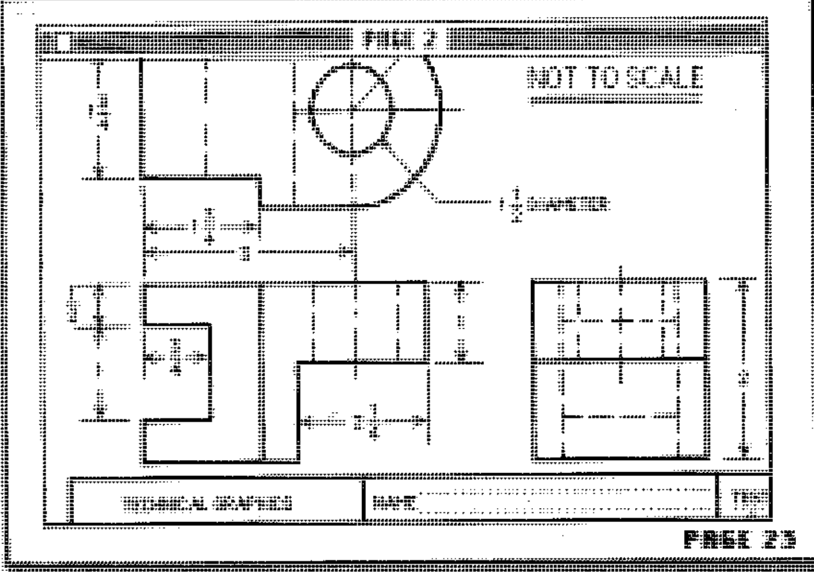

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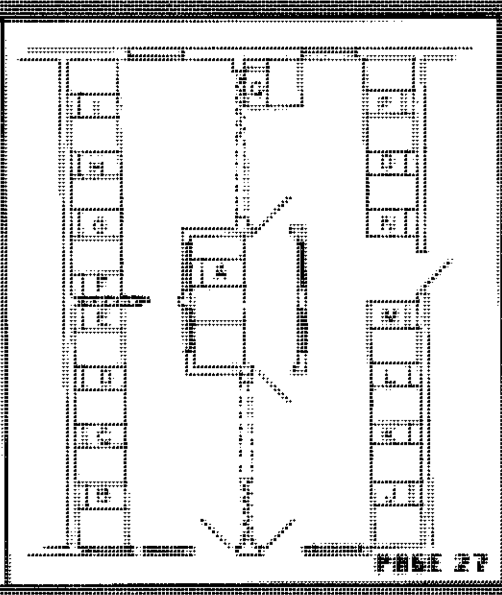

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ENGINEERING DESIGN GRAPHICS JOURNAL

AUTUMN 1994 VOLUME 58 NUMBER 3

The Distinguished Service Award

Amogene DeVaney

Robert, friends of the Engineering Design Graphics Division and guests. It is with pride and much humility that I accept this Division's Distinguished Service Award.

I an proud, because this is the Division's highest honor.

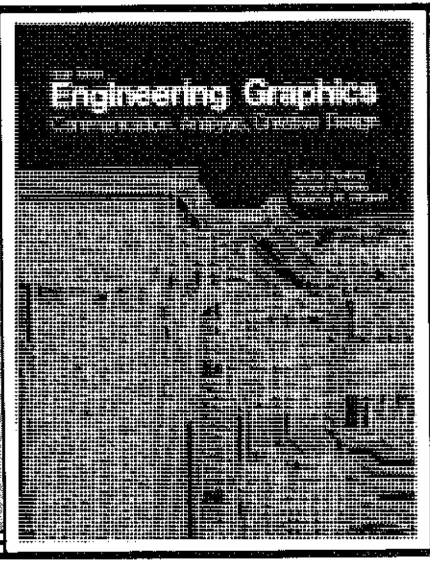
I am humble when I think that my name shall appear among those outstanding individuals who have received this award before me. I have attended many presentations such as this. I have felt excited and proud for the person receiving the award, but I never imagined that I would ever be in this position.

I owe a great debt to the members of the Division who have contributed so much to my professional development. I am especially grateful to Dr. William Street and Dr. Irwin Wladaver: two of the great men of the Division who had a profound influence on the direction of the Division and on its individual members. They were my mentors, my teachers, my prods (we all need those, don't we?) and best of all, my friends.

Many changes have taken place in our Division since I joined in 1948. These changes have been brought about by the changes in Engineering Education, as Engineering Education adapted to the demands of advancing technology. The Division has been able to change, and it has taken a position of leadership. We have communicated these changes to our members through our conference programs, our summer schools, and our Journal. We shall be a vital part of Engineering Education as long as we keep this position of leadership.

I want to express to you my thanks and heartfelt gratitude for this honor. I shall treasure it as the pinnacle of my career. (This has been a transcription of Amogene's acceptance given at the ASEE national meeting in Salt Lake City, Utah.)

EDGJ



ENGINEERING GRAPHICS:

Communication, Analysis, Creative Design, Sixth Edition

by Paul S. DeJong, James S. Rising, and
Maurice W. Almfeldt
Iowa State University

1983/512 pages/paper/$19.95
ISBN 0-8403-2725-0

The newest edition of **ENGINEERING GRAPHICS** is, as always, a motivating, concise, readable, and readily adaptable textbook. Material has been updated wherever necessary, and the many beneficial suggestions of past users have been incorporated.

NEW MATERIAL

Computer Graphics and its associated technologies are discussed in relation to their increasing importance as a drawing and design tool.
Metrication is emphasized even further in this edition. The proper use of the SI system is stressed, and fasteners are treated as the focus of many areas and supplemented where necessary by their common-unit counterparts. Metric dimensions and units are used as the basis for illustration and problem layout.
Standards Changes are included whenever possible, especially in the area of dimensioning.
New Illustrations and Problems are introduced to help students learn the material.

CONTENTS

Tools of Communication/ Orthographic Projection and Space Geometry/ Presentation of Data/ Description of Parts and Devices/ Pictorial Drawing/ Design Synthesis and Graphical Applications/ Advanced Graphical Topics/ Reference and Data/ Appendix/ Bibliography/ Index

ENGINEERING GRAPHICS will help your students develop the professional literacy every engineer needs in making clear sketches and using and interpreting drawings. Order your complimentary copy for adoption consideration and you will agree. Just complete the attached coupon and mail it today.

Yes, please send me a complimentary copy of **ENGINEERING GRAPHICS: Communication, Analysis, Creative Design, Sixth Edition,** by Paul S. DeJong et al. 2043

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CALENDAR

ASEE ANNUAL CONFEENCES

1984 - Salt Lake City, Utah

1985 - Atlanta, Georgia

EDGD MID-YEAR MEETINGS

1985 - Kansas City, Missouri

1986 - West Lafayette, Indiana

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 industrial practitioners of Engineering Graphics, Computer Graphics, Design Graphics, and Creative Design.

YEARLY SUBSCRIPTION RATES:

U.S., Mexico, Canada	
ASEE-EDG members	$ 1.50
ASEE but not EDG members	$ 3.00
Non-members	$ 5.00
Foreign subscribers	$10.00

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BACK ISSUES are available at single copy rates (prepaid) and limited in general to numbers published within the past six years.

Subscription expiration date (last issue) is printed in upper right corner of mailing label, W83 for Winter 1983, S83 for Spring 1983, etc.

ENGINEERING DESIGN GRAPHICS JOURNAL OBJECTIVES:

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 fundamentals of engineering.
2. to stimulate the preparation of articles and papers on topics of interest to its membership.
3. to encourage teachers of Graphics to innovate on, experiment with, and test appropriate techniques and topics to further improve the quality of and modernize instruction and courses.
4. To encourage research, development, and refinement of theory and application of engineering graphics for understanding and practices.

DEADLINES FOR AUTHORS AND ADVERTISERS

The following deadlines for submission of article, announcements, or advertising for the three issues of the JOURNAL are:

Fall	September 15
Winter	December 1
Spring	February 15

STYLE GUIDE FOR JOURNAL AUTHORS:

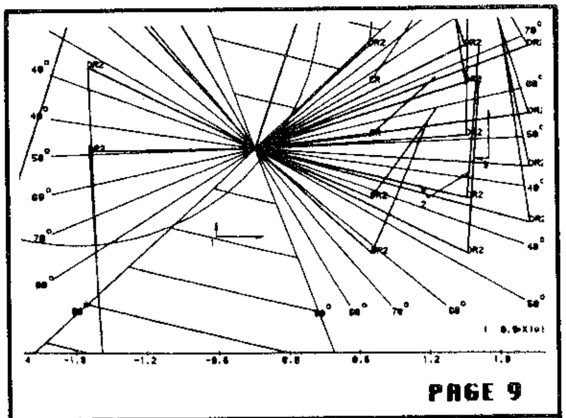
The Editor welcomes articles submitted for publication in the JOURNAL. The following is an author style guide for the benefit of anyone wishing to contribute material to the ENGINEERING DESIGN GRAPHICS JOURNAL. In order to save time, expedite the mechanics of publication, and avoid confusion, please adhere to these guidelines.

1. All copy is to be typed, double spaced, on one side only, on white paper, using a black ribbon.
2. All pages of the manuscript are to be consecutively numbered.
3. Two copies of each manuscript are required.
4. Refer to all graphics, diagrams, photographs, or illustrations in your text as Figure 1, Figure 2, etc. Be sure to identify all material accordingly, either on the front or back of each. Illustrations cannot be redrawn; they are reproduced directly from submitted material and will be reduced to fit the columnar page. Accordingly, be sure all lines are sharply drawn, all notations are legible, reproduction black is used throughout, and that everything is clean and unfolded. Do not submit illustrations larger than 198 x 280 mm. If necessary make 198 x 280 mm or smaller photocopies for submission.
5. Submit a recent photograph (head to chest) showing your natural pose. Make sure your name and address is on the reverse side. Photographs, along with other submitted material, cannot be returned unless postage is prepaid.
6. Please make all changes in your manuscript prior to submitting it. Check carefully spelling, structure, and clarify to avoid ambiguity and maximize continuity of thought. Proofreading will be done by the editorial staff. Galley proofs cannot be submitted to authors for review.
7. Enclosed all material unfolded in a large size envelope. Use heavy cardboard to prevent bending.
8. All articles shall be written using Metric-SI units. Common measurements are permissible only at the discretion of the editorial staff.
9. Send all material, in one mailing to: Jon M. Duff, Editor, Department of Engineering Graphics, The Ohio State University, 2070 Neil Avenue, Columbus, Ohio 43210.

REVIEW OF ARTICLES

All articles submitted will be reviewed by several authorities in the field associated with the content of each paper before acceptance. Current newsworthy items will not be reviewed in this manner, but will be acepted at the discretion of the editors.

AMERICAN ASSOCIATION FOR ENGINEERING EDUCATION
ENGINEERING DESIGN GRAPHICS JOURNAL
AUTUMN 1984 VOLUME 48 NUMBER 3



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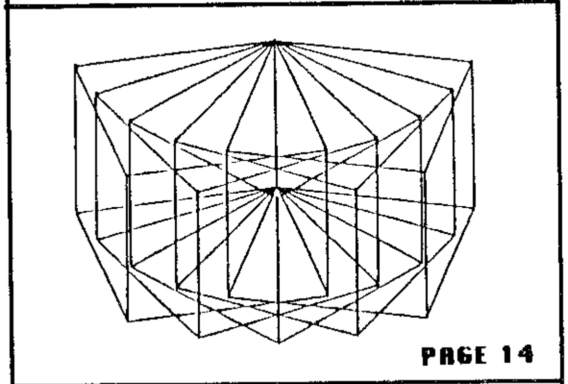

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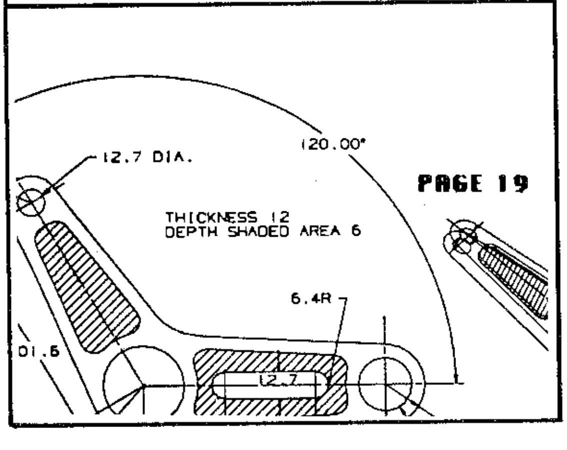

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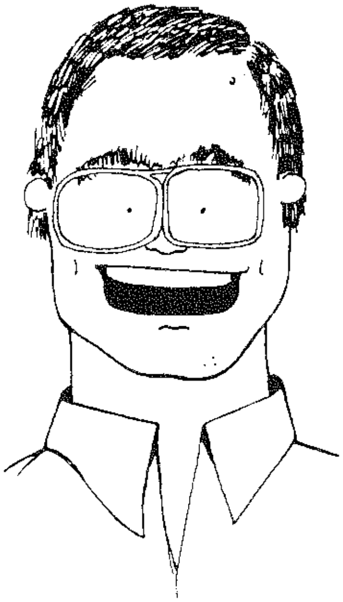
DEPARTMENTS

FEATURES

EDITOR'S PAGE



GOOD NEWS! Larry Goss from Indiana State University/Evansville just called to relate some of his experiences at the International Conference on Descriptive Geometry recently held in the People's Republic of China. Sounded like a very positive experience. There was some disturbing news, however. Seems that some individuals felt that the conference needed an "international journal" in which to publish the technical papers presented there. Thanks to Larry, the interests of EDGD and ASEE were well represented, noting to those in attendance that there already exists an international journal of graphics--this one. It would have been unfortunate had the conference not decided that the EDGJ could well represent graphics world-wide.

