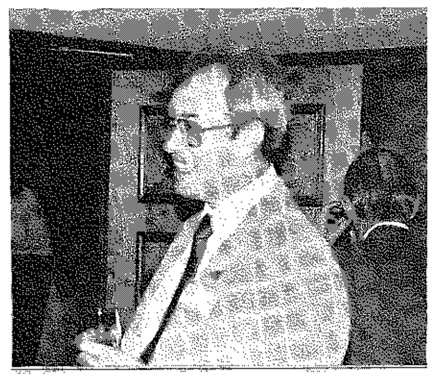
On the equipment side, Computervision, CADAM, and various PC CADD packages were cited as being used. There was not as much said, other than by the GM representative, about the current or future engineering workstations (SUN, Apollo, DEC, IBM RT). Refreshingly, these representatives dwelt on *how CADD is used to aid productivity* and not on the technology. Possibly this is a sign for engineering educators: forget about the equipment and get to the task at hand; namely, teaching design, geometry, and drawing.

Solids, solids, solids! Design engineers in the future will have to be able to use solid modeling techniques as the demands for increased productivity mount. But several of the panelists, notably and predictably Jeff O'Dell of Motorola, predicted a continued need for efficient 2-D drafting.

As far as the future goes, the panel stressed further integration of CADD and CAM, continued in-house training of engineers and technologists, and an increased emphasis on CADD as an engineering tool. *-ed*

Faces in the Crowd at Austin





review

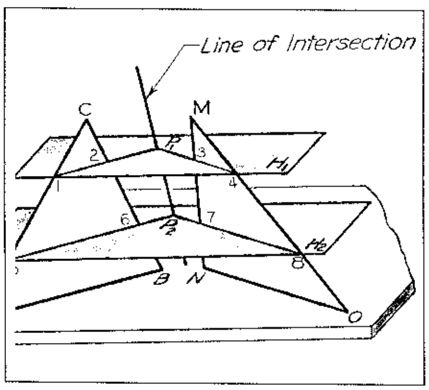
A REVIEW OF NEW PRODUCTS AND MATERIALS

Descriptive Geometry Mertic Seventh Edition

Macmillan Publishing Company

Pare', Loving, Hill, Pare'

This is the latest edition of a classic text in descriptive geometry and is accompanied by two sets of student worksheets. The text continues to cover the traditional topics in DG including several specialized topics that would be of interest to graphics theoreticians. A strong aspect of this text is the *pictorial-to-orthographic* presentation technique



for all topics— though the illustrations are a bit small. Possibly some of the room taken up by coordinate work problems at the back of each chapter could be used more effectively in larger figures. I know of no DG teachers who use this type of "student generated" lab sheets.

The topics are what one would expect for a full course in DG, with a short review of basic orthogonal theory. The inclusion of shades and shadows as an application of intersection theory is fundamentally sound. However, it is odd that an entire chapter is devoted to perspective drawing. Possibly it fits as another logical extension of intersection theory. But then why is axonometric drawing not covered as a logical extension of successive auxiliary views? The chapter on computer graphics projects is *extremely outdated* in its approach, one that uses calls to move and draw routines. It would be enough to permanently discourage anyone from using the computer as a graphics tool. Finally, it is puzzling why a text would be entirely metric, especially when in using computers, units are considered first and then scaled to represent real world values.

Still, **Descriptive Geometry** by Pare', Loving, Hill, and Pare' is a solid text for the teaching of descriptive geometry as a course separate from introductory engineering graphics.

Modern Engineering Graphics and Design

West Publishing Company

Gerard G.S. Voland

This ambitious project by the young author from Northeastern University is sort of traditional engineering graphics with a twist. It may do for engineering graphics what Carl Sagan has done for the cosmos: made the subject interesting, readable, teachable, and enjoyable. All of the traditional topics are there with the addition of several novel approaches. These include:

Learning Objectives - at the beginning of each chapter concise objectives are presented along with a preview of the chapter. This is common in public schools though unusual in college texts.

Highlights- interesting little tid bits of graphics history are presented in set off boxes.

Axioms- where "graphic truths" are stated, they are identified with a color screen background.

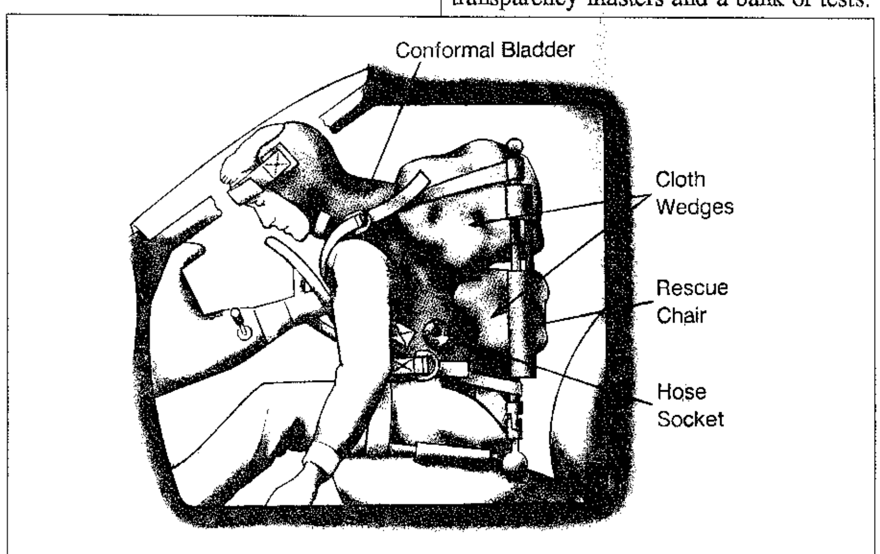
Learning Checks- typical questions *with* their answers.

Engineering in Action- engineering case studies with great illustrations!

Computer Graphics in Action- applications of computer graphics theory also presented as case studies.

The basic computer graphics instruction is up front, like the rest of the graphics tools. An attempt to build generic instruction based loosely on the AutoCAD interface presents the reader with "screens" describing most, if not all, common computer graphics functions.

Modern Engineering Graphics and Design includes a strong emphasis on engineering design, both in an individual chapter and throughout the book with the "Engineering in Action" case studies. The text is accompanied by an *Instructor's Guide* that includes transparency masters and a bank of tests.



IN MEMORIAM

Purdue Professor, ASEE Leader

J. Howard "Howie" Porsch, Professor Emeritus of Engineering Graphics at Purdue University passed away October 18, 1986 after declining health and a short illness. He was 82.

Active in ASEE, Howie taught Graphics at Purdue from 1928 to 1970, retiring in 1970. During that period of time he acted as department chairman for 24 years. Howie Porsch served as chairman of the Engineering Design Graphics Division, was the recipient of the Distinguished Service Award in 1970, and represented ASEE on the American National Standards Institute in the development of drawing standards. J. Howard Porsch is survived by his wife Bernice.

A Recognition of Industry Pioneer

The editor received this letter from Frank Oppenheimer in February, 1987. It is included here along with the requested obituary. -ed

"I enclose herewith some material concerning my relationship with **Steve Coons**. After I learned of his death in 1980 I did not contact the editor of the Journal—as I had planned. During recent meetings I noticed that Steve's name never came up in any discussion about "computer-aided design" despite the fact that Steve Coons was one of the first—maybe THE first—who actually practiced these methods. I remember that he worked for Fisher Body and during a meeting he gave one of these ingenious presentations showing the tremendous possibilities of CAD. I am sure that you might be interested in the enclosed obituary by Dr. Havany and maybe there is a possibility to publish it—or part of it—in The Journal. The release by the original publisher is enclosed.

Kindest regards,

Frank

STEVEN ANSON COONS

Outstandingly gifted students usually earn degrees. Engineers, whose ideas are widely adopted in industry, usually earn quite a lot of money. Good people, who never harm anyone and show only kindness towards their environment, usually receive kindness and consideration in return.

None of these things happened to Steve Coons, though he fulfilled all the conditions. A brilliant scientist, the author of procedures that are today used in all the world's major aircraft, automobile and ship design offices, a generous, warm-hearted person whose every thought was to help others, he died inpecurious and almost isolated from his friends, at Boulder, Colorado on August 19th, 1979.

Born in New York state in 1912, he became a student at MIT in 1932 and left to become a free-lance professional photographer in 1936. When the war broke out, he took a job with the Chance-Vought-Sikorsky Aircraft Company, where up to 1947, he developed the mathematical methods for defining and computing airframe shapes that are now the basis of computer programs used throughout the aircraft industry. After a period as a designer of hi-fi sound reproduction equipment, he joined the faculty of MIT in 1948, becoming first an Assistant and in 1960, an Associate Professor. After 21 years at MIT, he transferred in 1969 to Syracuse University, from where he retired as Emeritus Professor of Systems and Information Science in 1976. He then spent a year as Visiting Fellow at the Computer and Automation Institute, Hungarian Academy of Sciences, finally moving to Boulder, Colorado where he held a part-time consulting job.

At the core of this colourful career lies his tremendous pioneering work on complex surfaces: the discovery of what have come to be know as "Coons' patches" or "Coons' surfaces." Characteristically, the much-referenced work in which he published these results is not a best-selling, royalty-paying textbook, but an MIT ReportMAC TR 41/, entitled "Surfaces for Computer Aided Design of Space Forms" /1964. It is today the foundation for *many* doctoral theses and engineering textbooks and of course, for the surface description techniques used in the "free-form" surface industries.

Steve Coons' other great heritage are his pupils - Herzog, Sutherland, Negroponte, Riesenfeld - to mention but a few of the familiar names. Many of his written works have never been published - they were contained in one or another of his charming letters or the helpfully critical observations with which he was so generous. Even so, his influence on the present-day evolution of computer-aided design has been enormous. References to his works may be found in almost every issue of the American, British,

continued on page 22

EVALUATION OF FIVE MICROCOMPUTER CAD PACKAGES

James A. Leach
Auburn University

INTRODUCTION

During fall 1985, I directed a comparative analysis of the following five microcomputer CAD software packages:

AutoCAD (V. 2.17)
by Autodesk,Inc.
CADKEY (V. 2.0)
by Micro Control Systems,Inc.
CADVANCE (V. 1.0)
by Calcomp
Super MicroCAD
by Imagimedia Technologies
VersaCAD Advanced (V.4.00)
by T&W Systems, Inc.

The study showed a similarity among package formats and features, but the greatest differences were among command entry methods, advanced features, potential applications, and numbers of users.

THE APPLICATION

The purpose of this evaluation was to select a microcomputer-based CAD package to be used primarily for a college-level introductory engineering graphics course. The proposed course would integrate the use of microcomputer graphics with the traditional graphics fundamental concepts and tools. The selected package must be simple enough for first-time users to apply the most basic graphics concepts, but complete enough to facilitate upper-level course work throughout the spectrum of engineering fields.

THE EVALUATION

Five upper-class students with similar experience in graphics and micros participated in the study, each receiving 3 hours credit for Special Problems course IE 490. Each participant examined one package and reported on the following: (see chart)

1. Installation and configuration
2. Documentation
3. Command entry methods
4. 2-D geometry creation
5. 3-D geometry capabilities
6. Editing features
7. Special features
8. Output
9. Ease of learning

Each participant installed and learned a system, aided only by the documentation and vendor support. Four typical graphics course drawings were generated by each system for comparative purposes. Each participant recorded time and activities in a log. To conclude the study, a written report of each package was prepared and a demonstration of all packages was given to Engineering, Architecture, and Industrial Design faculty members.

Hardware used during the evaluation was somewhat mix and match. However, in order to present an equal comparison during the demonstration, all the software packages were run on IBM XTs with 10MB hard disk drives, 640K RAM, and 8087 coprocessors. All systems had IBM Color Graphics monitors and Microsoft Mouses. Hewlett-Packard 7470 plotters were used exclusively throughout the study. The large number of hardware reconfigurations and software installations which were performed revealed some significant differences among the packages for these procedures.

THE PACKAGES

AutoCAD (V.2.17)
This package has a good balance of several important characteristics: ease of use, a strong set of features and capabilities, and a wide and flexible range of applications.

"...simple enough for first-time users to apply the most basic graphics concepts..."

AutoCAD will run on any of 31 micros and will support 120 peripherals. Installing this software on a hard disk system is a simple "copy *. *" operation. The menu driven configuration program only requires the operator to respond with the particular system components. The corresponding device driver files are automatically copied to form the ACAD.CFG file. If you intended to AutoCAD run on a dual floppy system, the installation procedure (not explained in the documentation) is more complex. AutoCAD may be run with a dual monitor setup or with a single monitor using F1 to toggle between text and graphics screen.

Upon entering the "Drawing Editor", the user can create graphics with the center screen provided with three lines of text below called the "command line" giving prompts for user-defined information. Along the top is a "Status Line" giving status of modes (LAYER, SNAP, ORTHO), and a coordinate display giving either absolute, relative or polar coordinates. On the right is the screen menu accessed via mouse to flip through menus, submenus, commands and subcommands. A positive feature unique to AutoCAD is the ability to enter "flat" commands by keyboard at any time, negating the problem of sorting through the menu system. First-time users need only know the command names--not the menu in which they are located. Another aid is the on-line HELP command which invokes a list of all possible commands or a screen of instruction for any one selected command. The documentation (AutoCAD User Reference) is well written and complete, but topic organization could be improved by adding an alphabetical list of commands with page numbers near the front of the manual. AutoCAD's 2-D drawing features are complete, including the commands POINT, LINE, ARC, CIRCLE, ELLIPSE and RECTANGLE. A distinguishing criterion for comparing CAD packages is the ability to draw arcs. AutoCAD rates highest with 11 possible methods. Drawing with TRACE and PLINE will create lines and arcs of user-defined widths or tapers. SNAP and GRID modes for 2-D geometry creation allow entities to lock to grid points. Grids may be rotated about any point, and an isometric grid is available. With the powerful mode OSNAP (object snap), entities can be "snapped" to other entity endpoints, intersections, tangent points, midpoints, etc. OSNAP can be left "running" or used intermittently within drawing commands.

Editing features include COPY, MOVE, MIRROR, ERASE and BREAK. OOPS will replace accidentally ERASEd entities. Rotating is a two-step process accomplished by first storing shapes as BLOCKS and then rotating upon INSERTing. The INSERT COMMAND also allows insertion of previously defined parts (BLOCKS) or entire drawings from disk into other drawings. The ARRAY command makes multiple copies of selected entities in a rectangular or circular pattern, such as copying a single tooth to form a gear. The CURVE FIT feature used to edit a PLINE may give some surprises and should be improved.

CadKey is an impressive, professionally designed micro-based system...

Other AutoCAD features include 41 predefined and unlimited user-defined HATCH patterns, predefined and user-defined TEXT fonts, eight available LINETYPEs, and unlimited LAYERs. AutoCAD supplies high-resolution output to both plotters and graphics printers. Drawing file management is relatively efficient, whether by using the internal file utility menu or the SHELL command which accesses DOS from within the program.

A major problem during the dual floppy system use is AutoCAD's inability to close a file larger than the available disk space. No warning is given when this limit is approached, and if surpassed, the session is bombed. Then the user must recall and rename the backup file created from the previous session and learns to SAVE more often. A hard disk system is recommended to run this program. The latest version of AutoCAD boasts 3-D visualization. This version, which does not provide full 3-D capabilities, is termed 2 1/2-D. From a 2-D drawing, the user can specify an "extrusion thickness" and "elevation." Anything generated along the Z-axis then must be a line or plane perpendicular to the XY-plane. For example, thickness may be added to a circle to form a cylinder but not a cone. The VIEWPOINT of the observer with respect to the object may be changed to any position. This is uniquely controlled by using the input device to dynamically rotate a three-pole axis on the screen. Perspectives are not available. How AutoCAD will upgrade to full 3-D should be interesting, since the original philosophy was strictly 2-D based. Judging from present AutoCAD performance, the next release should be a smoothly operating full 3-D package.

Some useful advanced features are MENU, which allows use of customized menus, and SCRIPT, which reads commands from a text file. With SCRIPT, the user can automatically generate drawing setups or construct an entire drawing for presentations. Another presentation aid, VSLIDE, sequences through previously created drawing files. ATTRIBUTES are special drawing entities that contain text such as part specs comprising a bill of materials. This text information may be processed for transfer to database programs such as dBASE II and Lotus 1-2-3. Another powerful capability is the use of variables or expressions in response to AutoCAD's prompts. In addition, graphic data can be written to a DXF (drawing Exchange File) which has several possible uses. Autodesk invites third-party vendors to access DXF files for writing compatible software. Over 150 programs created by independent parties can interface and enhance AutoCAD's capabilities. Programs include symbol libraries for architectural and construction industries, databases, menus, finite element analyses, CNC post processors, and so on. These products, although independently marketed, are in the AutoCAD Applications Catalog.

AutoCAD is an excellent choice for a micro-based CAD system because of its ease of use, smooth operation, advanced capabilities, and wide range of applications. Because AutoCAD is the most widely used CAD package in the world, users have assurance of future support and upgrades. List price for the full AutoCAD (V.2.17) program is $2500.

CADKEY (V. 2.0)
CADKEY by Micro Control Systems is the only smoothly operating, true 3-D microcomputer CAD package of those evaluated. Although far behind AutoCAD in sales and usage, CADKEY is very highly regarded among professionals and daily users. CADKEY's tree menu structure causes difficulty for first-time users, but Immediate Mode Commands offer efficiency for experienced users. The 3-D capabilities of this package offer interesting possibilities especially for the engineering and manufacturing fields. Overall, CADKEY is an impressive, professionally designed micro-based system fairly priced at $2700.

CADKEY version 2.0 is available only for IBM and IBM compatible hard disk drive systems. Installation and hardware configuration are simple menu-driven operations. A hardware-based security device is required for operation, making pirated software copies unusable. The documentation is lengthy and a bit intimidating, but this is somewhat understandable for a 3-D system. Thank goodness for the tutorial which leads the learner through some basic operations (with minimal explanation), building confidence on the system.

CADKEY's command set for drawing primitives and creating 2-D geometries is complete. The system provides the usual methods of primitive creation including point, line, arc, circle, rectangle, polygon, and grid snaps. Using the number of available methods for creating arcs and circles as a criterion, CADKEY rates high with 8 and 6, respectively. An especially nice feature (superior to AutoCAD) is the fillet routine which calculates the fit of arcs between lines or other arcs. CADKEY can also draw lines parallel and perpendicular as well as tangent to arcs.

Three-D shapes are created by entering 3-D coordinates initially or by rotating or extruding previously drawn 2-D shapes. Eight predefined views enhance the efficiency of visualization, but only five are necessary: front, top, side, isometric and axonometric. Placement of the three principle views (front, top and side) with correct relationship on one screen must be done manually by several operations. CADKEY's 3-D capabilities, classified as wire-frame imaging, cannot automatically remove hidden lines or create perspectives. Therefore, CADKEY is not a true solid modeler.

CADKEY's file structure is based on five file types: part, pattern, plot, CADL and DXF. Part files contain complete information on the part, but a pattern file must be created for any part intended to be inserted into another drawing. Unlike the other packages, CADKEY requires a separate plot file in order to produce any output. CADL is CADKEY's Advanced Design Language, The DXF files allow compatibility with other 2-D programs, specifically AutoCAD, the originator of DXF. CADL and DXF files are useful for translating graphic data for CNC operation or finite element analysis.

CADKEY's learning curve is longer than most because of the key sequences which must be remembered for quick command access. Number key sequences can speedily step through the menus to access specific commands rather than pick through them as would be done with the input device. Immediate Mode Commands, usually an ALT+ or CTRL+ key sequence, will immediately invoke certain commands while remaining nested in others, bypassing the menu altogether. However, not all commands operate in the Immediate Mode. These greatly speed drawing time, but require reference, a great amount of experience or an extremely good memory.

In summary, CADKEY is a contender for most 2-D systems, lacking only a few editing features. Its powerful 3-D capabilities make this package an excellent choice for professional engineers.

CADVANCE (V. 1.0)
After being purchased by Calcomp, CADplan was upgraded and released as CADVANCE, a package used mainly for architectural and building industry applications. *CADVANCE, although strictly 2-D, is the fastest and easiest package to learn and use.*

This package requires a hard disk drive system with 512K RAM. A security device must be installed between the printer and communications port for system operation. Installation and configuration are relatively simple step-by-step processes given in the documentation.

The well-written and organized documentation is set up in chronological order: installation, tutorial, command list and detailed explanations. The command list is indexed for future reference. The on-line HELP assistance is structured identically to the manual, giving command, subcommand, instructions and documentation references.

One of CADVANCE's most prominent features is its three-level menu system. The main menu is a constantly displayed column of primary commands. A different submenu appears next to the main menu for each command on which the cursor is placed (the same concept as employed in LOTUS 1-2-3). The status line appears across the bottom of the screen and is governed by the submenu. Items on the status line include such things as line weight, line type, active layer, coordinate points, grid snap, and snap to intersections or nodes. One of the package's most convenient features is that the user can change these parameters without leaving a submenu command.

CADVANCE has several features which are intended for architectural, interior design or building industry applications. Two commands called DOOR and WINDOW prompt the user for standard size, direction of swing, and placement. From these specifications, the door or window (plan view) is automatically inserted into the selected wall. From the DRAW command, one of the status line selections locks lines to a defined angle increment, such as 90°, 45°, or 30°. This feature can be very helpful during the construction of floor plans or isometric pictorials. The FIXT and FIXC commands are used to fix (trim) the corners and T's of parallel lines; no doubt this is also an aid for wall construction.

Another CADVANCE feature is the ability to easily plot drawings to a calculated scale. The display size is defined by the UNIT subcommand, setting the "world size" and the decimal or fractional accuracy. Plot sizes are then specified as a proportion or scale of the "world size." Plot output is good except that ellipses are drawn as polygons rather than smooth curves as they appear on the screen.

Other capabilities of CADVANCE include semiautomatic dimensioning, six text options, texturing, and internal file management. A bill of materials facility can be used with external database programs. Any drawings previously created with CADplan can be converted or uploaded to the CADVANCE system.

CADVANCE differs from the other systems, being obviously designed for 2-D architectural use but it is able to perform that function very well. The menu system makes this program easy to learn and fast to use.

CADVANCE, although strictly 2-D, is the fastest and easiest package to learn and use.

Super MicroCAD
This package seems to have some interesting features and a range of potential applications but proved disappointing during our evaluation because of the difficulty involved in configuring and running the system. Super MicroCAD has built-in 3-D features, including perspective generation, in addition to several add-on capabilities.

Unfortunately, Super MicroCAD has no automatic or menu-driven installation and configuration routine. The user must copy device driver files and construct a CONFIG.SYS file, which requires knowledge of configuration procedures and technical specifications of the specific peripherals. The documentation offers one example CONFIG>SYS file for generic peripherals. Imagimedia Technologies will, however, tailor the user's MicroCAD copy for his or her hardware system for an additional fee. Super MicroCAD requires an IBM PC or a compatible system (four brands supported) with 256K. The system supports only 12 total input devices, plotters and printers.

Super MicroCAD's documentation gives very little supplemental information other than what can be found through interaction with the system. This is because the manual is comprised primarily of hard copies of the on line "help" facility. There is, however, a complete list of commands, followed by page numbers, and a quick explanation of each.

Command entry in Super MicroCAD is possible by using the keyboard or by accessing a screen menu or tablet menu with an input device. The screen menu is composed of one long list of commands which can be scrolled up or down to locate the desired command. Using this scrolling process is more time consuming than flipping directly to another menu but eliminates the need to learn several menus. Keyboard entry is done with function keys, letter keys, and combination ALT+ or CTRL+ letter keys. This method is similar to CADKEY's key sequences for speeding through menus. The screen menu gives reminders for the corresponding function key entries. This combination of command entry methods is advantageous for both first-time and experienced users. The user may prepare and use macros to enhance efficiency of command entry sequences. A digitizing pad with a menu and user-defined macros can also be used nicely for command entry.

Commands for creating 2-D entities include the traditional line, arc, circle, ellipse and polygon, and the unusual helix. Snaps are available as well as two rotatable grids. Editing features are move, duplicate, rotate, translate, scale and stretch. Layers are limited to 999. Any of ten line types may be selected by pressing the number keys. Other features include crosshatching with predefined patterns and automatic but limited dimensioning capabilities. Some features unique to Super MicroCAD are functions for computing center of gravity and moments of inertia.

Super MicroCAD's 3-D features are definitely the highlight of the system. The operator can quickly toggle between plan and elevation view with F2 which creates a combination 2- and 3-D system. A unique feature is the "cursor observer" which allows setting up perspective views and even "walking tours" through 3-objects by varying cursor location with respect to the object. Super MicroCAD, like most 3-D programs, can quickly compute and keep status on distance between nodes in 3-D space. Hidden line removal is possible only with the addition of a $100 package.

The character set (which is rotatable in 3-D) is surprisingly a $150 add-on. Competing systems typically include several text fonts in the base price. The volume calculations package for solid objects costs $250. A bill of materials module ($250) allows creation of a parts library with text data for each component. The $1495 SAP-86 (Structural Applications Package) adds a 2-D and 3-D finite element capacity to the system. The total system price excluding SAP-86 is $2250

Super MicroCAD appears to be a powerful and competitive program. However, because of the difficulty involved in configuring and running this system, we could not accurately compare it with the others within our time constraints. I suggest that this system be purchased only by experienced micro users or those users willing to spend the extra time and expense necessary to set up this system properly. The popularity of Super MicroCAD is reflected by its relatively small market share and by the existence of few independent reviews of this system.

VersaCAD Advanced

This last package included in our evaluation is well rounded in application, ease of use, capabilities and price, and emulates AutoCAD more closely than any of the others. VersaCAD supports many IBM and IBM compatible computers and is also available for the Apple IIe as CADAPPLE.

VersaCAD is a 2-D drafting package with 3-D add-on capabilities. The base program retails for about $2000 with add-on options such as 2-D and 3-D surface modeling and bill of material database interface for about $500 each. A hardware-based security device is required for system operation. As with AutoCAD, VersaCAD supports a large number of peripheral devices.

The operations for configuring and installing the system are well explained in the documentation but are fairly involved, including formatting disks, copying files, creating a CONFIG.SYS file for setting up a virtual disk, creating an autoexec.bat file to load the virtual disk, and running an ENVIRO program to set peripherals.

VersaCAD Advanced has some nice features within the command entry and menu structure. Commands may be given via keyboard or with the screen menu via input device. The menu is a tree-structure system, which can be awkward for some operations. This rigidness is offset, not by using "flat commands" as in AutoCAD, but by utilizing Keyboard Functions; i.e., function keys, letter keys, and CTRL + key sequences. The operator can use Keyboard Functions at any time from any place in the menu structure and without losing his or her place--similar to CADKEY's Immediate Mode. At any time then, the operator may toggle snap mode, change input mode (polar, absolute or relative), change origin location, change cursor size, update global properties (line style, width, level, color, rotation), or vary digitizer scaling, as well as select several other options. Keyboard Functions speed progress but require some experience or a good memory. An excellent help facility is always available and is accessed by pressing the ? key.

"It is now AutoCAD's move..."

Entity creation and editing features of VersaCAD Advanced rate among the best. The conventional commands for creating shapes are present such as point, line, arc, circle, ellipse, rectangle and polygon. The curve-fitting routine, "bezier", works nicely. The package rates low, however, on our benchmark for drawing arcs with only three possible methods. A unique editing feature is the sequential un-delete which allows any previously deleted entity to be recalled at any time, unlike the AutoCAD OOPS which brings back only the last erased item immediately following that erasure. Mirroring is possible along an axis at any angle compared to AutoCAD's mirroring only horizontally or vertically. The copy, rotate and scale commands function smoothly. VersaCAD will accommodate several line types and colors on the same layer (impossible with AutoCAD). Another useful feature is the symbol library of almost 100 "sub-drawings"; e.g., doors, windows, fixtures, plumbing symbols, electrical schematic symbols, and fastener heads.