The bottom line is that the EDGJ will have access to the papers from the international conferences on descriptive geometry and will publish them as they interest our readership. Winter issue should see the first of these papers so watch for it.

I'm sure that Larry and the others who went to China will have much to say about the conference when we see them in Kansas City.

The software exchange that was started last issue is continued in this issue with a piece on what we are doing here at Purdue with the Macintosh. I've had one on my desk for a couple of months now and I'm favorably impressed. It is the first computer (this sounds like a replay from an Apple commercial) that actually does graphics like people do graphics, not like programmers do graphics. I would venture to say that were each graphics teacher to have one on their desk, productivity would probably triple. I documented making up a test on the Mac to demonstrate to you, the readership, the type of software applications that might be of interest. If you are doing something with computers to help you in your job of teaching graphics, share this with the readers of the EDGJ.

There has been some movement in personnel within graphics programs this year, yours truly included. Several other publications keep their readership aware of this through a "**People & Places**" column. I invite you to notify the editor of changes in personnel, programs, etc. for inclusion in such a column. Just drop me a note and I'll include it.

The 1985 ASEE national will be at Georgia Tech next year with Vera Anand of Clemson University acting as program chairman. I'll be serving as program chairman for the 1985 Mid-Year conference to be held here at Purdue. I'll send out a call for papers but start thinking about attending.....and giving a paper.... now.

●EDGJ

ERRATA

In Don Bunk's piece on " Oblique methods" in the Spring issue of **EDGJ**, several equations were left out. Several of our readers brought this to the attention of the editorial staff and we recieved the correct additions from Joe Weglarz at IBM. They are reproduced here in open space so you might copy the equations and add them to the spring issue text.

The equations relating oblique length and receding angle as a function of the lines of sight should read as follows:

a) $L_0 = \frac{L}{\tan\alpha}[1 + (\tan\alpha \ \tan\beta)^2]^{\frac{1}{2}}$

b) $\theta = \tan^{-1}[\tan\alpha \ \tan\beta]$

c) $\beta = \tan^{-1}\left\{\left[\frac{(\frac{L_0}{L}\tan\theta)^2}{(1+\tan^2\theta)}\right]^{\frac{1}{2}}\right\}$

d) $\alpha = \tan^{-1}\left[\frac{\tan\theta}{\tan\beta}\right]$

Where:

α = plan approach angle

β = profile approach angle

θ = receding angle

L_0 = oblique length

L = true length

IN REVIEW

Geometric Tolerancing, by Richard S. Marrelli. Glencoe Publishing, 1984. 129 pp with workbook.

If you want to teach ANSI Y14.5M-1982 this is **the** teaching aid. Well laid out, with step-by-step student exercises, it covers all aspects of the subject. The organization would also be fine for use as a reference rather than as a text.

Principles of Automated Drafting, by Daniel L. Ryan. Marcel Dekker, 1984. 315 pp.

A strange book that does not cover automated drafting as a general non-equipment specific topic, nor could it be used for training on a particular system. Not developmental, not for introductory students.

Computer Graphics-a Programming Approach, by Steven Harrington. McGraw Hill, 1983. 434 pp with psudo-code routines.

A good book for someone who already knows how to make machines that can't draw to draw. A book for graphics programmers, not for graphics makers.

Graphic Science and Design, Fourth Edition, by French, Vierck, and Foster. McGraw-Hill, 1984. 684 pp.

The latest edition of a standard text. A must just for the man-years of examples. Includes a chapter on BASIC language graphics programming.

Introduction to FORTRAN IV, by Hammond and Rogers. McGraw-Hill, 1983. 325 pp.

A non-graphics book for those who can't avoid programming. Still card oriented, not as good as the Moore and Makela book from Reston Publishers

CAD-CAM Systems, by Charles Knox. Marcel Dekker, 1983. 309 pp.

Not a student textbook, it may be used as a teacher's reference for the uninitiated. Gives possibly the best over all picture of CAE yet in print.

The Visual Display of Quantitative Information, by Edward R. Tufte. Graphics Press, 1983. 190 pp.

A handsome book done from the heart rather than from the bottom line of a profit sheet. Too expensive to be used as a text, it is a must for anyone teaching data presentation

MID-YEAR MEETING

"Engineering Graphics for the Future"

hosted by
The University of Missouri Engineering Programs in Kansas City
at the
Kansas City Hilton Plaza Inn

Sunday, November 25

1:00 pm Hotel Check-in
4:00 p.m.-6:00 pm Registration in Hilton Plaza Inn Lobby
6:00 pm Executive Committee Dinner and Meeting
Board Room A
Moderator-Garland Hilliard
8:00 pm Hospitality Hour
Consulate Rooms 3 and 4
All registrants and Spouses invited

Monday, November 26

8:00 am Registration in Regency East Foyer
8:30 am Introduction and Welcome to Kansas City
Regency East Room
MORNING PAPER SESSIONS
Regency East Room
Moderator—Prof. Edward Galbraith
California Polytechnic,
Pomona
9:00 am Prof. Len Nasman
Ohio State University
"Laser Discs and Microcomputers State-of-the-Art-Instructional Technology for Engineering Graphics."
9:25 am Prof. Wallace J. Franklin
The U.S. Merchant Marine Academy
"Freshmen Engineering Graphics at the U.S. Merchant Marine Academy with Emphasis on the Design Process."
9:50 am Prof. Peter W. Miller
Purdue University
"Creating Effective Visuals."
10:15 am Coffee/Refreshments Break
10:45 am Gary Bertoline
Wright State University
"Teaching the Basics of CAD"
11:10 am Prof. David E. Roth & Prof. John Grode
The Behrend College of the Pennsylvania State University
"Improving Instruction of Engineering Graphics While Utilizing Microprocessors"
11:35 am Prof. Emeritus Richard S. Marrelli
Los Angeles Pierce College
"Geometric Tolerancing in Design Graphics Education—For the Present and Future"
12:00 noon Business Luncheon
Embassy Room
Moderator—Garland Hilliard
AFTERNOON PAPER SESSIONS
Regency East Room
Moderator—Prof. Jerry V. Smith,
Purdue University
2:00 pm Dr. Mihir K. Das
California State University, Long Beach
"Lessons From the Transitional Change to Computer Graphics"
2:25 pm Prof. Mary A. Sadowski
Purdue University
"Research With a Futures Thrust"
2:50 pm Prof. George W. Eggeman & J. J. Held
Kansas State University
"Visualization and Matrices"
3:15 pm Coffee/Refreshments Break

3:45 pm Prof. John M. Duff & Prof. Judy A. Watson
Purdue University
"Training in Computer Graphics on Commercial Systems—Opportunities for Academic Programs"

4:10 pm Prof. Robert P. Kelso
Louisiana Tech University
"Nonorthodirectional Orthographic Projection"

4:35 pm Prof. Richard Latimer & Prof. James T. Weiss
The University of Alabama
"Graphics and CAD Hardware and Software"

5:00 pm Adjournment for the day
Kansas City Restaurant Guide Provided

Tuesday, November 27

8:30 am-12:00 noon Computer Graphics Seminar
Regency East Room
Sponsored by Document Service Center
A Subsidiary of AMGRAF, Inc.
Free to all registrants and spouses.

12:15 pm-5:00 pm Luncheon and Tour of Independence, Mo.
Bus leaves in front of hotel
Ticket required

6:00 pm Cocktail Hour (Cash Bar)
Regency East Room

7:00 pm Annual Mid-Year Conference Banquet
Regency East Room
Ticket required

Wednesday, November 28

MORNING PAPER SESSIONS
Regency East Room
Moderator—Betty Butler
University of Missouri
at Kansas City

9:00 am Prof. Roland D. Jenison, Iowa State University & M. Gawad Nagati, Wichita State University
"Computer Modelling of Geometry in Engineering Graphics"

9:25 am Prof. Josann W. Duane & Prof. Mike Khonsari
The Ohio State University
"Graphics for Finite Element Analysis"

9:50 am Prof. Brue A. Harding
Purdue University
"MicroCAD; a Reality Now?"

10:15 am Coffee/Refreshments Break

10:45 am Prof. Ronald E. Barr
The University of Texas at Austin
"Computer Graphics Models of the Human Body for Engineering Analysis and Design"

11:10 am Dr. Robert K. Krzywiec
Westminster, Md.
"Multi. . .Multi—Graphs of Multi. . .Multi—Indices"

11:35 am Prof. R. L. Pendleton & Hu-Cheng Li
South Dakota School of Mines and Technology
"What in the World is CAD/CAM"

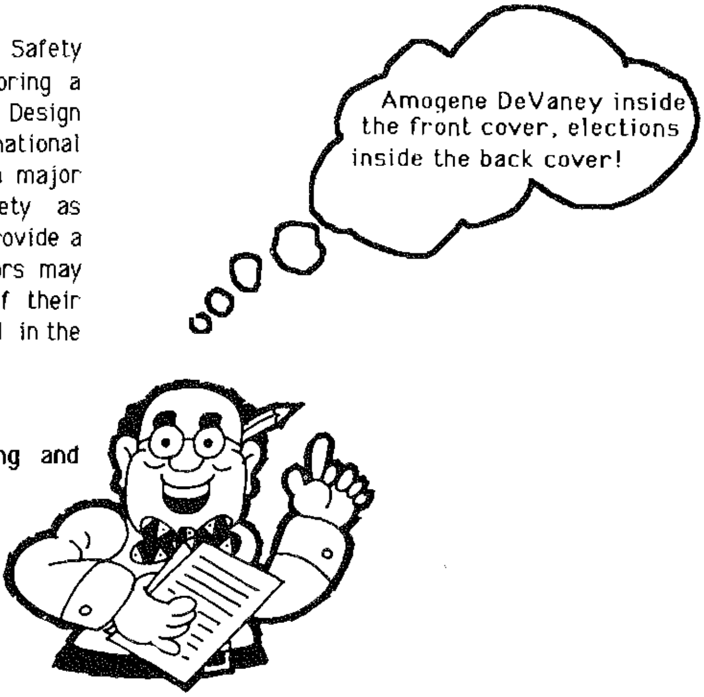
12:00 noon Conference Adjournment and Departure

NATIONAL MEETING

CREATIVE DESIGN DISPLAY SPECIAL CATEGORY

The National Institute for Occupational Safety and Health (NIOSH) and EDGD are cosponsoring a special category if the Creative Engineering Design Competition and Display at the ASEE 1985 national meeting. This special category focuses on major engineering problems in health and safety as identified by NIOSH. This competition will provide a national arena in which engineering educators may share teaching techniques and the fruits of their student's design efforts. If you are interested in the full details contact:

Professor Gerald Voland
Department of Industrial Engineering and
Information Systems
330 Snell Hall
Northeastern University
360 Huntington Avenue
Boston, MA 02115



Chairman's Message

Garland K. Hilliard
North Carolina State University

For most of us, if we are educators, an exciting new academic year is already underway. Collectively, as members of the Engineering Design Graphics Division, we are headed into the 57th year in our quest for continued excellence in engineering education. As the oldest and one of the largest divisions of ASEE, we can be proud of our many and varied accomplishments. Needless to say, I am extremely honored to have been chosen to serve as Chairman of our organization this year. I promise no radical new ideas, but am committed first to assuring that what we are already doing is the very best for the Division and individual members.

The Division is grateful for our past leaders. Surely, without them, we would not have grown and prospered for over one-half century. I am particularly grateful for our more recent past officers. I can assure you that their continued active contribution and support reflects in the Division's growth and prominence.

Printed elsewhere in this issue of the Journal is the Organization Chart 1984-85. We congratulate and welcome the following persons whom you recently elected:

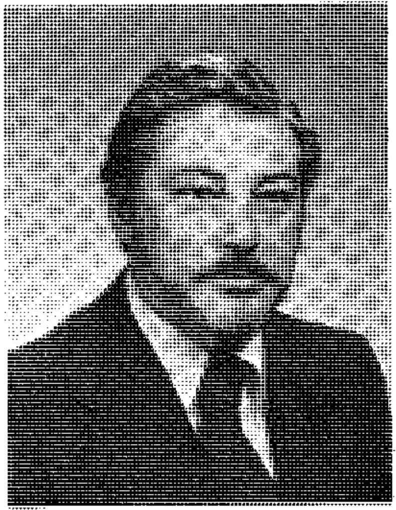
Robert J. Foster - Vice-Chairman
Robert L. Lang - Director, Technical and Professional Committees
Retha E. Groom - Director, Zones Activities
Frank M. Croft - Advertising Manager - Journal

A major reason the organization chart is published in the Journal is to inform you of the many varied activities in which the Division is engaged, as well as the persons responsible for administering.

A Divison this large, however, cannot serve its members effectively with the input of a relative few. Although there are more persons serving on various committees than the chart indicates, most committees would welcome your questions, concerns, suggestions, insight, and most of all, your active support and participation. If you are interested in a committee and would like to become more involved in the innerworkings of the Division, feel free to call or write the person in charge.

In June, 1978, we celebrated our 50th Anniversary in Vancouver, British Columbia. An historical highlight of that occasion was the first International Conference on Descriptive Geometry which featured participants and papers from all over the world.

By the time you read this issue, another International Conference on Engineering and Computer Graphics will have been held in Beijing, China. Steve Slaby, last year's recipient of the Distinguished Service Award, deserves another award for his diligence and hard work on the Division's behalf in co-sponsoring the conference with the China Engineering Graphics Society.



Another historical first that has grown, prospered, and benefitted thousands is the Journal you are reading now. With rudimentary beginnings as the T-Square Page in 1930, the Journal is now widely circulated in the U. S. and abroad - in schools, libraries and industry. To my knowledge, it is the only forum and mouthpiece that reflects the scholarly, theoretical, and practical aspects of our discipline as well as current news of interest.

True, the Journal has recently experienced a few problems - especially as it affects us, the readers - in meeting publication deadlines. However, these problems like past adversities faced by the Division are succumbing to the dedicated efforts of the Publications Committee. Jon Duff and his staff deserve our thanks as they quietly contribute the necessary hours during their academic year to assure that the Journal maintains, if not excels, its past history of excellence. Kendall-Hunt, our publisher, also deserves the thanks it has earned through their kindness and cooperation over the years. Without them we would not be able to deliver the Journal at its present quality and cost.

Our warmest praise and congratulations go to Amogene F. DeVaney, this year's recipient of the Distinguished Service Award - the Division's highest award. She joins the list of the honored few who have received the award since 1950.

The 1984-85 Mid-Year Conference will be November 25-28 and hosted by the University of Missouri at Kansas City. Reports from Ron Barr, Betty Butler and Jerry Smith, our program chairpeople, indicate that this will be a meeting you will want to attend. In addition to the planned program, the Mid-Year Conference offers an excellent opportunity for us to interact more closely on common interests, issues and concerns. I hope to see you there!

As we begin a new year, we can look back with pride at the Division's long list of accomplishments, only a few of which I have mentioned. We have stood in the forefront not only in engineering drawing, but also design, computer graphics, freshman programs and engineering and technical education in general. Yes, I am proud to be a division member and look forward to serving as your chairman in the coming year.

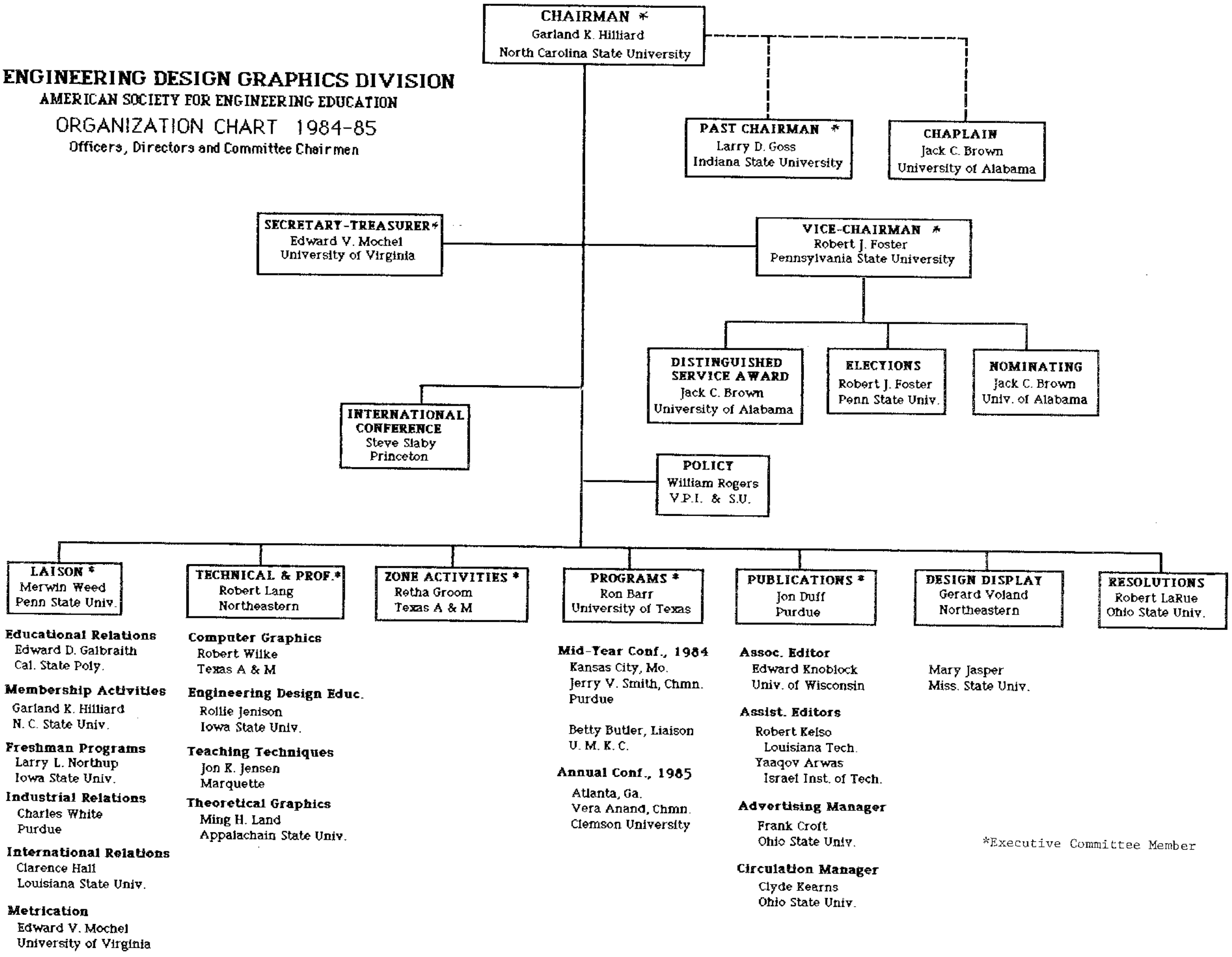
Garland

ENGINEERING DESIGN GRAPHICS DIVISION

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

ORGANIZATION CHART 1984-85

Officers, Directors and Committee Chairmen



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Betty Butler, Liaison
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Annual Conf., 1985
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FEATURES

MECHANICAL DESIGN

RECSYN II: A POWERFUL APPLICATION OF INTERACTIVE GRAPHICS IN MECHANICAL ENGINEERING

Kenneth J. Waldron
Jeffrey A. Ficke
Shin Min Song
Department of Mechanical Engineering
The Ohio State University

Introduction

It is no accident that interactive computer graphics has impacted mechanical engineering perhaps more than any other field. Mechanical engineers deal with objects which function, or fail to function, largely because of their geometry. The need for manipulation and transmission of geometric information made the drafting table an essential tool of the mechanical engineer and made the design draftsman an aide as essential as a secretary to a manager. The introduction of interactive computer graphic hardware and software has, of course, replaced the drafting table with a computer terminal in many instances.

Traditionally, however, the mechanical engineer's use of graphic methods went far beyond machine drawing. It also went far beyond the use of descriptive geometry for manipulation of spatial objects which can now be partly replaced by three dimensional computer graphic systems. In mechanism kinematics, the use of geometry as a mathematical tool was raised to a very high level of sophistication. This use of geometry was not solely due to the geometric nature of the systems dealt with. In many instances graphical, or geometric methods are far more efficient than algebraic methods. The problem of determining the link directions of a mechanism can be solved in seconds graphically by simply drawing the mechanism to scale, but this requires several pages of complicated algebraic and trigonometric manipulation for manual analytic solution. The extent of the elaboration and sophistication of graphical methods in this area can only be appreciated by studying classical texts such as Beyer [1].

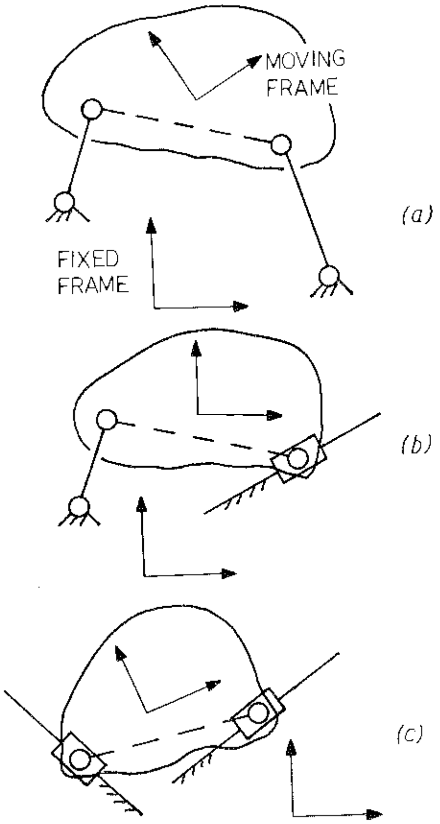
Linkage kinematics is then a natural area for interactive computer graphics. In the 1960's there was a decline in the use of graphical techniques and increasing interest in algebraic formulations. This was a result of the introduction of large, batch processing computers. More recently, interactive computer graphic systems have fostered a return to the exploitation of graphic techniques. In the area of linkage synthesis, packages such as KINSYN [2,3,4], LINCAGES [5,6] and MECSYN [7] have appeared which, in varying degree, take advantage of the capabilities of geometric information transmission and rapid interaction offered by modern systems.

RECSYN II is a relatively recent addition to this list. It does not yet have all of the capabilities of some of the packages listed above. RECSYN was developed in 1979, making it possible to take advantage of some important recent developments in the theory of graphical linkage synthesis [8,9]. These developments have made possible the use of a more direct solution sequence and more efficient utilization of the optimization possibilities of rapid interaction. As compared to the earlier programs, a relatively large amount of information is conveyed to the user in graphical form via plots of loci, hatched areas etc. Control of the program is predominantly by cursor selection from displayed menus. Since there is no objective information available as to the efficiency of conveying this type of information graphically as compared to alternative mixes of alphanumeric and graphical presentation, it is not possible to justify this format on those grounds. Acceptance by user appears good after a short learning period.