Shortcomings exist in text insertion, dimensioning and section capabilities. Only two text fonts are provided with the program and prove awkward in manipulation of their size and location. The semiautomatic dimensioning requires manual placement of text within dimension lines. The dimensioning options are limited, lacking both angular and radial dimensioning. Predefined sectioning patterns are not available in the program, only the ability to section with solid lines at user defined angles and spacing.

VersaCAD utilizes ingenious systems to prevent time and work-file losses. A device called Failsafe prevents the user from becoming trapped in a long chain of undesired command sequences. Pressing ESC will abort the sequence and return to the origin. If the user completes a work session and finds insufficient disk space to save the drawing, VersaCAD allows the user to exit the program, provide the necessary disk space, and return to save the file which has been concurrently held in memory. The user has the option to save the current parameter values, windows, plot specs, and function key values used during the session and save only a "clean drawing".

VLINK is the only advanced feature in the VersaCAD Advanced base package. VLINK is used for translating drawing files to a T&W Systems exchange format called TWGES (T&W Graphic Exchange Specification) which is analogous to AutoCAD's DXF format. Drawings created on earlier VersaCAD versions require this translation for conversion to version 4.00.

Two add-on options ($500 each) are the IGES translator (Initial Graphics Exchange Specification by the U.S. Bureau of Standards) and VLIST (a very advanced bill of materials and database facility). VLIST, like the ATTRIBUTES of AutoCAD, provides the capability of managing user defined text data on specific part drawings and cross referencing with other applications programs. Its power is proven by the ability to search on user defined specifications and highlight the found part drawings on the screen.

The T&W Systems 3-D add-on package which runs outside of VersaCAD Advanced was not available for the IBM during our evaluation. However, from what I have recently seen of T&W's Drawing Contest Winners Series, the 3-D option appears to have some powerful abilities including automatic hidden line removal. It is now AutoCAD's move.

VersaCAD Advanced completes closely with AutoCAD as the top general-purpose CAD package. Features which may seem weak such as arc creation, text insertion, dimensioning and sectioning are counterbalanced by other unique features such as failsafe, undelete, work-file saving options, VLIST and 3-D capabilities. VersaCAD users should feel satisfied with this tool and secure with the longevity of its technological competitiveness.

Key

1 very poor, 2, 3 average, 4, 5 excellent

○ Not Available ◒ Optional ● Included in base package

	AutoCAD v. 2.17	CADKEY v. 2.0	CADVANCE v. 1.0	SUPER MICROCAD	VERSACAD v. 4.0
1. INSTALLATION					
Installing Software	4	5	3	2	3
Configuring System	5	5	4	1	3
2. DOCUMENTATION					
Organization	3	3	4	2	3
Complete	5	5	4	2	3
Concise	3	2	3	4	3
Tutorial	●	●	○	○	●
Quick Reference Chart	○	○	●	●	○
3. COMMAND ENTRY					
Screen Menu (Mouse or Keys)	●	●	●	●	●
Digitizer Capability	●	●	●	●	●
Tree Structure Menu	●	●	●	○	●
Single Level Menu	○	○	○	●	○
Nested Commands	○	●	●	○	●
4. 2-D GEOMETRY CREATION					
Lines, points	●	●	●	●	●
Arcs	5	4	4	3	3
Circles	4	4	3	3	2
Polylines (variable width)	●	○	●	○	○
Parallel lines (single command)	○	●	●	●	●
Ellipses (single command)	●	●	●	●	●
Polygons (single command)	○	●	●	●	●
Splines	○	●	●	○	●
Helix	○	○	○	●	○
Freehand sketching	●	○	○	○	○
Text & manipulation	5	3	4	2	2
Solids	●	○	○	○	○

Key

1	2	3	4	5
very poor		average		excellent

○ Not Available ◓ Optional ● Included in base package

	AutoCAD v. 2.17	CADKEY v. 2.0	CADVANCE v. 1.0	SUPER MICROCAD	VERSACAD v. 4.0
5. 3-D GEOMETRY CREATION					
Extrusion from 2-D	●	●	○	○	◓
Full 3-D creation	○	●	○	●	◓
Auto isometric	○	●	○	○	◓
Isometric grid (2-D)	●	○	●	○	●
Perspective generation	○	○	○	●	○
Hidden line removal	●	○	○	◓	◓
6. EDITING AND MISC. FEATURES					
Snap, object snap	●	●	●	●	●
Entity selection methods	3	4	3	2	5
Erase, unerase	●	●	●	●	●
Move, copy array	●	●	●	●	●
Mirror	●	●	●	○	●
Fillet, Chamfer	●	●	●	●	○
Named Layers	●	○	●	○	○
On-line help	●	○	●	●	●
Dimensioning	5	4	2	2	2
Hatching patterns	5	2	2	2	2
Blocks & manipulation	5	5	3	3	4
Inquiry commands	2	3	4	4	3
7. SPECIAL FEATURES					
Attributes (Bill of Material)	●	○	●	◓	◓
Scripts, slide shows	●	○	○	○	○
Programming language	●	●	●	○	○
Exchange format (DXF)	●	●	○	○	●
IGES	●	◓	○	○	◓
Macros	●	●	●	●	○
Customized screen menus	●	●	○	○	○
DOS shell	●	○	○	○	○

and secure with the longevity of its technological competitiveness.

The Comparison

To quote Steven M. Lord from his article in Mechanical Engineering, "Reviewing these packages is somewhat of an exercise in futility." The competition among software of this caliber and the speed at which upgrades are marketed make an evaluation such as this valid for only a short time. Two of the five packages evaluated here announced new versions and one offered a new add-on option--all within three months. None of the packages tested significantly superior to the others with respect to basic features and capabilities. Of the five, only Super MicroCAD indicated an inferiority, largely due to our inability to adequately test its potentials.

Key

1	2	3	4	5
very poor		average		excellent

○ Not Available — ◓ Optional — ● Included in base package

	AutoCAD v. 2.17	CADKEY v. 2.0	CADVANCE v. 1.0	SUPER MICROCAD	VERSACAD v. 4.0
8. OUTPUT					
Supported printer-plotters	3	3	3	1	2
Supported plotters	5	4	4	1	5
Plotting controls	4	4	3	3	4
Plot to scale	3	4	4	3	3
Resolution	4	4	2	4	4
Plot direct from editor	●	○	●	●	●
9. EASE OF LEARNING					
Menu organization	3	3	5	4	3
Keyboard commands	○	2	2	4	3
From system interaction	4	3	5	3	3
From documentation	3	2	3	1	3
Speed - 1st time user	4	2	5	4	3
Speed, experienced user	3	5	3	4	4

However, one difference among the five packages that does stand out is the numbers of users and third-party vendors. AutoCAD leads the market by a surprising margin. Autodesk has established a good reputation and continues its rapport with the 35,000 users and 100+ third-party vendors. This success does not necessarily mean it is a better package but does indicate longevity and flexibility. And, in the highly volatile industry of high tech microcomputer software, these are important considerations.

THE RECOMMENDATION

When selecting software for the educational environment, several objectives must be satisfied. First, the choice must be a flexible, general-purpose package to accommodate applications in a wide variety of engineering fields. Second, the package must be relatively easy to learn, especially for first-time users who are also neophytes with basic graphic concepts. Third, advanced features including 3-D are desirable for lower-level and necessary for upper-level course work and graduate and faculty research. Fourth, flexibility and longevity are required. We have seen funds for graphics programs consumed by purchases of hardware (usually mainframe systems) and software which become obsolete in a few years. Now, micro-based, general-purpose CAD systems seem to offer the greatest flexibility and longevity. Industrial acceptance and third-party support are indicators of longevity and flexibility. Industry has clearly exhibited the direction it is taking. Students need experiences similar to those they will encounter in industry. The optimum package for fulfilling all of our educational objectives is not presently available.

The best choice at this time would be a trade-off between a package with full 3-D capabilities such as CADKEY and a package with a strong foundation in industrial and third-party support such as AutoCAD.

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Steven Coons

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French, Soviet, Czechoslovak or other journals devoted to this field, papers on his "patches" have been delivered at IFIP events in Rome, Scotland, Budapest, London, Moscow and Tokyo.

When I last spoke with Steve, a couple of months before he died, he was full of new ideas - about the fundamental thought-processes involved in the creative aspects of design. He left them for us, the survivors, to develop. He would have done it with more mathematical clarity, greater industrial applicability, a more elegant style and a better sense of humor. Fortunately his memory will remain with us, to guide and help us, as he was always so ready to do.

J. Hatvany

SURFACE MODELING, SOLID MODELING AND FINITE ELEMENT MODELING

ANALYSIS CAPABILITIES OF COMPUTER-ASSISTED DESIGN AND MANUFACTURING SYSTEMS

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INTRODUCTION

The structure for 3-D modeling and analysis was originally introduced during the late 1960's. During this early development period, interactive processing was usually restricted to key-punched cards which were batched through a large mainframe computer. Particularly slow by today's standards, these workhouses consumed large amounts of expensive computer time while performing geometric calculations on simple designs. These systems also were not capable of refined graphics, such as hidden line removal, transformations and surface shading (Barnhart, 1984, p. 40).

However, with the introduction of the 16 and 32 bit microprocessors in the late 1970's and early '80's, many of the limitations restricting the progress of 3-D modeling technology disappeared. Today, machines running CAD/CAM software span a broad range, from low-cost personal computers that make the technology affordable to even the smallest of firms, to the most powerful supercomputers that routinely perform tasks formerly considered too computation-intensive to handle at a reasonable time and cost. The four main types of computers generally used for CAD/CAM include microcomputers, minicomputers, mainframes and supercomputers.

Most CAD/CAM systems rely on minicomputers as the processing machine as they tend to offer the best price/performance ratio. A relatively powerful minicomputer based system costs between $125,000 to $500,000 (Krouse, 1985, pp. 61-65).

Wire-frame modeling, surface modeling, solid modeling and finally finite element analysis establish a logical transition from primitive to highly advanced methods in 3-D interactive graphics. Each method has unique application attributes and provide a different amount of data relating to any given part being designed.

Today, numerous commercial modeling programs are available ranging in price from $1,000 to $1,500,000. The cost variance depends upon the varied levels of support services provided with the software. Educational and research facilities offer the least expensive programing containing minimal software support. Companies which offer more expensive versions provide support services such as training sessions and programing updates (Barnhart, 1984, pp 41-41).

"Today, CAD/CAM software spans a broad range, from low-cost personal computers that make the technology affordable to the most powerful super computers..."

PURPOSE OF THE STUDY

The purpose of this study was to explore the following concepts in the field of computer-assisted designing: 1) Surface Modeling, 2) Solid Modeling, and 3) Finite Element Analysis.

The study was intended to organize and present information that will enable a layman with no previous knowledge of these concepts to compare and contrast the capabilities of each. The study also included a comparison of various systems offered by selected manufacturers.

LIMITATIONS OF THE STUDY

The study defined and extensively evaluated the above mentioned concepts, although this report should not be considered as a user's manual for any specific system. There was no study conducted on software fabrication., Also, as far as the comparison of the various systems was concerned, the study was limited to the manufacturers who are listed to have these systems in the SME CAD/CAM Productivity Equipment Series. Since minicomputers tend to offer the best price/performance ratio only the minicomputer based systems were explored.

DEFINITIONS

1) Surface modeling. Surface modeling is a surface generation technique, which gives the designer complete control over the analytic nature of the surfaces ranging from the traditional analytic surfaces to the highly complex sculptured surfaces. Surface modeling can be viewed as the extension of wire-frame modeling. Whereas, wire-frame modeling uses entities like points, lines and simple curves (circles, conics, ellipses) to create 3-D models, surface modeling uses surfaces to generate 3-D models (SME, 1985, p. 40). The surface modeling technique describes an object by shaping a thin, flexible skin in three-dimensional space to represent the surface of the object. The surface can be defined in the computer data base as a net of three-dimensional surface points, as a network of polygon shaped planes, or as a mesh of curved surface patches (Scott, 1982, p.115).

There are numerous applications for the surface modeling technique. It is specially suited in the automobile industry where many parts with free form geometries, such as the body parts that are to be designed. The surface model can be used to perform analysis such as mass properties calculations and finite element analysis. Other functions include: surface fillets, surface intersections, flowline mesh generation, wrap and unwrap of ruled surfaces for blank development (SME, 1985, p. 199).

2) Solid modeling. The fastest available technique today for geometric designs is *interactive solid modeling*. A solid modeling system provides complete description of mechanical parts and assemblies. The user of solid modeling systems is generally menu driven. The basic construction elements are an expandable library of primitive solids. Examples of primitive solids are cubes, spheres, cylinders, etc. Interactive techniques are used to build complex shapes and structures from primitives (SME, 1985, p. 382).

Solid modeling has several advantages over wire-frame and surface modeling. Solid modeling overcomes the drawback of both the wire-frame and surface models by defining parts as solid objects. Unlike wire-frame and surface modeling, a cutaway section taken on a solid model reveals internal geometry of the part. Solid modeling requires much more memory than surface models as solid models store information about the edges and surfaces within the model. This data need not be stored in surface models, because it may be inferred from the position of the surface vertices. But, in surface modeling curved surfaces are approximated by combining planes, which produce faceted surfaces. As we try to refine and smooth a curved surface, the number of facets required increases, resulting in increase in computing time. Solid modeling is the most sophisticated design model available today and all sorts of analyses such as mass properties calculations, finite element analysis, animation etc., can be performed on this model (Hordeski, 1986, pp. 399-407). The model also provides visual verification of clearances and interferences in case of assemblies being modeled (SME, 1985, p. 383). Solid modeling is heralded by many as the wave of the future in CAD/CAM, and it undoubtedly has great potential.

Type of surface	Features	Applications
Traditional analytic surface.	Uses simple curves such as lines, circles, conics, etc. to synthesize complex surfaces using techniques such as tabulated cylinders, ruled surfaces and surfaces of revolution.	This technique can be used to generate surfaces which can be mathematically defined.
Polygon mesh	This technique generates complex surfaces using a set of connected polygonally bounded planar faces.	It is used to generate complex surfaces which cannot be defined mathematically.
Coons surface	This technique generates complex surface by specifying boundary conditions and blending of these boundary conditions.	This is a widely used technique based on curve fitting.
B-spline surface	It is similar to Bezier surface except that any number of adjacent points can be used to includence local shape of the surface. B-spline surface also offer the convex hull to manipulate the surface.	This technique provides the smoothest and most accurate approximation of the part being generated. Convinient to generate intricate geometries.
Bezier surface	This technique generates complex surfaces by specifying 16 control points. The convex hull polygon formed by the control points can be used to manipulate the shape of the surface.	This technique allows generation of an extremely fine patch sub division over entire surface, in case a small high curvature transition zone appears on the part. Bezier surfaces produce more realistic models than Coons surfaces.

Table 1

3) Finite element modeling and analysis. Finite element analysis is an important technique which allows the user to perform linear static and dynamic analysis and pinpoint the critical areas of stress and strain in the model without actually building and testing a prototype. The elimination of the prototype building and testing help design engineers in reducing design time-frames while optimizing product performance and quality (SME, 1985, p.30). Finite element analysis is performed by dividing the data into submatrices. Each of these matrices (elements) represents some critical part of the assembly. A finite element program combines the matrices in order to characterize the entire structure (Hordeski, 1986, p. 446).

Design engineers can quickly perform finite element modeling and analysis after the 3-D geometry of the part is created during the conceptual design state. Generally, it is possible to generate finite element models directly from the 3- geometry database. The geometric model is divided into many discrete sections called finite elements. The combination of these elements is called a finite element mesh. After the user specifies the distribution (density) of nodes and elements, a finite element analysis system is capable of generating finite element meshes automatically over the most complex geometric model. Nodes can be distributed uniformly over the model, or spaced more closely in areas where stress factors are apt to be critical and require high accuracy. In more advanced systems the user positions only the boundary nodes interactively and in seconds the computer automatically generates, numbers and displays all interior nodes and elements. Generally, the system provides tools to prevent creation of faulty meshes by automatically checking for ill-formed elements, duplicate nodes and unused nodes. A "shrinking" feature provides the capability to check for missing elements hidden by edges of adjacent elements. The computer instantly compresses element edges and separates their individual boundaries. Omitted elements are revealed when displayed as noticeable holes. Once the finite element models are created they can be studied from any orientation and at any magnification. These versatile checking and viewing features eliminate model creation errors and minimizes the possibility of submitting incorrect models for analysis. After the nodes and elements are generated the user interactively assigns a range of attributes including loads, restraints and material properties to any individual or group of nodes and elements. Loads and restraints are graphically displayed on the screen. The next step in the analysis process is calculating the behavior of the model due to the imposed loads, using algorithms to perform l static

Type of solid	Features	Applications
Constructive solid geometry	This technique generates by using: 1) wide variety of primitive solids. 2) Boolean operations. 3) Automatic hidden line removal.	Suitable for most engineering applications. However this technique is not suitable to generate complex surfaces as it becomes time consuming to find exact equations of intersection of the primitive solids.
Boundary representation (B-rep).	This solid generation technique includes: 1) Sweeps, volumes of revolution, ruled surfaces. 2) Boolean operations. 3) Automatic hidden line removal.	Wide range of solids including those with complex surfaces can be easily defined using this method.

Table 2

and dynamic analysis. The analysis results can be displayed graphically. Model deformation caused by the loads can be displayed as a deflected (deformed) shape, alone or superimposed on the undeflected model. Stresses and strain can be displayed as color contour plots on a color monitor. This enables the user to spot areas of high stress and thus the areas of potential structural failure. Printed output about the analysis also can be obtained, which lists nodal displacements, nodal strain energy, element stress and strain energy and reactions at the support points (SME, 1985, pp. 3-6).

Though finite element modeling in most cases can be integrated with any of the geometric models, solid modeling provides the most complete representation of the finite element meshes. The generation of the finite element models and the solutions of the resulting equations, typically numbering in hundreds or thousands, requires considerable computer power and time. Because solid models contain most of the information required to generate a finite element model, the latter can be generated with minimal user interaction and computer time (Krouse, 1986, pp. 38-40).

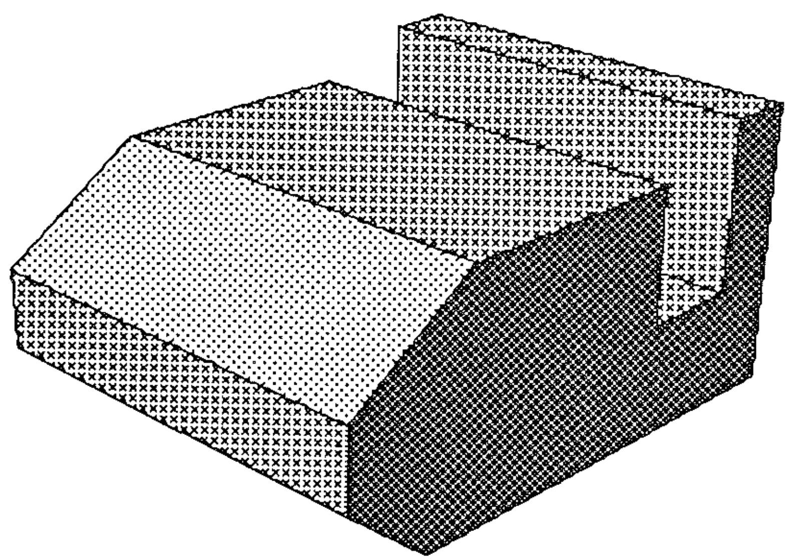
The preceding paragraphs presented basic concepts of surface modeling, solid modeling and finite element modeling and analysis. The following paragraphs will present and compare the highlights features of the above mentioned concepts.

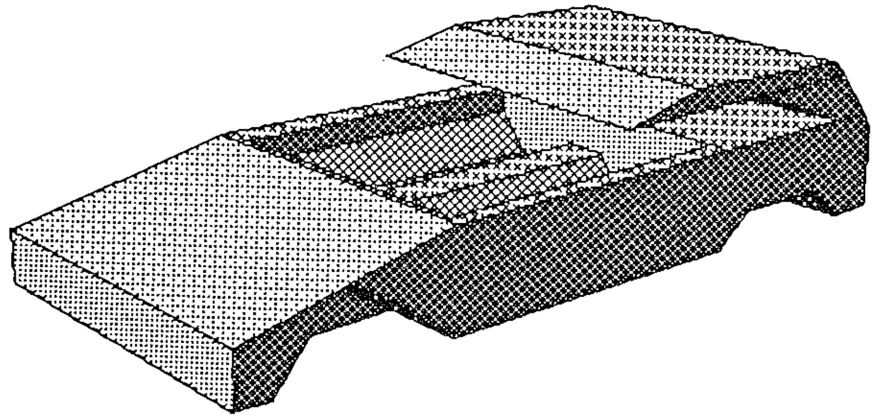
Though solid modeling is the most advanced technique of 3-D model generation available today, surface modeling is definitely the workhorse for advanced geometric modeling. Whereas surface modeling is an idealized model obtained by subjective curve fitting, solid modeling produces a model which resembles the actual part in all respects. Therefore, the user should tend to select the solid modeling systems. However, the cost and large memory requirements for generating a solid model are the main restraints that prevent the users from actually purchasing solid modeling systems. Besides the latest surface modeling systems provide almost all the facilities for designing that a solid model provides.

Refer to Tables 1 and 2 which summarize the surface modeling and the solid modeling, respectively. The comparison between the two systems is presented in Table 3.

SUMMARY

The purpose of the study was to review and compare advanced computer-aided geometric modeling and analysis techniques, namely surface modeling, solid modeling and the finite element modeling and analysis techniques. Since a study of computer-aided designing will be incomplete without suitable hardware, a survey was conducted to establish the capabilities of mini-computer based systems to handle the above mentioned 3-D geometric modeling and analysis packages.





SURFACE MODELING	SOLID MODELING
1) It is only a surface representation of a model which contains only surface information of an idealized product.	1) This model is the most complete representation of a product which also defines the details inside the surface of the model.
2) Moderate computer memory requirement as only the surfaces of the model are defined.	2) Large computer memory is required to store information about the edges and surfaces within the model.
3) Hidden line removal is interactive and therefore tedious. However most of the recent models offer automatic hidden line removal.	3) Automatic hidden line removal is provided as a standard feature.
4) This model can be used for N/C applications. However a certain amount of interaction may be required.	4) Specially suited for N/C applications.
5) Finite element model generated from this model relates to an idealized product.	5) Finite element model generated from the solid model relates to stress produced in the actual product.
6) Sculptured surfaces are especially suited for artistic designing.	6) Solid modeling is often time consuming when used to generate artistic designs.
7) Interference checking is possible with this model but visualization is required on the part of the user as to which side of the surface solid material is located.	7) Interference checking can be done without any difficulty.
8) Most of the advanced surface models offer mass properties computations such as volume, weight, center of gravity, moment of inertia and surface area	8) This model is very well suited for mass properties compuations.
9) Cross section of a surface model does not reveal the inside geometry as this model describes only the surface of an object.	9) Cross sectional view along any desired plane possible.
10) Surface modeling software is moderately priced.	10) More expensive than the surface modeling software.
11) This is the most commonly used 3-D geometric modeling system used today.	11) The popularity of this system is ever increasing and it is expected to be widely used by 1990.

Table 3

The logic behind selecting a minicomputer based system was that it provides the best cost-performance ratio in the CAD/CAM field today. A questionnaire was developed to obtain relevant information from different manufacturers regarding both the software and the hardware needed for the areas under consideration. Specific data about the systems can be obtained from the authors.

CONCLUSIONS AND RECOMMENDATIONS

The most encouraging conclusion arrived at during the study was that almost all the advanced 3-D geometric modeling and analysis packages are available to run on mini and supermini-computers. As a result it is safe to assume that most of the advanced computer-assisted techniques will be within the reach of a major part of industry.

Some of the fastest minis operate at speeds of 3 to 5 million instructions per second (MIPS) using emitter-coupled logic (ECL) circuitry. The range of processors permits firms to start with relatively low cost, entry-level machines priced below $15,000 and move up to more powerful equipment priced from $125,000 to $500,000 while keeping the same software. Minicomputers are generally considered to have the best price/performance ratio of any computer class and have some other compelling advantages for most CAD/CAM applications. While mainframes are often located in corporate data processing facilities, minicomputers are generally placed within the engineering department. So, the CAD/CAM system does not depend on outside computing resources. Moreover, unlike the single-user PC-based systems, minicomputers generally support several terminals and are readily networked, permitting widespread access to a share design and manufacturing database. One significant feature of most minicomputers is the *virtual memory operating system*, which is essential to running extremely large programs characteristic of tasks such as finite element analysis (Krouse, 1985, pp. 63-64).

As far as the software for 3-D geometric modeling is concerned, currently the best bet is the surface modeling packages. The advanced surface modeling packages that are being offered today can perform many of the graphics and analysis tasks, often attributed to solid models. Secondly, the computer requirements for surface modeling are comparatively less than those required for the solid modeling. Besides, surface modeling is a very versatile technique which can be easily edited so that portions of a surface may be stretched, scaled, repositioned or erased. These features make the surface modeling technique specially lucrative for creative and artistic designing. The only disadvantage while performing advanced analysis on a surface model is that more user-interaction is required as compared to a solid model. However, at present the price/performance ratio is definitely in favor of surface modeling.

On the other hand, the advent of the superspace minicomputers has dramatically reduced the time and cost of processing solid models, and interactive graphics interfaces have greatly simplified and speeded model building. As a result, more than 25 vendors now offer solid modeling packages. The number of installations increased from 40 in 1982, to about 600 in 1985, and most observers expect solid modeling to become the predominant design approach in mechanical CAD/CAM by 1990 (Krouse, 1986, p.30).

Company Name	Third-party software used
Prime Computer	PATRAN, NASTRAN, ANSYS.
Harris Corporation	PATRAN, ANSYS.
Data General*	MCAUTO/UNIGRAPHICS, MCAUTO/GFEM, PATRAN, EASE2, ANSYS., NASTRAN, DOGS, ANVIL-4000.
Control Data	NASTRAN, ANSYS., EASE2.
Applicon	NASTRAN, ANSYS.

* Data General is basically a hardware manufacturing company which has introduced the ECLIPSE 32 bit MV/FAMILY of minicomputers.
Data General offers software services only through the OEMs, who use their hardware. Data General OEMs include McDonnell Douglas, PDA Engineering, Swanson Analysis Systems, MacNeal-Schwendler Corporation, etc.

Table 4

The analysis of the questionnaires and the related specifications collected from the various companies pointed out the following features, which should be scrutinized while selecting 3-D CAD/CAM software.

First of all, it will be wrong to identify the three concepts, namely surface modeling, solid modeling and finally finite element modeling and analysis as separate entities while purchasing a CAD/CAM system. The survey indicated that most of the manufacturers offer modular systems which integrate the various modeling techniques. For example, one can generate a higher order model such as a surface model from the wire-frame database. There are two advantages to this type of modular system. One is that it permits the user to purchase only the capabilities that are currently needed, and then add others as the requirements grow. A typical user may select a simple 2-D drafting system and then migrate to a full 3-D design system with CNC machining, and engineering design and analysis capabilities. The second advantage is that it allows one to save valuable computer resources by using lower order modeling techniques such as the wire-frame modeling for the preliminary or simple designs and then use higher order techniques like surface modeling to generate more accurate and complex models. Also, it is possible to combine surface modeling and wire-frame modeling for the purpose of designing only the complex faces in a component using surface modeling. Therefore, while purchasing a CAD/CAM system one must take into account its compatibility for future expansion.

Another interesting fact observed was that most of the companies use entirely or partly, third part software, which serves as pre-processors or post-processors in the areas where their own softwares are not capable of providing the desired support. Table 4 shows the various third party softwares used by the different suppliers contacted during the study. Most commonly used third party packages include, PDA/PATRAN for constructing three-dimensional engineering analysis models, and SASI/ANSYS, EAC/EASE2 and MSC/NASTRAN for advanced finite element analysis. A significant milestone in CAD/CAM's history is the advent of the Initial Graphic Exchange Standard (IGES) committee in 1970's. This represents a major attempt to standardize data exchange formats. Excellent results have been achieved in passing information from one system to another system via IGES formats. It would be wise to buy a system which at least conforms to the IGES standards. But in 1987, the Project Definition Exchange Standard (PDES) will start to provide for greater flexibility. It will not be limited to mostly drafting related areas but will make data exchange standards much better for micro and mini usage as they relate to surface modeling, solids and manufacturing applications.