Linkage Synthesis

The problem at which the RECSYN program is directed is that of synthesizing mechanical linkages to generate nominated irregular motions of a machine member. This is a common problem in machine design. The primary mechanical linkage type synthesized by the program is called a four-bar linkage (Figure 1a). This is a simple mechanism but one capable of generating a great variety of irregular motions. The program is also capable of synthesizing two additional linkage types: slider-cranks (Figure 1b) and elliptic trammels (Figure 1c). The wide variety of possible coupler (floating link) motions is obtained by varying the link lengths and the positions, relative to the linkage, of the fixed and moving reference frames.

descriptive geometry manipulation of spatial objects can now be partly replaced by 3-D computer graphics

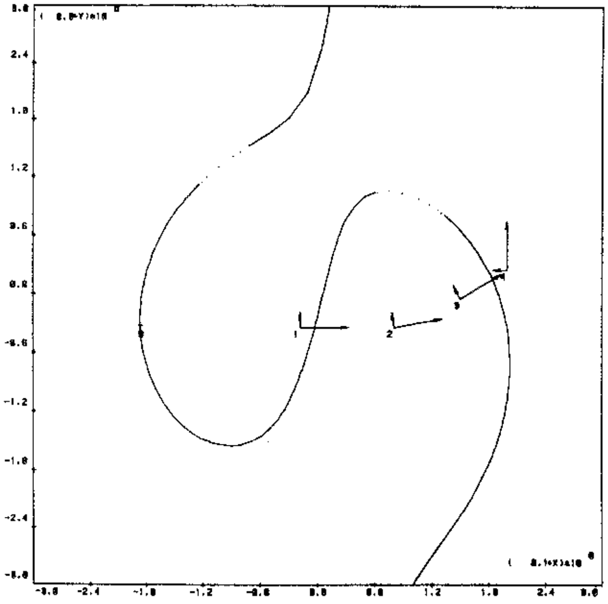


Since it is not, in general, possible to proportion the linkage to exactly follow a specified coupler trajectory, a number of positions on that trajectory are designated as "design positions". This program, in common with those of references [2-7] is constructed to generate solution linkages which exactly pass through the design positions. The program can synthesize linkages to satisfy 2, 3, 4 or 5 design position specifications. Although these may seem to be too few design positions to force accurate approximation of an irregular plane trajectory, practical machine design problems seldom require exact generation of a trajectory. It is common for accuracy in a few key body positions to be much more important than the remainder of the trajectory. This approach has, therefore, proved to be one of considerable practical utility.

The tighter the specification, that is: the larger the number of design positions, the smaller the dimension of the solution space. Not more than six solution linkages can exist for a five position specification. Conversely, for few design positions the dimension of the solution space is large (6 for 2 positions, 4 for 3 positions, 2 for 4 positions). This is advantageous from the point of view of the machine designer since it allows optimization of the design according to criteria which may be applicable but which are not controlled by the program. Accordingly, while interaction with the user is helpful even for five position solution, it becomes essential for fewer design positions.

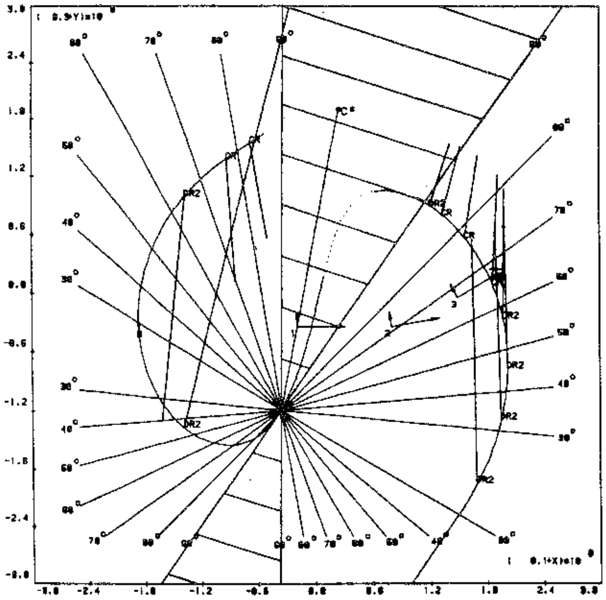
Operation of the Program

With the exception of the five position case, in which the few solutions which exist (6, 1 or 0) for a given set of design positions are all generated, the solution is a two stage process. The two stages select the two cranks of the linkage. (The cranks are the members which are pivoted to the base at one end and to the coupler at the other.) It is assumed that the linkage will be driven by rotating one of these cranks. Selection of this driving crank is always the second stage of the process. Selection of the other, the passive crank, is the first stage.



The selection procedure is best illustrated by following the sequence for solution of a four position problem. After entry of the design positions the display of Figure 2 is generated. The design positions are shown by the L shaped symbols which represent a reference frame attached to the moving body. The curve displayed is called a circle-point curve. It is the locus, drawn on the moving plane in its first position, of all points which may be chosen as the moving pivots of cranks of the solution linkage. In the language of algebraic geometry it is a circular cubic curve. The user selects the passive crank by choosing its moving pivot on this curve using the graphic cursor. This selection is assisted by several features of ghe program. For a quick overview of the available selections, an animated display of the cranks corresponding to successive points on the curve is available. The user may also make a trial selection, in which case an evanescent display of the crank corresponding to the selected point is generated. The point B marked on the curve is the slider point: the point whose four positions are colinear. As the slider point is approached moving along the curve the cranks become longer. Thus, this point is not only useful for designing slider-cranks but is a useful guide to crank length. It may be seen that portions of the curve are dotted rather than plotted as a solid line. These portions of the curve must be avoided since they give spurious solutions. An evanescent display of the double wedge shaped hatched area of Figure 3 can also be viewed for a trial selection. This is to avoid choices which will not give a good selection range in the second stage of the process because the hatched area is too large. These last two features are part of a package which eliminates spurious solutions. This package is unique to this program. Other linkage synthesis programs test for spurious solutions after the selection process is complete, thereby requiring more trials for the identification of good solutions.

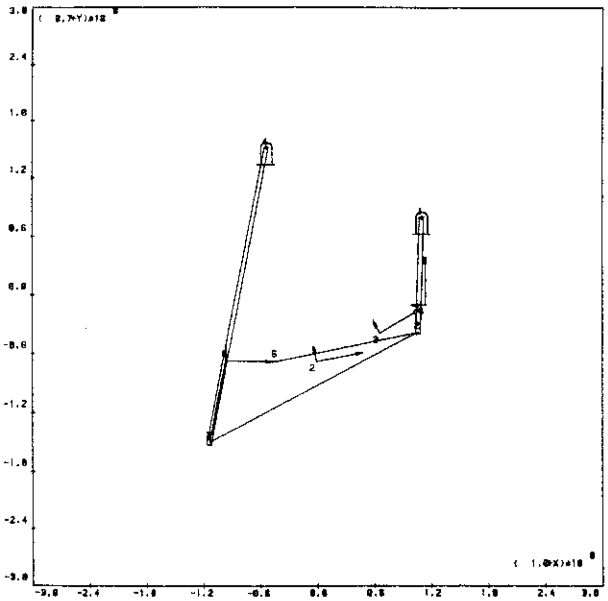
When selection of the passive crank has been completed, the display shown in Figure 3 is generated. The driving crank is selected using this display in a manner similar to the selection of the passive crank. Once again, the display has a number of features designed to assist in selection. A trial selection can be made. The computer will then present an evanescent display of the complete solution linkage. A code is also displayed in stored mode at the selected point. This code indicates the Grashof type of the solution [1]. The primary importance of this is in indicating if the driving crank can rotate completely or must oscillate. The codes allow mapping of regions of the curve which produce a given Grashof type. Several are visible in Figure 3.

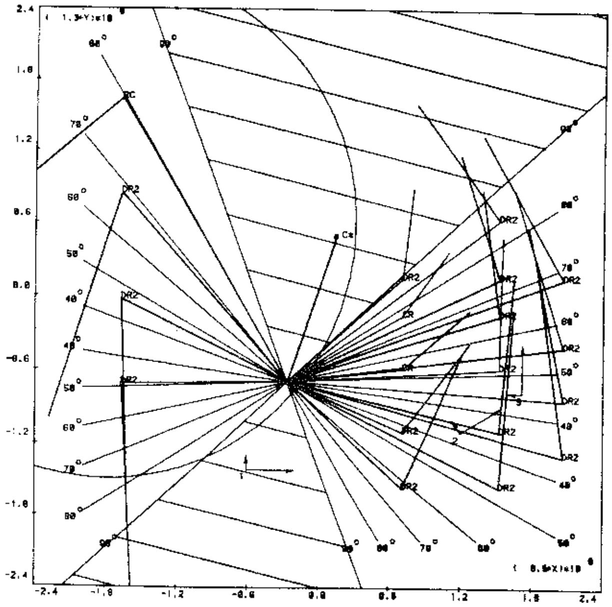


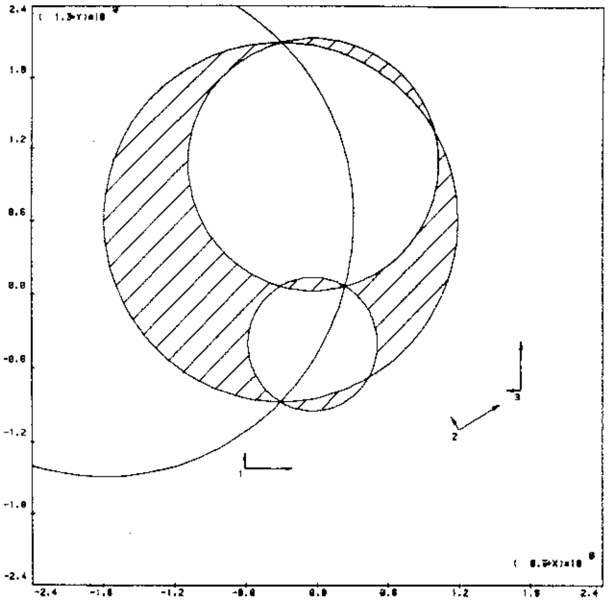
Comparison of Figure 3 with Figure 2 reveals that the dotted portions of the curve are now different. They now indicate solutions which would progress through the design positions in the wrong order. The hatched area indicates other areas of the curve which must not be considered to avoid spurious solutions. Finally, the radial lines indicate values of a parameter called the transmission angle which is useful for optimizing the dynamic properties of the mechanism.

After selection of the driving crank, the solution linkage is displayed as shown in Figure 4. It may be animated, to visually check its motion characteristics, and analyzed to produce velocity and acceleration plots, etc.

The other portions of the program have displays formatted to correspond as nearly as possible to those described above. Figure 5 and 6 are the displays for 3 position solution corresponding to Figures 2 and 3. Here, however, the whole plane is available for selection rather than points on a curve. An area of the plane which gives spurious solutions when used for passive crank selection is the hatched area of Figure 5. This area corresponds to the dotted portion of the curve in Figure 2. The unhatched circle is the locus of slider points. It corresponds to the single point B of Figure 2.







Equipment

The program is currently implemented on a VAX 750 computer with Tektronix 4014 terminals. Most development, however, was performed on a PDP 11/60 computer and several early versions are running on various 16 bit minicomputers. The evanescent and animated displays are software refreshed using the standard Tektronix 4014 write through capability. An alternative, greatly improved, refreshed display is also accommodated in the program but is dependent on a special modification of the 4014 providing in-terminal refresh and animation.

Summary

A sophisticated and complex graphical procedure has been implemented in an interactive graphic format. The original manual graphical procedure, described in reference [1] required several hours of work to produce even one solution and usually days to obtain good solutions. This process is not reduced to a matter of minutes. At the same time, much more information is presented to the designer to improve optimization of the solution.

Despite the inspiration of this work by classical graphical methods, the algorithms used are not direct translations of the graphical constructions. Algebraically efficient algorithms have been formulated and used. Some of these formulations have been discussed in references [10] and [11].

The program employs a uniform solution procedure for problems with different numbers of design positions and a uniform display format. It has been extensively used by undergraduate and graduate engineering students without prior instruction in its operation, and with minimal documentation. The fact that they could sucessfully operate it indicates the clarity of the menu messages and the robustness of the user interface and of the program itself. It is expected that the program will become a widely used industrial machine design tool in the near future.