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STUDENT ATTITUDES TOWARD DRAWING FOR ENGINEERS

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ABSTRACT

In the Fall of 1984 Arizona State University introduced a new concept in teaching engineering graphics and computer literacy to freshman engineering students. Two new courses, ECE 105 Languages of Engineering and ECE 106 Introduction to Computer Aided Engineering, were implemented. Since both the content and method of teaching engineering fundamentals (especially for the first of the two courses) differed from that which the students may have expected, an attitudinal survey was designed and administered to all students at the beginning and end of the semester for each of the two courses. This paper presents the results of statistical analyses of these data, as well as an interpretation of their meaning to engineering education in general.

INTRODUCTION

In the Fall of 1984, Arizona State University introduced new concepts in the teaching of drawing to engineers. These have been embodied in a two-course sequence, known as ECE 105 Languages of Engineering and ECE 106 Introduction to Computer Aided Engineering. These courses were designed to promote the understanding of natural laws, societal values, and the nature of engineering, in addition to improving student competencies in various engineering, design, and communication tools. The courses are intensely microcomputer oriented. They combine freehand drawing, computer programming, engineering analysis and design using applications software, including ideation and documentation drawing software. The computer concepts taught in these courses have been presented elsewhere (1).

Drawing for the engineer is taught in the two courses through a three-hour per week graphics laboratory utilizing methodology and techniques which are unique in engineering education (2). Engineering graphics has traditionally been taught as a technical subject involving abstract and theoretical concepts based upon descriptive geometry and projective techniques (Figure 1). ECE 105 teaches freehand drawing based upon observation (Leonardo da Vinci style), using techniques and exercises from art instruction developed specifically for freshman engineering students(3). The second course, ECE 106, emphasizes rapid freehand drawing for design ideation coupled with documentation drawing using the microcomputer (CAD) (Figure 2). Descriptive geometry, orthographic projection, and drafting or instrument drawing *are not* a part of these courses.

The teaching strategies used in these courses are based in part on published research in cognitive psychology which points to different modes of processing information by the human brain. Left mode information processing is sequential, analytical, and symbolic. By contrast, right mode processing tends to be more non-temporal, holistic, and spatial, and is important for visualization and the transfer of ideas to paper via freehand drawing.*

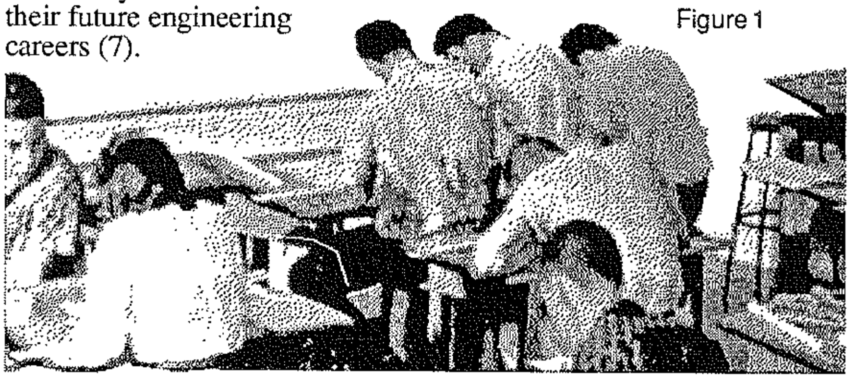
"...freehand drawing based upon observation (Leonardo da Vinci style)."

Engineering students are usually quite adept at math and science, or left-mode activities, but they are less comfortable and less mature in their abilities to handle right-mode activities such as freehand drawing. Left mode teaching strategies, predominant in engineering curricula, further encourage the strengthening of students' left mode skills while doing little to promote right mode skill development. Traditional instruction in drafting is extremely left mode, because of its reliance upon terminology, sequential steps, and deductive logic. Several writers have pointed out that left mode cognitive strategies may actually inhibit the acquisition of right mode skills, such as drawing (4, 5, 6). As a result, many engineering students are convinced that they are unable to draw in a freehand mode. Some even graduate from engineering degree programs lacking the drawing skills necessary for effective functioning on the job, such as design visualization and transfer of ideas to paper.

* For further discussion of this subject see Bower's previous paper in the **EDGJ**, Volume 50, Number 3.

For this reason, a strong component in our approach to teaching ECE 105 is constant encouragement and support of the students' efforts. We try to convince the students that, with practice, they should be able to do a credible job of freehand representational drawing and that this ability will serve them well in their future engineering careers (7).

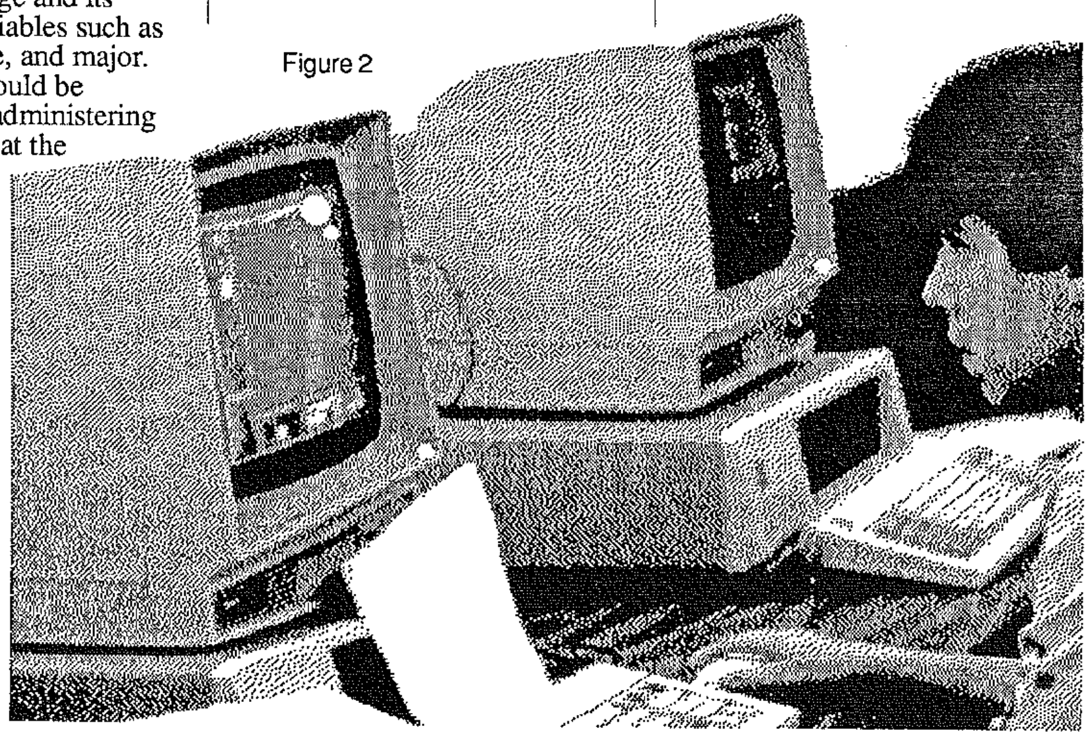
Figure 1



Because of the innovative course content and teaching style, we wanted to assess the students' attitudes toward these two new courses. Although comments and student evaluations of their teachers had been overwhelmingly favorable to the courses since their inception, we wanted to investigate the extent of attitudinal change and its relationship to variables such as students' class, age, and major. We felt that this could be accomplished by administering an attitude survey at the beginning of the semester and re-administering the same survey at the end of the semester. Any differences in results between the pre-course and post-course attitude surveys would represent attitude changes that could be attributed to the courses.Separate survey instruments were developed for ECE 105 and 106 students. Each survey took five to ten minutes for students to complete by marking a five-position scale on machine-scored sheets.

"Descriptive geometry, orthographic projection, and drafting instrument drawing are <u>not</u> part of these courses."

Figure 2



ECE 105 FINDINGS

The ECE 105 survey consisted of 17 questions as shown in Table 1. Questions one through eight probed student attitudes toward their skills in various aspects of drawing using a five-point scale from "better than most college students" to "not as well as most

Item #	Pre-course (n = 704)	Post-course (n = 365)	Change**
1.	2.97	2.01	+0.96*
2.	3.67	2.35	+1.32*
3.	3.03	2.02	+1.01*
4.	3.00	1.95	+1.05*
5.	2.94	2.16	+0.78*
6.	3.52	1.96	+1.56*
7.	3.13	1.99	+1.18*
8.	2.72	2.17	+0.55*
9.	1.81	1.8	- 0.04
10.	2.09	1.42	+0.76*
11.	2.58	2.29	+0.29*
12.	2.15	1.89	+0.26*
13.	2.21	1.97	+0.26*
14.	2.55	2.30	+0.25*
15.	2.21	2.03	+0.18*
16.	2.27	1.76	+0.51*
17.	1.69	1.43	+0.26*

* Significant at 0.05

Items 1-8 were scored "Better than most college students" = 1; "not as well as most college students" = 5.

Items 9-17 were scored "Strongly agree" = 1; "Strongly disagree" = 5.

** A positive change represents a positive improvement in student attitudes.

TABLE 3. Means By Item for the ECE 105 Pre-and Post -Course Assessments.

to support a conclusion of improved self-image and more positive self assessment following instruction.

ECE 106 FINDINGS

The ECE 106 survey (see Table 4) consisted of 19 items. The first four items asked students to indicate their classes within the university, their ages, and their majors. Items 5 through 19 solicited student opinion on a variety of topics such as the content of ECE 106, their own skills at engineering drawing, and the abilities and duties of practicing engineers. These items were to be answered on a scale ranging from "strongly agree" to "strongly disagree." Eleven of the fifteen items were worded so that the "strongly agree" end of the scale indicated the most favorable attitudes and was assigned a value of 1. At the opposite end of the scale, "strongly disagree" was assigned a value of 5. For items 10, 13, 14, and 18, the "strongly disagree" response was coded as 1, since this represented the most favorable student attitudes.

The pre-course administration of the survey was conducted during the first week of the 1985 fall semester using 119 students in eight ECE 106 sections. The post-course administration used 56 students from the same sections during the final week of the semester. As was the case for ECE 105, the major reason for the difference in group size for the two survey administrations was the optional attendance policy during the final week of class. Data collected from items 1 through 4 are reported in Table 4. Pre and post course assessment means for items 5 through 20 are reported in Table 5.

Analysis of variance was conducted on the data from items 5 through 20. As was found for ECE 105, a positive change in student attitude occurred during the interval between the pre and post course assessments. This finding was interpreted to indicate that the course was effective in changing student attitude toward drawing as measured by the survey. Again, as was found for ECE 105, analysis of variance results indicate that students' answers varied significantly by item. The interaction effect, also

CLASS
1.A. Freshman
1.B. Sophomore
1.C. Junior
1.D. Senior
1.E. Other

AGE
2.A. Under 20
2.B. 20-25
2.C. 26-30
2.D. 31-35
2.E. Over 35

MAJOR
3.A. Electrical Engineering
3.B. Mechanical Engineering
3.C. Senior
3.D. Civil Engineering
3.E. Chemical Engineering

4.A. Other Engineering
4.B. Construction
4.C. Architecture (College of)
4.D No Major
4.E. Other

Please answer the following items using the code below. This questionnaire will be given to you before and after you take ECE 106, so if you feel you lack information to answer certain questions, please just do the best you can.

A. Strongly agree
B. Agree
C. Neutral or undecided
D. Disagree
E. Strongly disagree

5. Engineers spend little of their time doing drafting.
6. Engineering design is important to my career.
7. Engineers often delegate drafting to others.
8. The ability to sketch is important to my career.
9. The ability to draw realistically is important to my career.
10. The ability to draft is important to my career.
11. ECE 106 as currently taught will be valuable to my career.
12. ECE 106 and ECE 106 blend well together.
13. There is too much sketching in ECE 106
14. There is too much computer graphics in ECE 106.
15. The balance of subject mater in ECE 106 is about right.
16. I can use sketching to help me think and conceptualize.
17. I can use the computer for design documentation.
18. I need a course in drafting in addition to ECE 106.
19. A drafting course would be less valuable than ECE 105 and ECE 106.

Please mark the answer that matches your situation. Use the machine scored forms you will be given.

TABLE 4. ECE 106 Drawing Applications Questionnaire

significant, indicated that the amount of improvement in student attitude differed significantly among items.

Results of Duncan's multiple range tests indicate that significant pre to post-course administration changes occurred for items 11, 13, 14, and 15. These items solicited student opinion on the content of ECE 106. At the pre-course survey administration, student attitudes toward the course as measured by these items were generally neutral, probably due in large part to the students' reluctance to judge the course prior to completing it. By the post-course administration, attitudes had improved by a low of .32 and a high of .64 points on these four items. These findings were interpreted to mean that students were generally satisfied with the experiences offered them in the course, and that they perceived that the two kinds of drawing, freehand ideation drawing and computer-aided documentation drawing were effectively combined in the course.

For item 17, which asked students whether they could use a computer for design documentation, attitudes also improved significantly between the testing periods. This is probably because ECE 106 was, for most students, their first formal exposure to documentation drawing. The remaining items (5 through 10, 12, and 16 through 19), which addressed the importance of skills to career success and students' perceptions of the duties of engineers on the job, did not change significantly between the testing periods.

Three of the items (5, 7 and 18), all related to drafting, show slight movement in the undesired direction. This lack of change in the positive direction may be due to the strong pre-conceived notions of many college freshmen that drafting is an important and time consuming activity for engineers. This notion was likely reinforced by students' completion of a design project that incorporated documentation drawing just prior to the post-course administration of the survey.

Of particular note are the results for item 16, which asked students whether they could use freehand drawing to help them think and conceptualize. For both the pre- and post-course assessments, mean responses indicated generally favorable attitudes toward this concept. The similarity of pre- and post-course responses may be due to the generally positive attitudes of entering students after exposure to the content of ECE 105, making dramatic gains in positive attitudes during ECE 106 less likely. Another possible explanation for this result may be that growth in this cognitive skill would take more time than a fifteen week semester provides.

Alternatively, the results of items 8, 9, and 10 show slight non-significant growth in positive attitudes. That is, students' perceptions moved toward the belief that (for engineers) proficiency in freehand drawing is a more desired skill than is expert draftsmanship.

Six analyses of variance were conducted to determine whether significant differences existed among students in the various classes, age groups, and majors on the pre-course and post-ccourse surveys. The only overall

Item #	Pre-course (n = 119)	Post-course (n = 56)	Change
5.	3.00	3.21	- .21
6.	1.83	1.71	+.12
7.	2.45	2.50	- .10
8.	1.93	1.86	+.07
9.	2.17	2.11	+.06
10.**	3.60	3.43	+.17
11.	2.41	2.09	+.32*
12.	2.79	2.63	+.64*
13.**	3.06	2.70	+.64
14.**	2.87	2.52	+.35*
15.	2.91	2.52	+.39*
16.	1.97	1.98	- .01+
17.	2.12	1.71	+.41**
18.**	2.72	2.77	- .05
19.	2.69	2.55	+.14

* Significant at 0.05

** These items were scored "strongly disagree" = 1; "strongly agree" = 5. The remaining items were scored "strongly agree" = 1" "strongly disagree" = 5.

TABLE 5. Means by Item for the ECE 106 Pre- and Post-course Assessments, Items 5-20.

Sources of Variation	Degrees Freedom	Mean Square	F	Pr>F
Administration	1	12.59	7.36	0.0074
Item	14	42.87	62.70	0.0
Interaction	14	1.33	1.94	0.0510

TABLE 6. Analysis of Variance Summary Table for ECE 106 Pre-and Post-course Assessments.

difference found was among majors on the pre-course survey (p = .0456). Duncan's multiple range tests performed on data from this analysis revealed that the civil engineering students' responses (x = 2.82) were significantly less favorable than were the responses from four other groups:

elect engr (x = 2.52)
mech engr (x = 2.44)
other engr (x = 2.43)
architecture (x = 2.29).

Duncan's tests performed on data from the other analyses of variance revealed that even though overall differences among classes, age groups, and majors were not significant, the following significant differences existed among specific groups: the attitudes of juniors (x = 2.22) were significantly more favorable than were the attitudes of freshmen (x = 2.80) and sophomores (x = 2.49) on the post-course survey, the responses of students aged 26 to 30 (x = 2.38) were significantly more favorable than the responses of students under 20 years of age (x = 2.60) on the pre-course survey, and chemical engineering student responses (x = 1.89) were significantly more favorable than responses from

elect engr (x = 2.38)
mec engr (x = 2.36)
aero engr (x = 2.71)
civil engr (x = 2.42)
other engr (x = 2.50)
other majors (x = 2.67)

on the post-course survey.

CONCLUSION

Positive and significant improvement in student attitudes toward their own drawing abilities and the importance of drawing in their lives and careers were found. These results indicate that the new and unique teaching techniques used in these courses have assisted students in improving their self image and sense of accomplishment in freehand drawing, visualization, and computer-assisted drawing. These results are gratifying, for we have seen from student evaluations and informal comments that most students find the teaching approach stimulating and comfortable. Students are spared the anxiety of attempting to learn an abstract "system" before they are comfortable with visualizing the three-dimensional world.

Therefore, we have concluded that continued use of these techniques, which include drawing based on observation, rapid freehand drawing for ideation, documentation drawing using the microcomputer, and constant encouragement and support of students' efforts, are viable methods for training more effective and capable engineers.

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TRADITIONAL ENGINEERING GRAPHICS VERSUS COMPUTER-AIDED-DRAFTING: A VIEW FROM ACADEME

by

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Introduction

It is the rare person who has not heard of the power of computer-aided-drafting, CAD, to assist the engineer in a primary role of engineering: design. Indeed, many engineers are using CAD packages to assist them in their design work. So well covered in the media is the power of CAD that many persons may have the impression that manually expressed engineering graphics is an antiquated relic lingering within engineering curricula. Perhaps the day has arrived to answer this challenge to traditional engineering graphics.

The present discussion will argue for a legitimate role of manually expressed engineering graphics within engineering education as a needed support base for CAD work. One must first be careful to indicate what is meant by CAD and by engineering graphics within the scope of the discussion. The term CAD is to be limited to computer-aided-drafting in which the computer generates hard-copy output for a design. This is in contrast to computer-aided-design in which the engineer interacts with the computer to develop the interrelationship among various design components and to determine various forces, stresses, and other reactions on such components.

Engineering graphics is defined here as the body of knowledge from which various orthographic views can be placed in the appropriate locations and dimensioned so as to represent with correct standards a particular design. The representation showing top, front and side views may be of a single part or a complex assembly. It is realized that engineering graphics can and does include areas such as graphical solutions to empirical equations, graphical vectors and calculus, and descriptive geometry. However, these areas beyond the layout of orthographic views are not included within this discussion.

"Let the student learn manually the variables involved in drafting."

Engineering graphics may be expressed with manual methods through the person of a drafter or by instructing a computer to generate the needed hardcopy. In each case, the end point is identical: the creation of design on a two-dimensional format, such as paper or film, from which the design may be constructed using the provided spatial and dimensional information.

No one doubts the value of engineering graphics to enable the expression of design, whether done manually or by computer. <u>The overriding question is how to best teach engineering graphics</u> so that the graduates can be most effective as designers. Several methods have been used over the years to teach this subject. It would be well to touch briefly on these methods.

1 The original and longest lasting method to teach engineering graphics is to have students use manual drafting equipment, following instructions from a teacher and textbook. The student does everything from sharpening the pencil to taping down the paper. Triangles and T-square or a drafting machine are used as well as compass dividers. Concepts of graphic expression emerge as the various views of an object are constructed. The student learns the how of projection as well as the why. An appreciation for precision and accuracy also emerges. The endpoint of this total process is at least a drafter and perhaps a junior design engineer. This method is used to some extent in many college programs today, though others have de-emphasized it.

2 A second method of using television to teach engineering graphics saw much interest in the 1960's and 1970's. The method was seen as an excellent way to introduce concepts and techniques via a master teacher. Large numbers of students could be processed in a cost-effective manner. Unfortunately, students (and some professors) were less than enthusiastic about this medium. Professors found that enormous amounts of time were required to perfect TV lectures. Students often saw the results as amateurish and dull compared to commercial T.V. Today the use of TV is seen as a possible supplement to other methods of instruction for engineering graphics, but little active research is being done with TV in this subject area.

3 A third method of instruction is that of coupling engineering graphics with the solution of simple design problems. This method grew to popularity in the late 1960's and carries over into the present time. The method is widely acclaimed as a valuable way to show the use of graphics within a practical problem. Students realize that they need to know the concepts of projection in order to develop their designs. Since much of engineering graphics instruction is typically in the freshman year, the design problems are basic and highly graphic in manner. Problems often involve motion analysis of simple machine components, or they may be static structures such as perhaps a chair for special purposes. The method has been well received, though some persons who teach design in the junior and senior years feel that one cannot rightfully teach design to freshmen who have no background in engineering subjects such as mechanics. Nevertheless, the method remains useful when properly implemented so that design problems are not overly ambitious.

4 The final method of instruction, using computers, will be the focus of the discussion for the remainder of this article. Naturally, this is a recently evolved method. Before 1980, very little was done in the area of teaching engineering graphics via computers. Cost of equipment was high and appropriate software was scarce. Today, advocates of this method are numerous and very vocal as to its advantages. As we continue the discussion, realize that the four methods just highlighted are not mutually exclusive. Many combinations of them can be found. One could say, however, that the manual method competes head-on with the computer method, followed by the use of design, and then TV use as a distant fourth.

What Students Should Learn

One should first have a conviction as to what a student should learn within a subject and before a method of instruction is recommended. In the area of engineering graphics, there are various beliefs as to proper content and thrust.

First let us consider the target population of students. When the term engineering students is used, let us be certain as to whether we have in mind bachelor of science students, bachelor of engineering technology students, or associate-degree engineering technology students. Each of the three groups has its own niche in both education and industry.

At the risk of oversimplification, the bachelor of science students are the most analytically oriented of the three and the least manually skilled. They should describe three-dimensional space as an array of data bits, some experts would argue. One should educate students to be data analysts who see 3-D objects as mathematical models. Skill in manually generating drawings is of low priority, some educators will say. Others will disagree.

Students seeking to become engineering technologists instead of engineers often seek the bachelor degree in engineering technology. This degree is more hands-on oriented than the bachelor of science degree. The "how" is at least as important as the "why". As the graduate works with people, it is expected that an understanding of concepts be coupled with a reasonable degree of skill in expressing design plans. The skills may use either the computers ability to generate drawings or one's own manual talents. Which ability should be primary is subject to debate.

Students in engineering technology who receive an associate degree in a design - related area should be ready to provide almost immediate service to the employer. Ability to generate a drawing is assumed, whether manually or by computer. For this reason, many programs in design-related engineering technology offer more drafting credits than do baccalaureate programs.

The student in any engineering-related program will be expected to be able to express design information. Concepts of engineering graphics must be known by all students. However, associate-degree students in particular must know drafting skills.

Therefore, since all types of engineering programs need some means to express design in engineering graphics, one must ask the questions: *What is the minimum content necessary to express design plans?* A reasonable amount of research has been done on this subject. Typical of this research are the results provided by the Industrial and Professional Advisory Council of the Pennsylvania State University's Engineering College.

Results obtained in 1984 from about 100 respondents representing many industries indicate that students distinctly need ability in:

* multiview projecting

* working drawings

* the design process

* empirical equations and graphical calculus

* graphs

The first three of these areas definitely relate to the expression of design. The last two areas are seen to be needed by bachelor of science candidates, but may receive less emphasis for engineering technician programs. Knowledge of graphics, however, is useful in any area of engineering.

It is of interest to note a 1986 study done at the Pennsylvania State University by Dr. Richard F. Devon. Within a freshman engineering graphics course, 443 students were surveyed as to their experience in mechanical drawing, computer use, and experience in CAD.

High Schools are providing more and more work in computers. About 50% of the students had 50 or more hours on computers and 69% of those students had a quarter or more of the experience in high school. The Basic language is the predominant language with 88% of the students having had at least some experience. In contrast, Fortran had been studied by only 20% of the students and to a much lesser extent, and Pascal by 28% of them.

Interestingly, 60% of the students had no mechanical drawing in high school and 95% had no CAD experience. This information suggests that college preparatory high schools are not strongly committed to the teaching of engineering graphics, neither manually and definitely not via CAD. Therefore, if we want students to learn graphics, we must make a commitment to teaching it at the college level.

To successfully learn multiview projection, a student must develop the ability to visualize 3-D objects. This ability is indeed fundamental. The Educational Testing Service (ETS) of Princeton, New Jersey, has noted a two-decade decline in this ability among high school students. A reduction in course-work in geometry and mechanical drawing has led to lower scores. Thomas Hilton, a senior researcher at ETS, is quoted as saying that ". . . spatial ability is believed to be critical to good performance in engineering and physical science." Therefore, it seems reasonable to state that students in engineering-related programs should somehow learn the ability to visualize objects in 3-D as a very fundamental requirement toward expressing design.

How Should Students Learn?

Accepting the premise that engineering students should develop the ability to visualize objects in 3-D and then to express them as elements of design, one is forced into the crucial questions: Does a student learn engineering graphics better by manual methods or by using a computer? Is this an either-or question?

One must state initially that research is distinctly lacking in the area of how well students learn engineering graphics when contrasting manual and computer methods. Evidence is fragmentary and fragile. However, data suggest that learning is maximized when concepts learned manually are followed up by reinforcement via computer software covering the same concepts. A sample of one study is that done by Retha Groom in the autumn 1983 issue of the *Engineering Design Graphics Journal.*

Some studies suggest that it is the powerful motivational factor of working with computers that helps students learn, compared to manual methods. Indeed, anytime motivation can be increased, learning often increases. However, as computers become more and more commonplace within curricula, the fascination with computers as a novelty begins to fade. A 1985 study by Pulos and Fisher of the University of California's Graduate Group in Science and Math Education is of interest. It reveals that at a suburban school where computers had been in use for sometime, students were less favorable toward computers than at a center-city school where computers were not as available. The authors suggest that computer coursework can be boring if the computer is not used creatively but merely as another form of busywork.

It is appropriate to mention one area of agreement among persons concerned with use of computers within engineering graphics. Engineers within industry believe that students should learn concepts of computer-expressed graphics, not that they be trained to be expert on specific hardware. Also, engineering students need not be versed in the details of high-powered costly 3-D systems. Industry will gladly acclimate the graduate engineer to a corporation-specific computer system, assuming the graduate is sound in basic concepts.

Manual Method

Pro:

* High flexibility exists in terms of portability and formatting of the output drawing.
* Costs are low for minimal drafting equipment.
* Use of equipment is rapidly learned.
* For a single one-time small drawing, speed is better than doing the same drawing on a computer.
* An appreciation of accuracy and precision is offered the student.

Con:

* The method is unrealistic if learning of skills, not concepts, is the sole goal since CAD can deliver more line quality and accuracy than any drafter.
* The method tends to focus on the means (drawing) not the end (design) if instruction is not carefully structured.
* The method may project a negative, old-fashioned image to students if the method doesn't lead to eventual use of computers.

Computer Method

Pro:

* The method can be highly motivational when first introduced.
* A simulation of modern industrial practice is available.
* Costs are going to the right direction - downward.
* Material can be offered in a standardized software format, thereby encouraging uniform quality independent of a particular instructor.
* Pen plotter output is of high accuracy and uniformity.

Con:

* Current software is distinctly poor, incomplete, and scarce for the teaching of engineering graphics.
* Effort to produce good software is time-consuming and expensive.
* CAD instruction tends to be machine specific, leading to cross-over problems when students transfer to other machines in industry.
* Lower cost systems have handicaps to efficient learning, such as monitor screens with insufficient resolution and size and cumbersome command sequences.