Acknowledgement

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●EDGJ

COMPUTER PICTORIALS

A SHORT ALGORITHM FOR ORTHOGONAL AXONOMETRIC REPRESENTATION

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of Technology

Abstract

The paper presents a short algorithm and a computer program for orthogonal axonometric representation of an object under a freely chosen direction of projection. The result is an orthogonal trimetric axonometry. Orthogonal dimetric and isometric representations and orthographic projections are obtained as particular, with corresponding simplifications of the program. Practical examples are given.

Main Solution

Orthogonal axonometric representation of an object or system is obtained by its parallel projection onto a picture plane perpendicular to the direction of projection.

Let this direction be determined by two angles τ and θ, Fig. 1, and let the picture plane $K_x K_y K_z$ be perpendicular to it: $\sphericalangle OO'K_x = \sphericalangle OO'K_z = 90°$.

$O'K_x$, $O'K_y$ and $O'K_z$ are projections of the axes x,y and z of the given system, i.e. they are the axes of the axonometric representation. Let the corresponding distortion coefficients be m,n and q.

In the right-angled triangles $OO'K_z$, $OO'K_x$, and $OO'N$:

$$OO' = ON \cdot \cos\theta$$

$$OK_x = \frac{ON}{\cos\tau}$$

$$O'K_x^2 + O'O^2 = OK_x^2$$

$$m = \frac{O'K_x}{OK_x} = \sqrt{1-\cos^2\theta\cdot\cos^2\tau} \qquad \ldots(1)$$

$$q = \frac{O'K_z}{OK_z} = \cos\theta \qquad \ldots(2)$$

By the main equation of orthogonal axonometry [1]

$$m^2+n^2+q^2 = 2 \qquad \ldots(3)$$

Whence

$$n = \sqrt{2 - m^2 - q^2} \qquad \ldots(4)$$

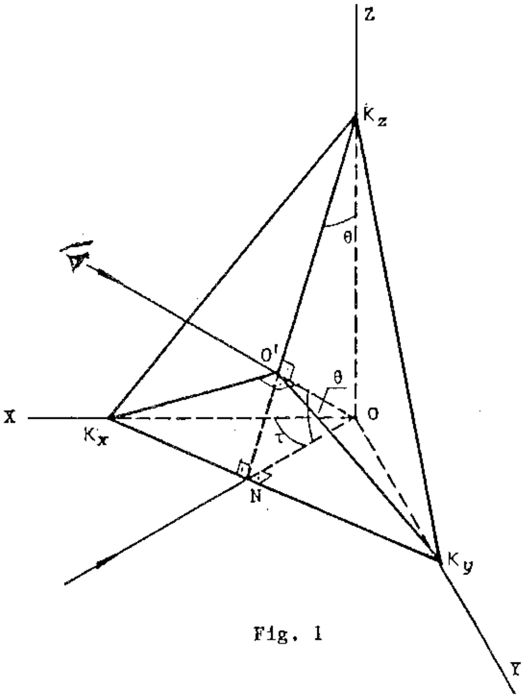

Fig. 1

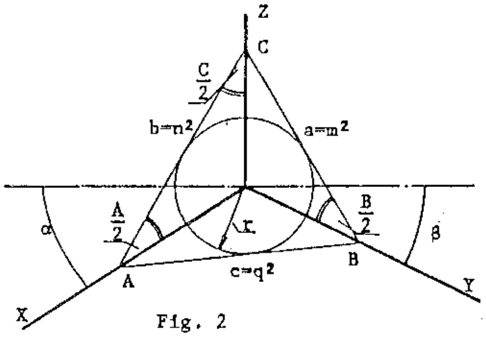

Fig. 2

According to Weisbach's theorem [2], the axes in any orthogonal axonometrical representation are obtainable as bisectors in a triangle whose sides are proportional to the squares of the corresponding distortion coefficients. In Fig. 2, demonstrating this theorem, the sides of the triangle are taken as equal to these squares.

The radius r of a circle inscribed in this triangle is

$$r = \frac{(p-a)(p-b)(p-c)}{p}$$

and the angles are: $\tan\frac{A}{2} = \frac{r}{p-a}$

$$\tan\frac{B}{2} = \frac{r}{p-b}$$

$$\tan\frac{C}{2} = \frac{r}{p-c}$$

where $p = \frac{a+b+c}{2}$

In our case (see eq. 3):

$$p = \frac{m^2 + n^2 + q^2}{2} = 1$$

$$r = \sqrt{(1-m^2)(1-n^2)(1-c^2)}$$

$$\frac{A}{2} = \text{arc tan}\ \frac{r}{1-m^2}$$

$$\frac{B}{2} = \text{arc tan}\ \frac{r}{1-n^2}$$

$$\frac{C}{2} = \text{arc tan}\ \frac{r}{1-q^2}$$

Hence,

$$\alpha = 90° - \left(\frac{A}{2} + \frac{C}{2}\right) \qquad \ldots (5)$$

$$\beta = 90° - \left(\frac{B}{2} + \frac{C}{2}\right) \qquad \ldots (6)$$

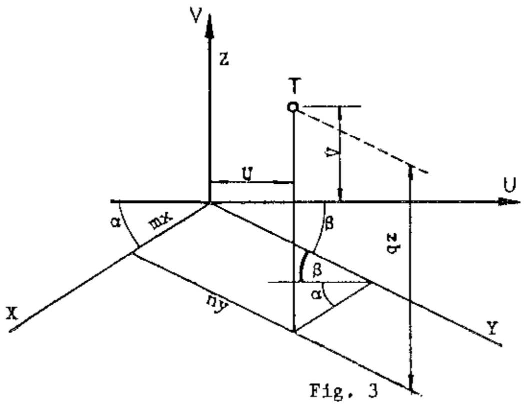

Fig. 3

The final representation of any point is plotted using the coordinates u,v in the computer program.

From Fig. 3, these coordinates are:

$$u = n\cdot y\cdot \cos\beta \ - m\cdot x\cdot \cos\alpha$$
$$\ldots (7)$$
$$v = q\cdot z - n\cdot y\cdot \sin\beta - m\cdot x\cdot \sin\alpha$$

Particular cases

In particular cases, the above equations are simplified:

For orthogonal isometry [3]:

$$m = n = q = \sqrt{\frac{2}{3}} \simeq 0.82$$

$$\alpha = \beta = 30°$$

If the scale of the drawing is set at 1.22, i.e.

$$m = n = q = 1,$$

then

$$u = 0.866\ (y-x)$$
$$\ldots (8)$$
$$v = z - 0.5\ (y+x)$$

For orthogonal dimetry [3]:

$$m = q = 2n = \frac{\sqrt{2}}{3} \simeq 0.94$$

$$n \simeq 0.47$$

$$\alpha \simeq 7°10'$$

$$\beta \simeq 41°21'$$

If the scale of the drawing is set at 1.06, i.e. $m = q = 1$ and $n = 0.5$, then

$$u = 0.38y-0.99x$$
$$\ldots (9)$$
$$v = z-0.33y-0.13x$$

Computer program

The data needed for axonometrical representation are those defining the object and the two angles τ (TAU) and θ (TETA) representing the direction of the projection rays (viewing direction). Let the object be given by an array (x(I),y(I),z(I)), then the computer program written in

FORTRAN can be as follows:

```
PQ=COS(TETA)
PM=(1-(PQ*COS(TAU))**2)**.5
PN=(2-PQ**2-PM**2)**.5
TM=1-PM**2
TN=1-PN**2
TQ=1-PQ**2
RO=(TM*TN*TQ)**.5
AA=ATAN(RO/TM)
BB=ATAN(RO/TN)
CC=ATAN(RO/TQ)
ALFA=1.57-AA-BB
BETA=1.57-BB-CC
U(I)=PN*COS(BETA)*Y(I)-PM*COS(ALFA)*X(I)
V(I)=PQ*Z(I)-PN*SIN(BETA)*Y(I)-PM*SIN(ALFA)*X(I)
```

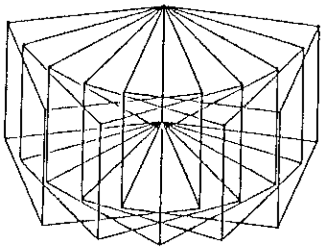

Fig. 6

This short program can be used to obtain different views of an object with τ and θ ranging from 0° to 90°.

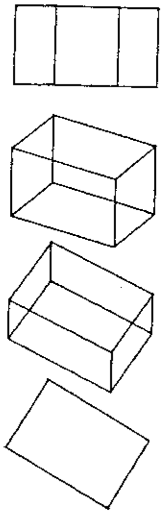

Fig. 4

Fig. 4 shows four views of a prism with τ = const and θ ranging from 0° to 90° in steps of 30°.

Fig. 5 shows further views of the prism, with both τ and θ varying in steps of 15°.

The proposed algorithm is suitable for animation effects as illustrated in Fig. 6.

A slight modification of equations (7) permits "circling" of the object, i.e. variation of τ from 0° to 360° (Fig. 7).

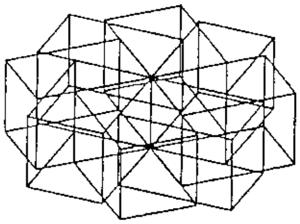

Fig. 7

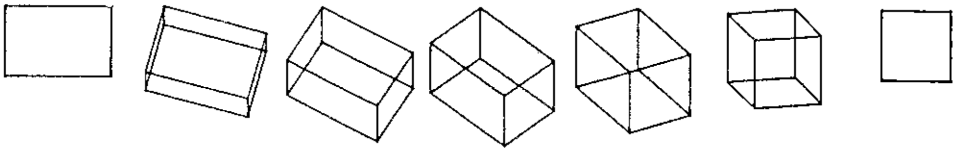

Fig. 5

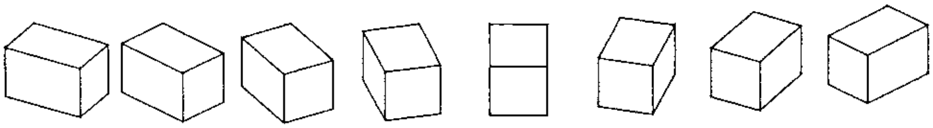

Fig. 8

The conclusion of the above program reads:

```
IC=1
IS=1
if (COS(TAU).lt.0.) IC=-1
if (SIN(TAU).lt.0.) IS=-1
U(I)=IC*PN*COS(BETA)*Y(I)-IS*PM*COS(ALFA)*X(I)
V(I)=PQ*Z(I)-IS*PN*SIN(BETA)*Y(I)-IC*PM*SIN(ALFA)*X(I)
```

Fig. 8 shows views of a prism from different directions with θ = const and τ varying from 30° to 135° in steps of 15°. Hidden lines are eliminated by a special subroutine.

Fig. 9 and Fig. 10 show a practical example of a trimetric representation preferable to "classic" isometry as a means of demonstrating a central rectangular opening in a machine part.