TABLE 1

It is appropriate at this point to list (Table 1) current advantages and disadvantages of the manual and computer aided methods in the teaching of engineering graphics.

To summarize these virtues and vices, one could say that the manual method features the strength of flexibility, low cost, and ease of use. Conversely, the manual method can degenerate into an exercise in developing drafting skill alone without sufficient emphasis on concepts.

Computers can be strongly motivational and can offer standardized material within purchased software. Unfortunately quality software to teach engineering graphics is scarce and fragmented into bits and pieces of the total field of knowledge. Typically, computer software replaces manual instrumentation with electronic instrumentation, but it does not provide a means of teaching the conceptual basis of graphics. The effect on the curriculum is to greatly increase the time needed to learn "use of instruments." With only so much time available, putting CAD in the curriculum can easily mean a weakening of the commitment to teaching the conceptual base.

Trends in Engineering Graphics Education

Earlier within this discussion, the questions were asked: Does a student learn engineering graphics better by manual methods or by using a computer? Is this an either-or question? Our discussion suggests that it is indeed not an either-or question.

There is strong support in industry to have students learn the concepts of engineering graphics before applying them on computers. Senior design engineers in the automotive industry have indicated to the author that the best use of sophisticated software is made by engineers with a sound background in engineering graphcs. Persons with a computer science background, on the other hand, have more difficulty adapting to CAD packages because of a lack of engineering fundamentals.

Young engineers without design experience are also at risk when they accept the output of CAD programs at face value. They tend to not challenge the computer output because they may not understand the background by which the computer program arrives at a particular output. Again, this situation can best be resolved by the engineer coming into a task with a solid background in fundamentals.

An understanding of the fundamentals of engineering graphics is as much a part of an engineer's necessary background as is mathematics, for example. It is interesting that engineering students still learn mathematics in a basic format: lecture on theory, examples in class, homework. Even though computers can easily solve particular equations using readily available software, few persons would trust an engineer to use blindly a program to solve equations if the engineer had no background in the concepts of mathematics. As also should one have a background in the concepts of engineering graphics before using software which facilitates graphical output.

Yet trends in engineering graphics education do exist. Several trends have been observed and are offered for consideration.

1. Engineering graphics as used to generate drawings is now more than merely a process to provide documentation., Engineering graphics must now have as an interactive with a computer. This use includes that of analysis and design, beyond simply drafting of designs.

2. The use of engineering graphics by engineers is actually on the increase as they design interactively prior to outputting the final design on paper, if a paper format is needed at all. Some designs are sent directly to the tooling stage without intermediate paper copies.

3. Rote and extensive drafting is slowly being relegated to drafters who provide a valuable service without themselves being graduate engineers. Drafters are increasingly found as graduates of associate degree programs and various certification programs.

4. Educators will find that they need to become more efficient in teaching the concepts of engineering graphics. Greater efficiency will be needed because the use of CAD will slowly increase and therefore will demand a greater portion of available time.

5. A merger is evolving between traditional engineering graphics and CAD within academia. The process is slow, primarily because of scarce software of quality which teaches engineering graphics. However, the direction is toward an eventual integration of the two areas, such that concepts traditionally learned, even if only by freehand sketching, are blended into application via CAD.

Conclusion

The title of this discussion implies a distinctly adversarial relationship between traditional engineering graphics and computer-aided-drafting. The title appears to set person against machine in the quest to best express engineering drafting, and hence design. It is perhaps natural that advocates of manual methods of drafting have a bias against computers, although it is the other bias that gets the most press. Might not the truth lie between the two extremes? A suggestion could be made to accept the best of each method to create a synthesis to maximize learning of engineering graphics.

Proposal

Allow the engineering student to begin learning using the manual method with its high flexibility, low cost, and speed for one-time execution of drawings. As mastery of concepts is achieved, allow the student to apply the concepts on the computer with its great ability to generate high quality output and to provide speed for repetitive tasks. Let the student learn manually the variables involved in drafting. Let the student manipulate the variables using the computer as the incredible tool that it is.

It is fortunate that education should be concerned with teaching fundamentals in that colleges can rarely match at the undergraduate level the expensive computer graphics systems routinely used by major industries. Industry wants educational institutions to concentrate on fundamentals. Therefore, such institutions need to strengthen ties with industry to most effectively couple the theory found in academia with the practice seen in industry.

It will be with genuine interest that those of us in education see the long-term results of striving to educate engineers so they may best do their task: to design effectively and efficiently those products needed to serve humanity. It is a reasonable prediction to state that the human hand and pencil will never become obsolete, and that computers will become ever better in providing assistance in the drafting/design process. The exact nature of the future balance between hand and machine modes remains an exciting unknown.

THREE-DIMENSIONAL INTERACTIVE DESIGN USING BEZIER CURVES AND SURFACES

by

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Introduction

Today's engineers find interactive computer graphics invaluable. Considerable time and expense can be saved by analyzing a possible design on a CAD system before building an actual prototype. For this purpose, computer graphics and CAD systems are used interactively so that a model can be continuously refined until a satisfactory design is obtained. To represent the shape of an object on the computer, one is required to use a geometric modeling technique. In recent years a variety of commercial packages for geometric modeling of real objects with a precise mathematical description have become available. Depending on the modeling technique, some of these software packages require significant computational power particularly for a three-dimensional representation of a model.

This paper offers an attractive method for interactive design of objects on the computer. A method is outlined which allows the designer to interact with the orthogonal views to construct a three-dimensional model of an arbitrary shape. Furthermore, to enhance graphical display, an algorithm was developed which enables the designer to efficiently create arbitrary smooth curves and surfaces. The algorithm is based on the Bezier curves. The derivation of appropriate equations and a description of method of interaction with the views comprise this paper.

Geometric Modeling Using the Orthographic Projections

For a rapid interaction with the views, the screen is divided into four separate sub-screens where the three othrographic projections and the pictorial (isometric or oblique) are to be displayed; see Figure 1. Splitting the screen in this fashion enables the user to easily move about from one view to another. To display the current position, a software cursor is displayed in each subscreen as shown in Figure 2a. The software cursors labeled C_1, C_2, and C_3 are initially located in the center of each view. The user interacts with an individual view by repositioning the current position using the hardware cursor, controlled from the keyboard or a mouse. For example, point $A_F(x_2, y_2)$ in Figure 2a is entered in the front view. As a result, the corresponding positions of the top and right side cursors are changed as depicted in Figure 2b. As shown, positioning the hardware cursor in one view enters only two new coordinates; the third coordinate, z in this case, remains unchanged. The coordinates of these points are written to a data file as entered. The data is used with a new graphics routine developed for displaying the pictorial of an arbitrary shape. The description of the method and sample outputs are presented in the following section.

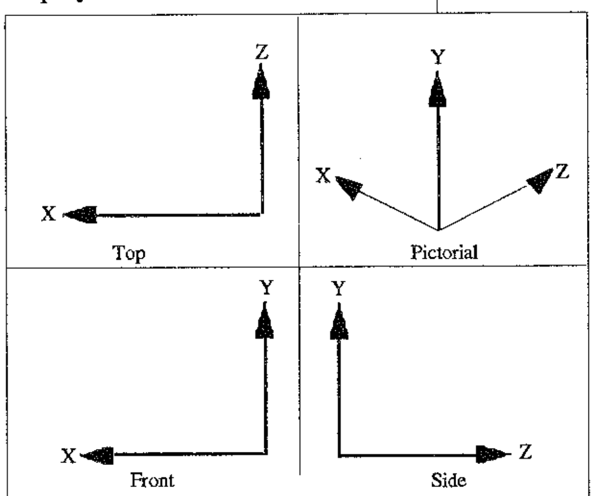

Figure 1. The Coordinate System

Curves and Surface Designs for Arbitrary Shapes

A powerful method for designing arbitrary smooth curves is named after P. Bezier, a French engineer [1]. A Bezier algorithm can be easily implemented on the computer since it can be described in a parametric form. The shape of a Bezier curve is completely defined by a series of points known as the control points. The control points are interactively entered as described previously. Based on the Bernstein polynomials, the Bezier algorithm computes the coordinates of a smooth curve that always goes through the first and last control points while being pulled towards the intermediate points. Hence, a Bezier algorithm defines an approximate shape of a curve based on the given control points. Additional details can be found in references [2,3,4,5,]. The reader

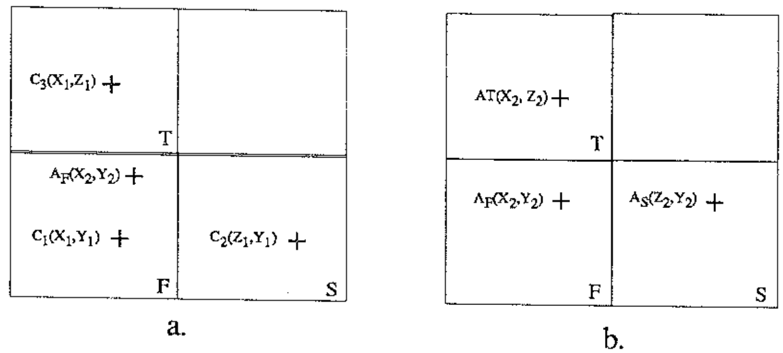

Figure 2. Software Cursor With Four Views

may refer to [2] for application of 2-D Bezier curves and programming methods and to references [3,4,5] for theoretical developments.

For displaying the pictorial, a new method was developed that is based on the three-dimensional Bezier curves. The crux of this method is that the user creates a wire-frame model of an arbitrary surface by producing the boundary curves which describe an approximate shape of the object; the algorithm generates the intermediate (in between) curves. This is illustrated in Figure 3a which depicts the user-defined boundary curves representing an approximate shape of a car body. The Bezier control points $C_1, C_2, \ldots, C_5$ entered for drawing one of the boundary curves are shown in that figure. The completed pictorial of the car body is presented in Figure 3b where the thicker curves are defined by the user, and the thinner ones (for example, the curve passing through points $S_{1,1}, S_{2,1}, \ldots, S_{m-1,1}$, and $S_{m,1}$) are generated automatically by the algorithm. In this fashion, the algorithm creates a wire-frame model for arbitrary smooth surfaces. The details of the algorithm is given below.

Referring to Figure 4, three arbitrary boundary curves labeled I, II, and III are shown. Using these boundary curves, the intermediate curves are drawn by joining several Bezier curves together. In order to have continuity between these curves, additional control points are necessary. To satisfy first-order continuity for intermediate curves, additional control points labeled N_1 and N_2 are placed along vector C. Vector C is the sum of vectors A and B positioned on point E. Vectors A and B are defined as follows:

$$A = E - D$$

$$B = F - E$$

Coordinates of points N_1 are computed from the following equations; see Appendix A for the derivation.

Coordinates of point E:

$$(x_0, y_0, z_0)$$

Coordinates of point G:

$$(x_1, y_1, z_1)$$

Coordinates of point N_1:

$$(x_2, y_2, z_2)$$

$$x_2 = x_0 + a_0 t$$

$$y_2 = y_0 + b_0 t$$

$$z_2 = z_0 + c_0 t$$

$$t = \frac{a_1(x_1 - x_0) + b_1(y_1 - y_0) + c_1(z_1 - z_0)}{a_0 a_1 + b_0 b_1 + c_0 c_1}$$

Where the variables are as defined below:

Vector C: $a_0 i + b_0 j + c_0 k$

Vector A: $a_1 i + b_1 j + c_1 k$

Point N_2 is computed by replacing vector A with vector B and placing point G halfway between E and F. Having computed the coordinates of N_1 and N_2, the computer automatically draws smooth curves which are continuous at connecting points. Appendix A also outlines a general procedure for drawing intermediate curves for cases where there are more than three boundary curves.

A computer program was developed for three-dimensional interactive design using Bezier curves and surfaces. Sample outputs are in Figures 5-9. Figure 5 represents the design of a car body with its three orthographic projections and Figure 6 shows the model of an airplane done by this method. Models can be rotated as shown in Figures 7 and 8 using the DI3000 subroutines available on the VAX computer.

Summary and Conclusion

An efficient method for interactive design in three dimensions is described which differs from the traditional method in that the user can interact with the front, side, and top views to obtain the pictorial. An interactive algorithm for design of arbitrary surfaces was also developed which enhances the wire-frame design of many physical objects such as car bodies, airplanes, etc. The routine is based on the Bezier curves and can be plotted with as little as nine sets of user-defined control points. Additional control points are automatically generated to display a smooth Bezier surface. Such an algorithm is useful for interactive geometric modeling.

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Appendix A
Derivation of the New Control Points

The derivation starts by relating the unknown point N_1 to point G which is halfway between D and E. The vector formed by points N_1 and G must be perpendicular to vector C making the new control point, N_1, evenly spaced along vector C. To satisfy these conditions, the dot product of vectors C and the vector formed by pints N_1 and G must vanish, i.e.

$$a_1 (x-x_1) + b_1(y-y_1) + c_1(z-z_1) = 0 \quad (1)$$

In the above equation x, y, z coordinates of N_1 are the unknown. However, point N_1 must lie along vector C in order for the Bezier curve to be continuous at point E. To satisfy this condition, the following parametric equations are substituted in equation (1).

t=

$$\begin{aligned} x &= x_0 + a_0 t \\ y &= y_0 + b_0 t \\ z &= z_0 + c_0 t \end{aligned} \quad (2)$$

After the substitution, t becomes the only unknown. Solving for t, we get:

$$\frac{a_1(x_1-x_0) + b1(y_1-y_0) + c1(z_1-z_0)}{a_0 a_1 + b_0 b_1 + c_0 c_1}$$

Coordinates of N_1 can now be obtained by substituting t back into the parametric equations (2). The procedure described above pertains to three boundary curves. In general, however, more than three boundary curves are involved. For these cases, when

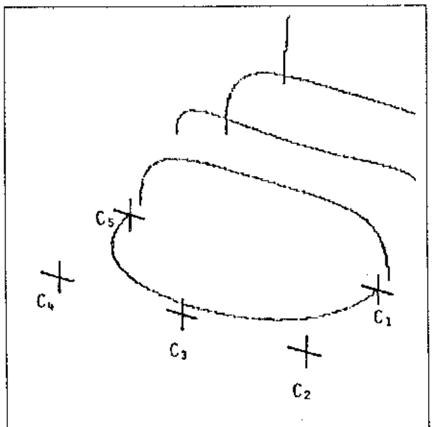

Figure 3a. User-Defined Boundary Curves

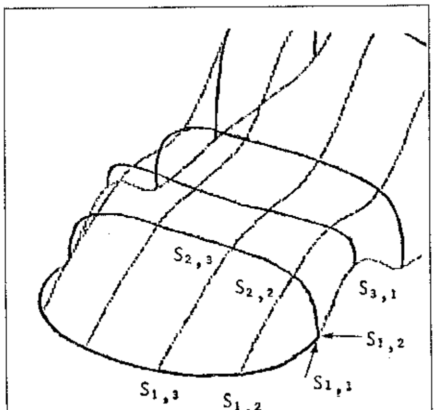

Figure 3b. Completed Wire Frame

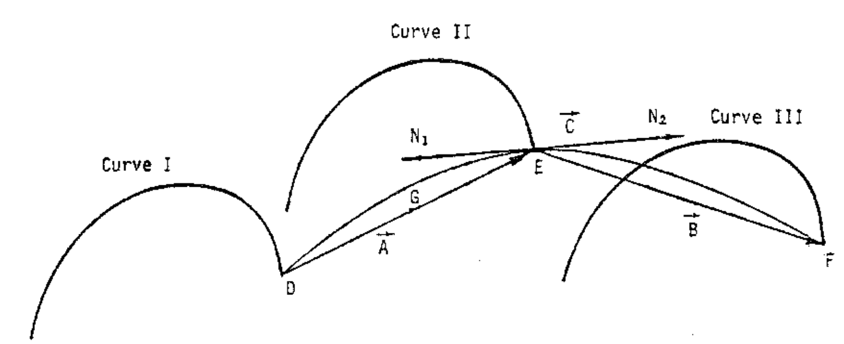

Figure 4. Bezier Surfaces Method

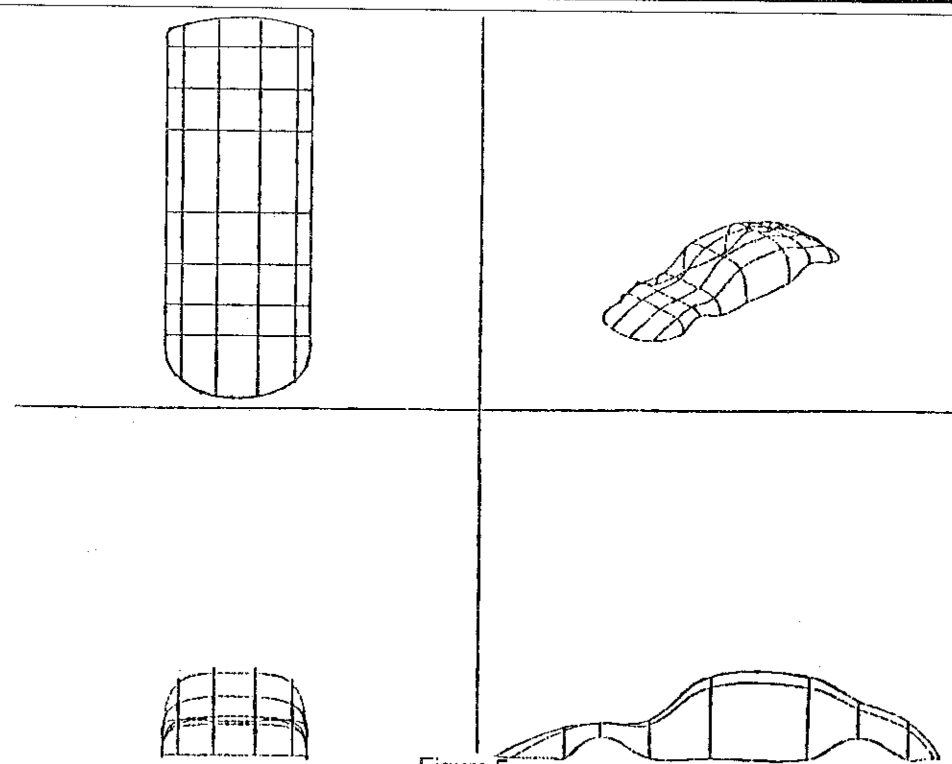

Figure 5

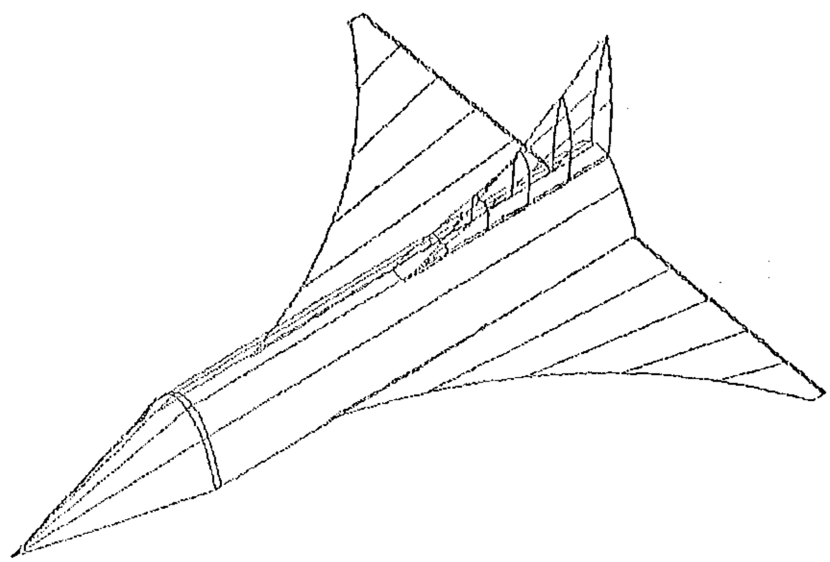

Figure 6

point involving the first or last boundary curve, the procedure is exactly the same as previously described. For the remaining (in between) curves two additional control points N_1 and N_2 are computed along vectors A and B respectively; see Figure 9. For the first additional control point, N_1, point G is placed one-third of the distance between E and F, and for the second control point, N_2, point G is two-thirds distance between E and F. Having computed the coordinates of N_1, and N_2, the Bezier curve will be drawn using points E, N_1, N_2, and F.

Copies of the FORTRAN program which produces these figures is available from:

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2070 Neil Ave
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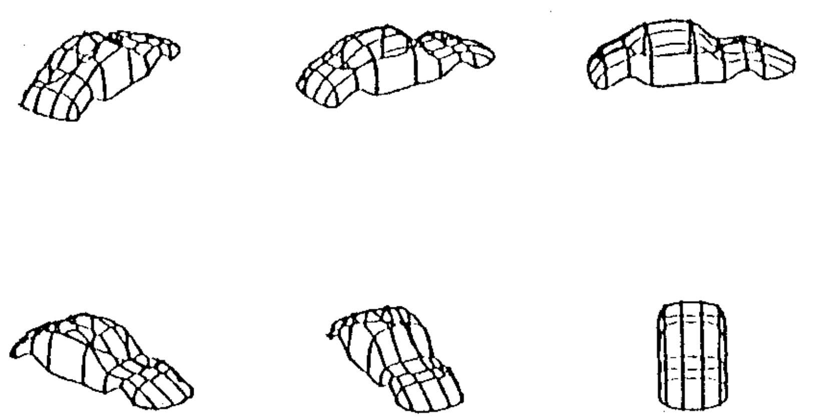

Figure 7

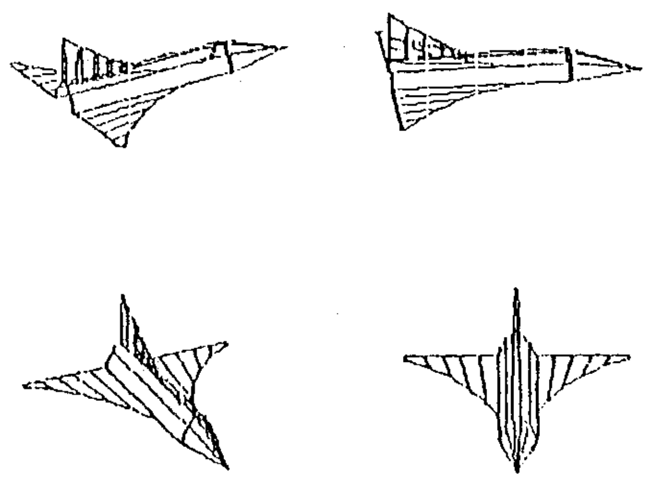

Figure 8

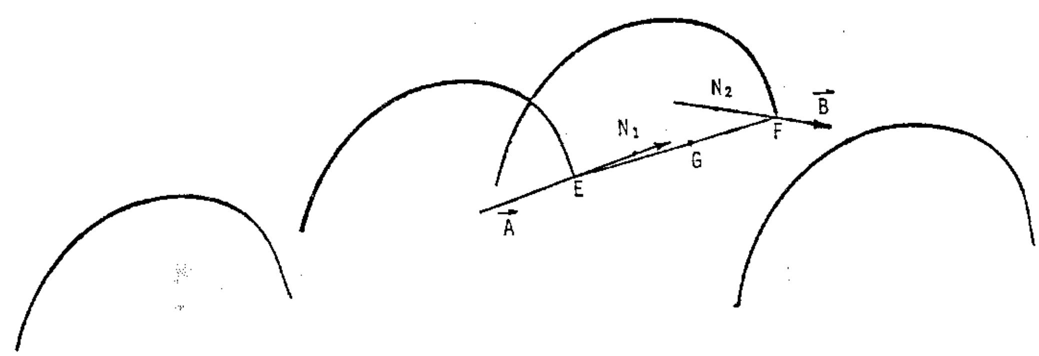

Figure 9

8. All articles shall be written using Metric-SI units. Common measurements will be accepted at the descretion of the editorial staff.

9. Send all material in one mailing to:

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All technical articles are submitted to the EDGJ Board of Review for blind review. This board represents national authority on graphic technology, engineering education, and technical specialties within engineering and technology. Authors will be notified as to the results of the review. Manuscripts may be accepted as submitted, accepted with provisions, or not accepted for publication.

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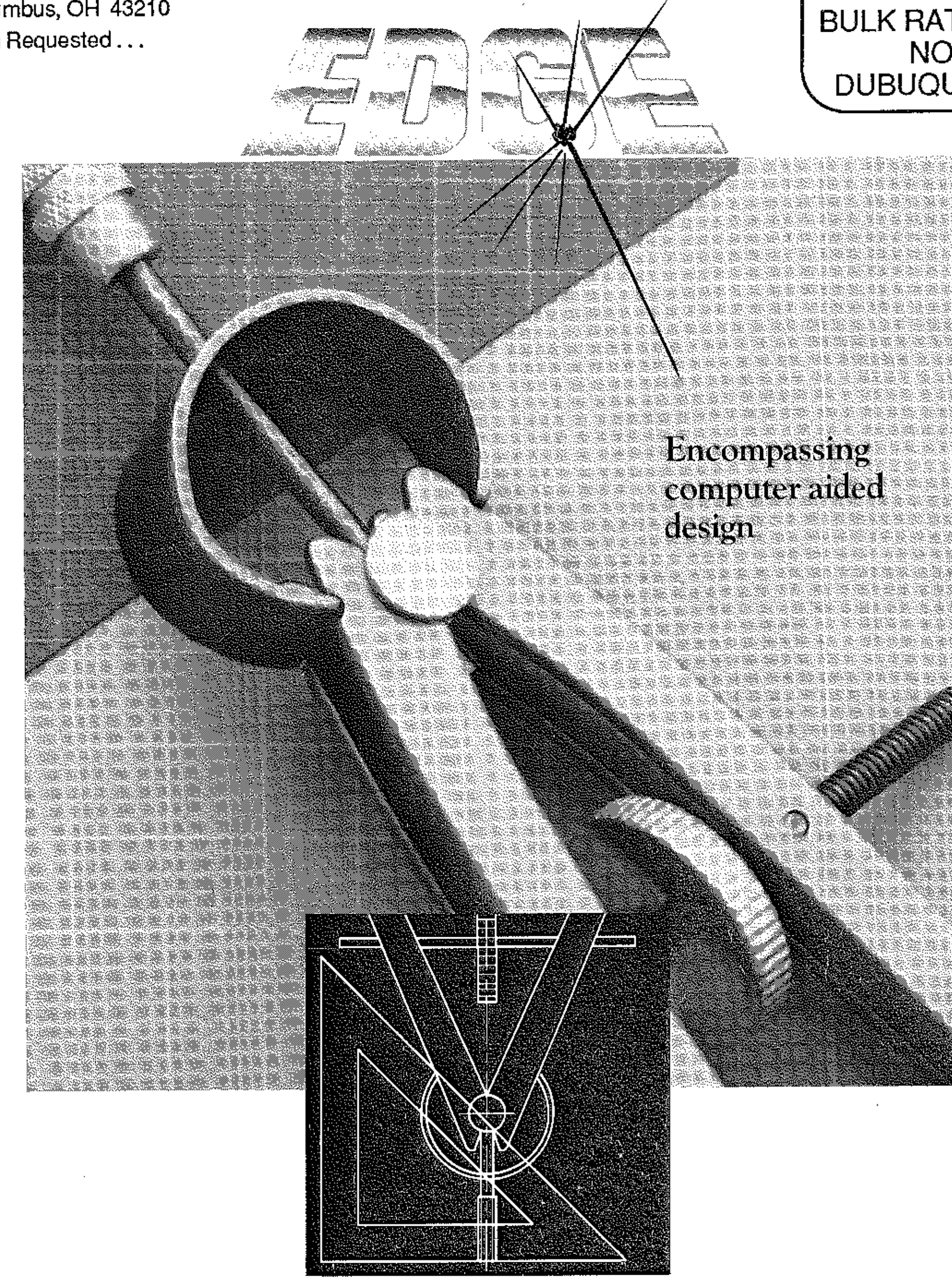

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