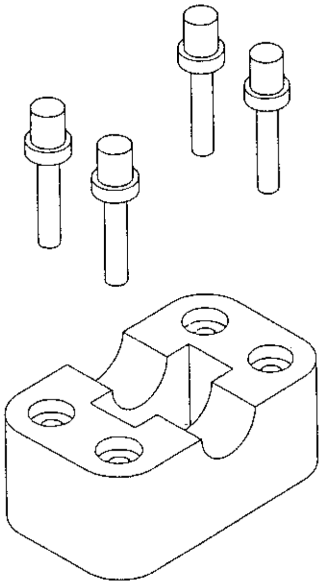

Fig. 9

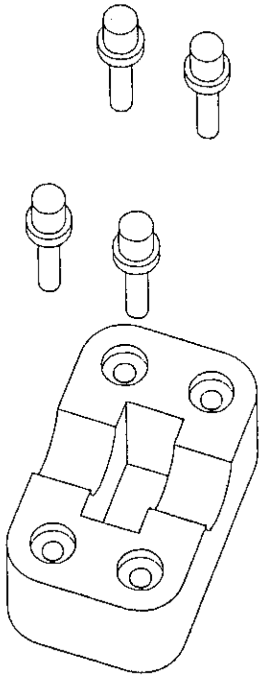

Fig.10

The orthographic projections and isometric representation in Fig. 11 and Fig. 12 are obtained by means of the program using different angles τ and θ:

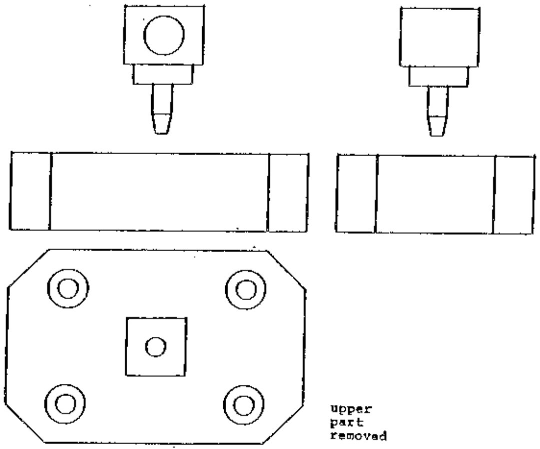

Fig. 11

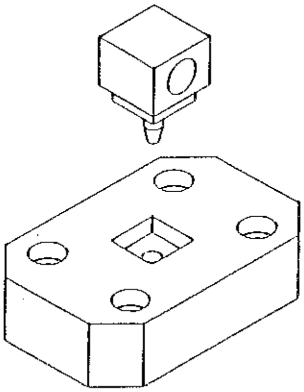

Fig. 12

For the front view $\tau = 90°$, $\theta = 0°$

For the top view $\tau = 90°$, $\theta = 90°$

For the left-side view $\tau = 0°$, $\theta = 0°$

For the isometric representation $\tau = 45°$, $\theta = 35.26°$.

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COURSEWARE

COMPUTER AIDED DESIGN PROBLEMS FOR SECOND-YEAR GRAPHICAL DESIGN

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The University of Missouri-Rolla introduced computer aided graphics to the second-year graphical design students during the 1981 fall semester. This was made possible by the purchase of new computer equipment and software in 1980. The Engineering Graphics Department received 17 Tektronix 4014-1 terminals, linked to an IBM 4341 host computer. The software selected was the Integrated Program for Aerospace-Vehicle Design (IPAD) version of AD2000. Before this industry software could be used it was revised to meet UMR's needs and renamed Interactive Design Facility (IDF). The software requires no prior knowledge of computers or computer programming. The students can create detailed 3-D drawings from "menus" with such drawing functions as lines, arcs, circles, crosshatching and dimensioning.

The first-year engineering graphics course covers both drafting board problems and the basics of computer aided graphics. The computer graphics problems are the same as the problems that are worked at the drafting board. The students spend one hour per week at the drafting terminal. However, because of the large size of the classes, it is necessary that they work in pairs.

A three-day short course is offered at the beginning of each semester to students transferring from other institutions that had graphics courses without computer applications. This gives these students the opportunity to become familiar with our computer graphics system and places them on par with their new colleagues.

EGR.25 - GRAPHICAL DESIGN

The second-year graphical design course is primarily for sophomore mechanical engineering students. The course is a two credit hour course; four laboratory hours per week and a one hour general lecture per week. As in the beginning graphics course, each class spends one laboratory hour per week at the graphics terminal. Each computer graphics problem is discussed during the general lecture prior to the students using the terminal. The students are made aware of the objectives of each problem and the appropriate menus to use for completion of the problem. When a problem is completed, a hardcopy or plot is produced for grading purposes. Tests are given at the completion of problems. A large percentage of the student's computer grade is based on the results of these tests.

The computer graphics problems are designed to include a new menu or introduce new items in a menu each week. Problems become more complex as the semester progresses. The first problem assigned is a review of the work completed during the first graphics course. A few examples of the second-year problems assigned during the semester are presented below.

selection of suitable computer problems has been the most difficult task encountered

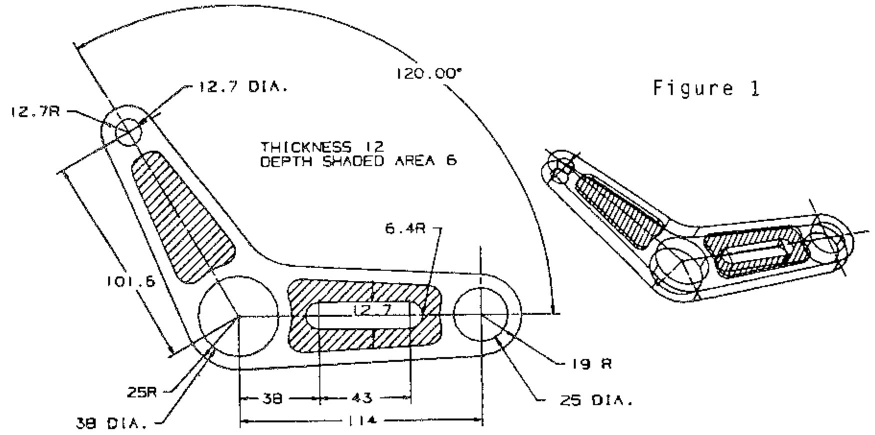


Figure 1

Figure 1 is an example of the type of problem assigned during the third week of the semester. The objective is to include depth, tangent lines, arcs and fillets, and dimensioning. The average student is able to complete this drawing in one and one-half hours. Since the terminal is scheduled for one hour per laboratory section per week, the students must work in pairs. Any problems that are not completed in the computer terminal laboratory time scheduled each week must be completed in the evenings or on the weekend.

Figure 2 is an example of the type of problem assigned during the fifth week of the semester. The objectives of this problem are to teach the student how to work with multiple views (as many as four) on the screen. This is accomplished by using a menu that enables the user to select a working view. Another command allows the user to change the depth ("Z" dimension) in the selected working view. A menu in the program allows the student to verify the ("Z") dimension. Menus covered on previous problems are also used on this problem. The average completion time for this drawing is two hours.

Figure 3 is an example of a problem assigned during the seventh week of the semester. The objective of this problem is to use the auxiliary view operation. At this point in the semester, it is important that the students understand how the computer will respond to commands entered. The student must also be able to visualize auxiliary views. This problem requires that the depth change as used on figure 2 be applied to the auxiliary view. Since the software does not include automatic or selective clipping (erasing of parts of entities), the student must add and delete entities (points, lines and arcs) to complete the drawing. Dimensioning is also required on this problem. The average completion time for this problem is also two hours.

The second year graphics class includes the study and design of cams and gears. Figures 4 and 5 are examples of a computer drawn displacement diagram and cam profile. These drawings prepared at the drafting board require about three hours to complete. The same two drawings created at the graphics terminal require about one and three-quarter hours and are much neater and more accurate.

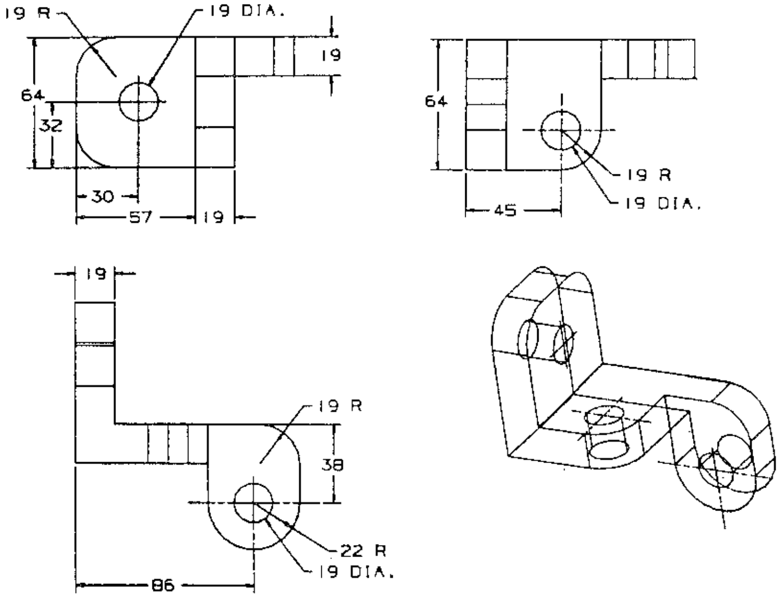


Figure 2

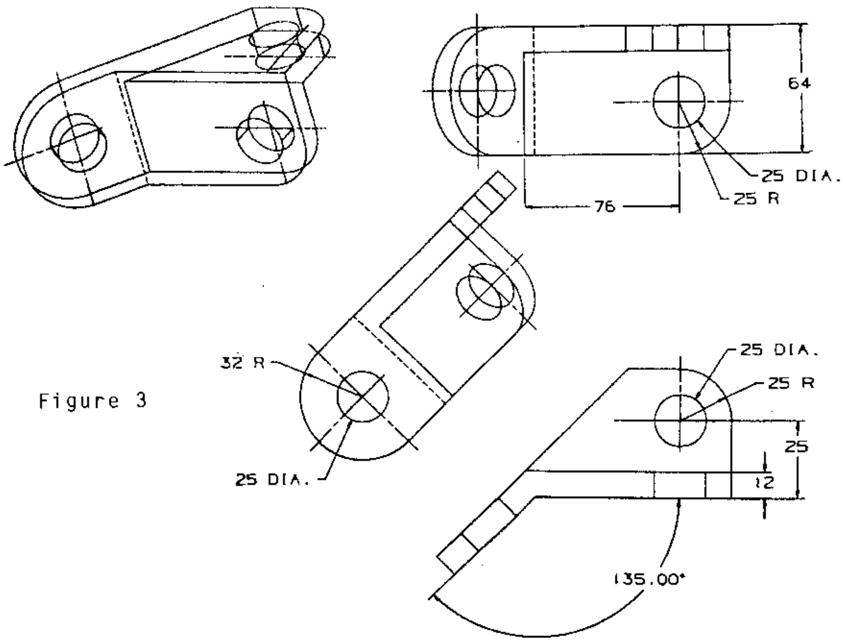


Figure 3

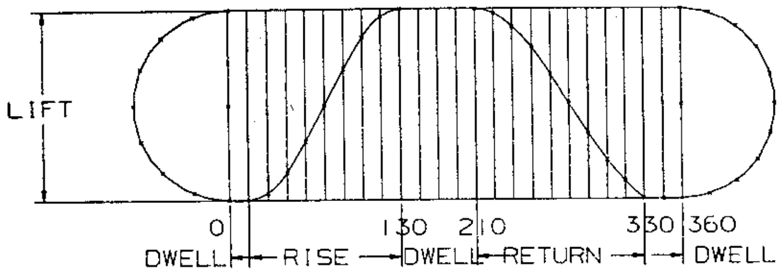


Figure 4

HARMONIC MOTION CURVE

Figure 6 is an example of a gear drawing prepared at the graphics terminal. The drawing requires the application of functions used for the previous problems and the following menus: mirror, duplicate and rotate, and projected entity. One half of a gear tooth is drawn then mirrored to form a single gear tooth. The duplicate and rotate operation of the software will draw the other 23 teeth. This problem requires about three hours to complete on the terminal.

CONCLUSION

When computer graphics was integrated into EGR.25, it was obvious that something had to go. Since the course was tailored specifically for the needs of mechanical engineering students, certain areas could not be deleted. The decision was made to drop the design project that had been assigned during the last three weeks of the semester. Another problem was the introduction of computer problems into the course curriculum, since these problems would differ from the drafting board problems for the first half of the semester.

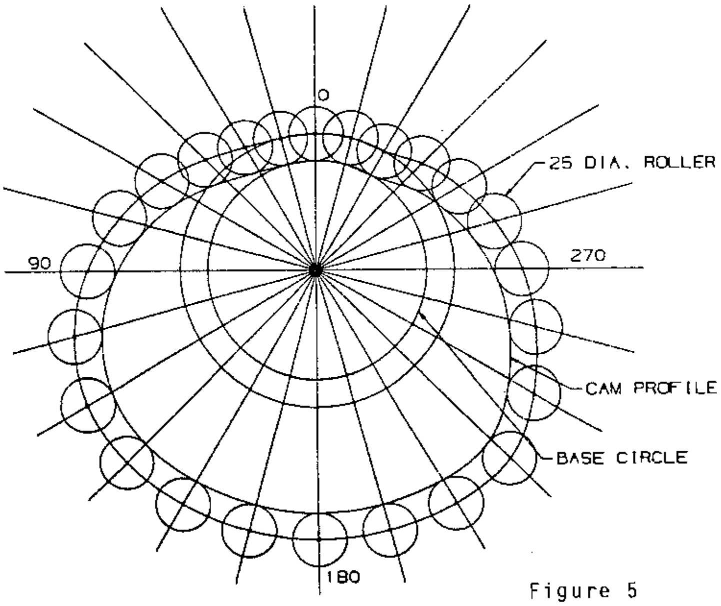


Figure 5

While working with the ortho grid, the snap lets you rapidly create geometry (Fig 7). The iso grid is more of an eyeball experience since Macpaint doesn't let you change the 8x8 snap grid (Fig 8). The Mac lets you tailor your image with **fat bits**, an experience that alone is worth the price of the machine (Fig 9).

A "toolbox" keeps you from having to redraw common graphic entities. The best way to use a toolbox or library of shapes is to keep it as a separate drawing. Copy the symbol(s) to your **clipboard** and then paste them on the drawing, moving them to final position with the **mouse**. Mac has a scrapbook where you can store images used over and over but you can't store more than a window-full, and you can't selectively cut from a large image. You can cut and paste anything that will fit in a window, such as a view you need to repeat (Fig 10).

Text is a blast with Macpaint! You work just like you always have: create the text somewhere--like on a typewriter, Leroy, or headliner--and then paste it into position. Don't like it there? **Lasso** the text and move it anywhere you want (Fig 11).

P2

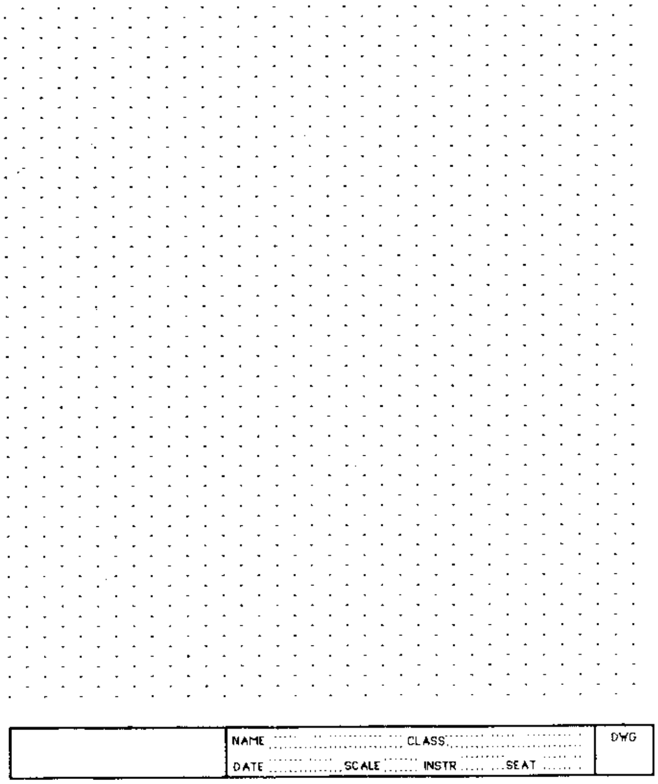


FIGURE 3

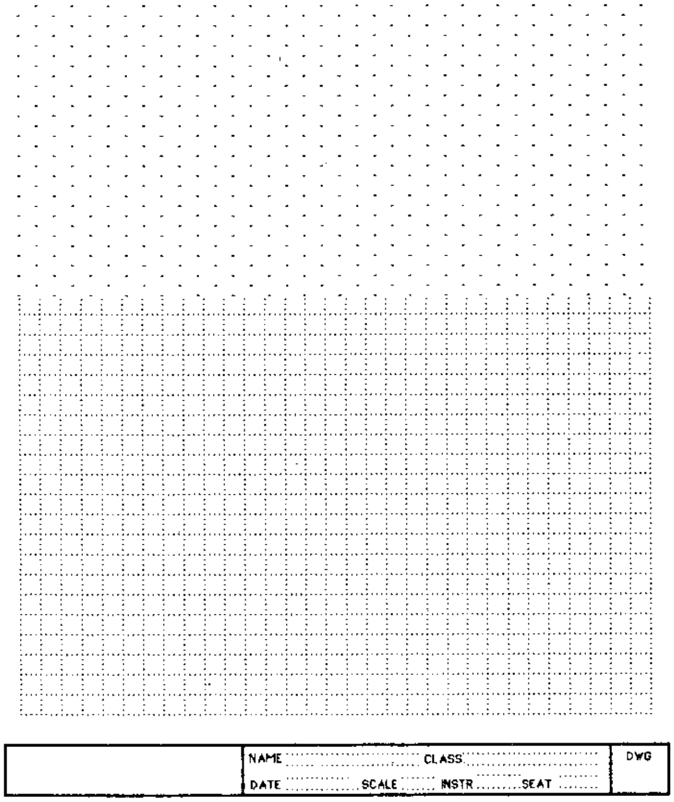


FIGURE 4

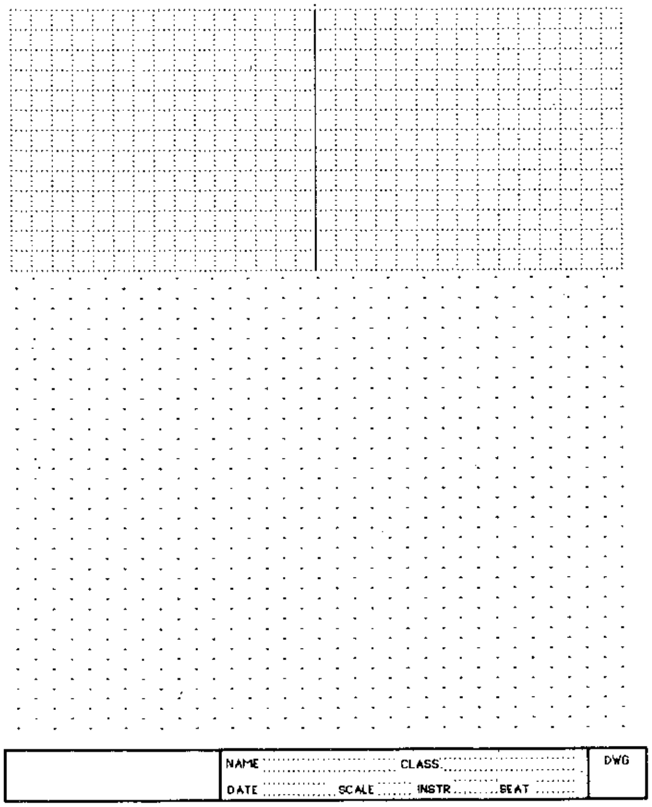


FIGURE 5

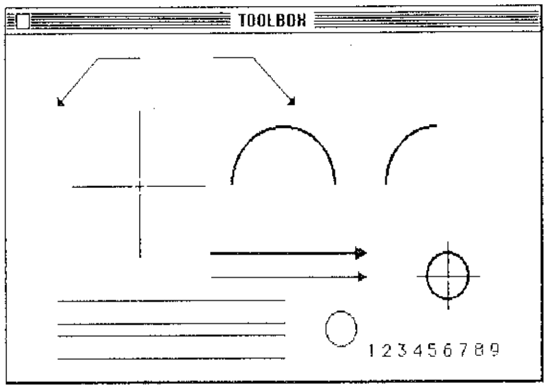
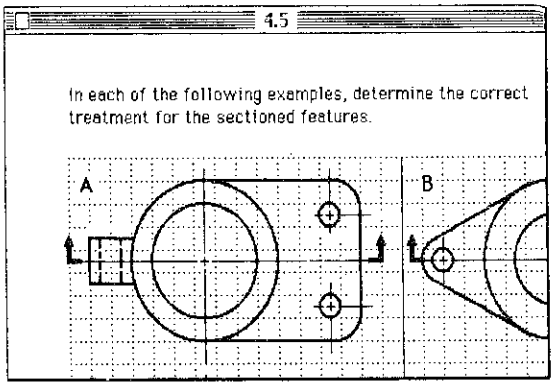


FIGURE 6



In each of the following examples, determine the correct treatment for the sectioned features.

FIGURE 7

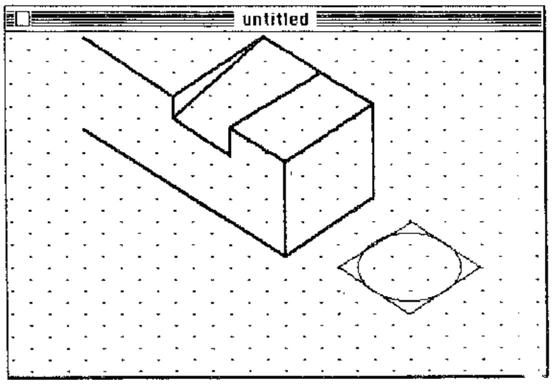


FIGURE 8

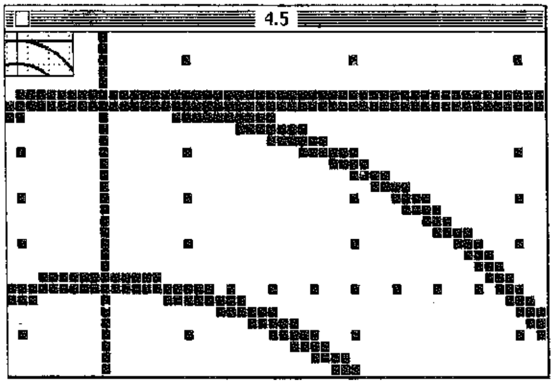


FIGURE 9

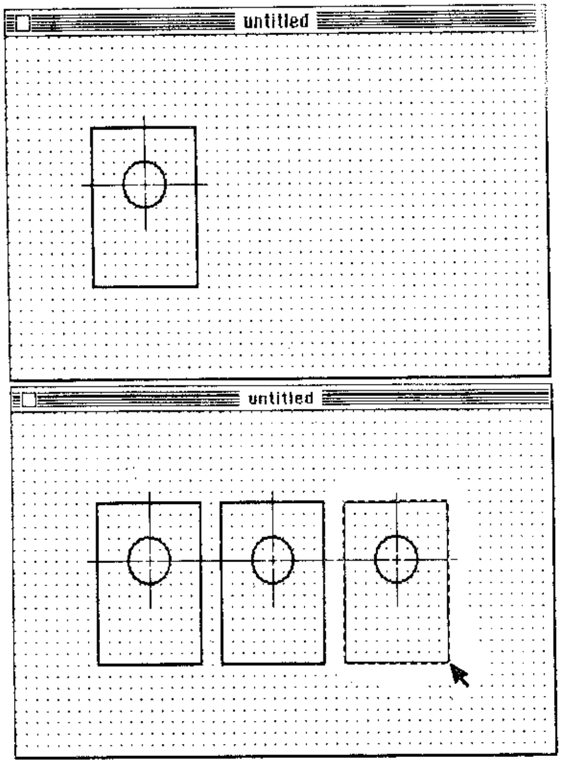


FIGURE 10

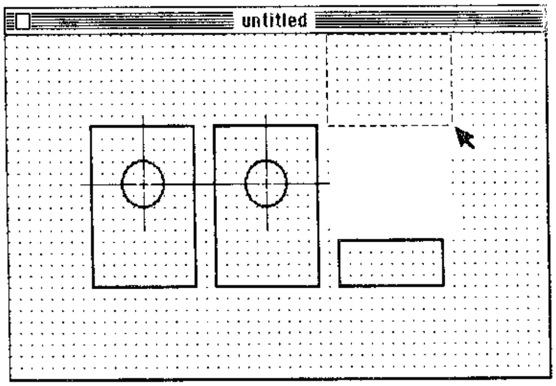


FIGURE 11

EDITING

Sometimes you have to erase linework used in construction, or to get the proper dashed line intersections. The **eraser** on the Mac just swipes away the graphics. Or go into **fat bits** if you have to clean up a small part. You can paint with white by choosing white as the pattern and selecting a brush shape--makes for easy erasing. If you erase some of the grid, **lasso** some good grid and let the snap position it exactly in place (Fig 11).

Want to "hint" at where you want the student to solve the problem? You can get almost the same results as a screen by choosing clear as your pattern and **spray painting** white over the linework (Fig 12)

PRINTING

The Imagewriter prints graphics like crazy, both in a **draft** and final form. Final printing cleans up some of the dot matrix effect. The ribbon is super black. The unit prints a page of graphics in about a third the time it takes an Epson to dump a page with SHIFT-PRINT SCREEN on an IBM PC.

LIMITATIONS

Memory, of course is the well-publicized limitation on the Mac. It brings new meaning to "flipping your floppies". Updated machines have 512K so that should go a long way.. Disk storage is another problem. You can put about 20 involved lab sheets on a data disk. The small screen takes getting used to, however the near-photographic quality of the images makes up for it.

Drawing with a **mouse** is a concession Apple made to those who can't draw without a computer. Why didn't they make it the size and shape of a loaf of bread and be done with it? Someone will take the smarts out of the **mouse**, put them at the other end of the cord, and just have a ball at the end of a drawing instrument, and I hope, very soon.

CONCLUSION

The Mac is dangerous. It debunks the computer, demystifies the technology, and puts ultimate graphics power on a very small part of your desk. It doesn't crash, needs no systems manager, asks you alot of questions so you won't get in trouble, and makes interesting sounds while doing so.

Once you have a version of a test or lab sheet, an alternate version is only minutes away; a new test, ready for the printer, is yours in an hour. With a good plotter, it could make even the most die-hard graphics veteran want to move their drawing table out of their office, and put a Mac on their desk.

By the Editor

EDGJ

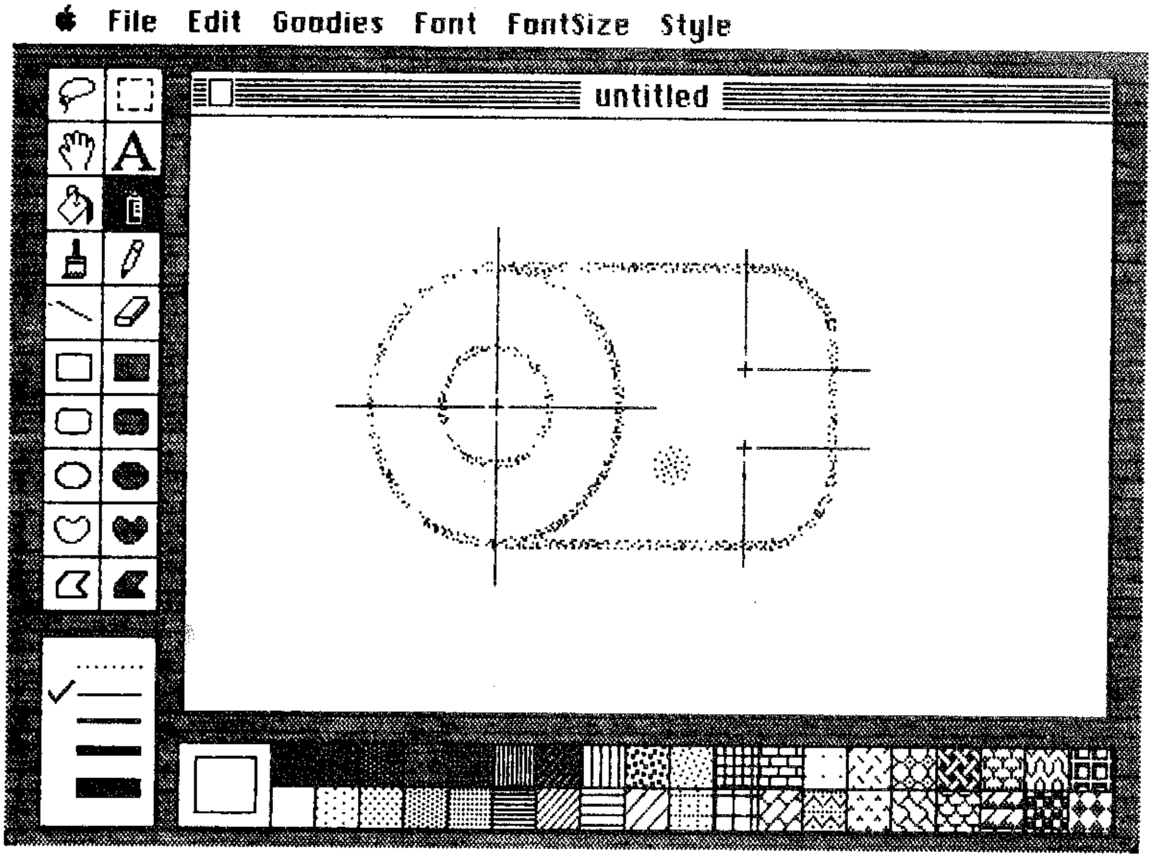


FIGURE 12

NEW PROGRAMS

UNIVERSITY OF MISSOURI-ROLLA COMPUTER-AIDED DRAFTING

by

WELLS N. LEITNER

The University of Missouri-Rolla installed its CAD/CAM system in 1980. It was first used in our freshman Engineering Graphics classes in the summer of 1981. Since then the equipment and software have been updated and improved.

The Engineering Graphics Department had a drawing laboratory remodeled to provide space for the computer graphics hardware. The resulting layout provides efficient use of the space available, is climate controlled and expandable (Figure 1).

Using the folding partitions, portions of the room can be isolated to accomodate more than one activity at a time. Figure 1 also identifies the location of the monitor's room. This center glass enclosed room has access to each part of the room and also has a terminal that is reserved for departmental faculty use.

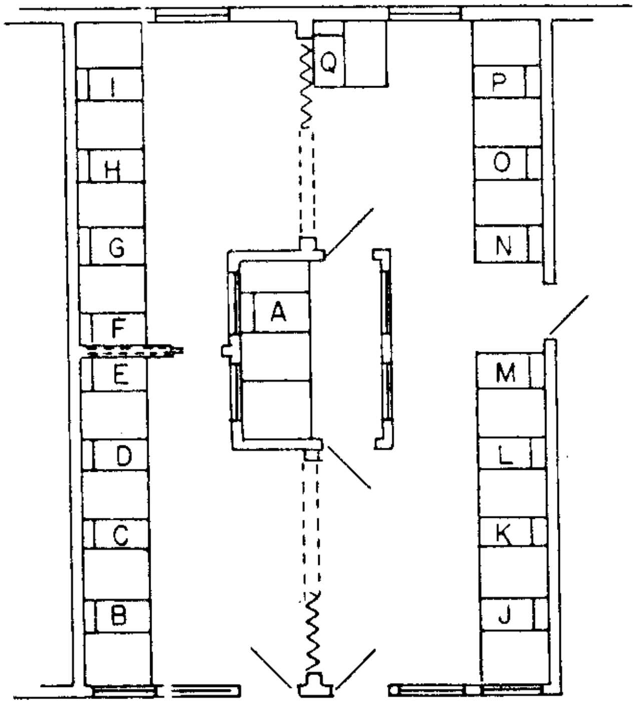


FIGURE 1

Seventeen Tektronix 4014-1 terminals in the department are equipped with Tektronix Graphics Tablet units (Figure 2). Use of the tablet is optional at each station. The terminals are connected by cable to an IBM 4341 host computer in the Math-Computer

FIGURE 2

Science Building approximately 400 feet away. Each group of four terminals is connected to a hard copy unit. All terminals are capable of sending drawings to the Calcomp plotter in the computer center building. A plotter is also scheduled for installation in the Graphics Department terminal room sometime in the future.

The software used in the Engineering Graphics drawing courses is UMR's version of a program called AD2000. It was obtained from the Integrated Program for Aerospace-Vehicle Design (IPAD) organization who acquired it from Manufacturing and Consulting Services (MCS), Inc. Other software available from these graphics terminals include Nastran, Supertab, and SAS/GRAPH. These packages are designed primarily for non-programmers for use in their specific academic areas of interest. Fortran and CMS may be used by those students who have developed more advanced programming skills.

The UMR version of AD2000 is referred to as Interactive Design Facility (IDF) Release 1.40. IDF is a menu-driven, interactive graphics package. It is typical of software used by industry; not as sophisticated as some, but on a par with many. It serves as an excellent introduction to computer-aided drafting. As such, many feel that it will enable our engineering graduates to perform at much higher levels.

A copy of the main menu is shown in figure 3. An example of one of the choices, Menu 16 (drafting), identifies the choices available for use in drafting on the computer terminal.

```
IDP RELEASE 1.30
 1. MODALS & FONTS
 2. BLANK/UNBLANK
 3. DELETE
 4. FILE/TERMINATE
 5. SPEC. FUNCTS/APPLICATIONS
 6. DATA BASE MGMT
 7. INPUT/OUTPUT/REGEN
 8. DISPLAY/DEPTH CONTROL
 9. POINT
10. LINE
11. ARC/CIRCLE/FILLET
12. OTHER CURVES
13. ENTITY MANIPULATION
14. DATA VERIFY
15. EXTENDED GEOMETRY
16. DRAFTING
17. N/C MACHING
18. ANALYSIS
```

The computer experience is thereby associated with the work that is done in the drafting rooms. Problems are selected carefully to ensure their suitability with respect to the time allowed. More problems, of course, are scheduled for the drawing board than for the terminals.

Student reaction to the use of the computer terminals has been mixed. The most competent students on a drawing board usually become adept at the terminal more quickly than the less capable students. Students who have had several high school drawing classes appear to be intimidated by the terminals more frequently than students who have had no previous drawing classes. The terminals seem most intimidating to the student who has learned to do some graphics programming. He or she wants and expects to be called upon to do something other than interact with existing programming. However, that difficulty is usually quickly overcome, and most programming types become highly competent and often excell.

There doesn't appear to be correlation between the ability to use a drafting machine and pencil to using a graphcis terminal. Many students expect somehow that the computer will do a drawing with little or no input from them. It's a shock to the poor student to find that the computer is exactly as lazy as he or she is.

In addition to the freshman graphics classes, the terminal room is used for sophmore graphic classes for Mechanical Engineers, a Mechanical Engineering design class, Electrical Engineering class, a Computer Graphics class from the computer center, and a class (Engineering Graphics 212) for additional terminal training. The fact that the terminals exist and have been used by students in graphics courses, has caused some departments to consider their use in other classes. Engineering departments are installing more terminals for use in their courses as applications become apparent.

When new terminals are installed in other departments, the load on our terminal room should be reduced. When that is done, we will increase the time each class uses the room from one hour to two so that each student can work alone at a terminal instead of having to share a terminal.

EDGJ

APPLICATIONS

APPLICATION OF BEZIRE CURVE
FOR
ENGINEERING DESIGNS

M.M. Khonsari, Ph.D.
The Ohio State University

Introduction

Bezire curves and surfaces are well-known design tools in CAD. Aircraft and particularly automobile industries have developed various practicable programs which utilize a Bezire scheme for surface design. While many degrees of sophistication of such programs exist in "real-world design", a simple Bezire program seems to be a very good and interesting exercise for computer graphics courses.

In this paper we briefly describe the principle behind the method, present a two-dimensional Bezire computer program written in FORTRAN, and document sample results. We will also make some suggestions on extending the program to more interesting and challenging cases for subsequent exercises in computer graphics.

Background

Over a decade ago, P. Bezier of Renault developed a computer modeling program for designing the outer surfaces of Renault automobiles. His method was based on the Bernstein polynomial approximation. Bezire curves are represented in a parametric form which is desirable in computer-aided design because they can easily be displayed.

Basically, the shape of a Bezire curve is controlled by a set of points which form an open (or closed) polygon. The series of points are referred to as the control points and the polygon as a Bezire polygon. Each set of control points have their zones where they may dominate the shape of the curve by "tending to absorb" the curve toward themselves. The result is a smooth curve known as the Bezire curve which always passes through the first and last control points.

Design of Arbitrary Curves

The algorithm works as follows. For n+1 arbitrary control points, corresponding to the Bezire polygon vertices of $P_0(X_0,Y_0)$ to $P_n(X_n,Y_n)$, the Bezire curve is defined in the following parametric form:

$$P(t) = \sum_{i=0}^{n} P_i B_{i,n}(t) \qquad (1)$$

where $B_{i,n}(t)$ is a blending function defined by

$$B_{i,n}(t) = \frac{n!}{i!(n-i)!} t^i (1-T)^{n-i}$$

Equation (1) is a vector equation. Therefore, its X-Y components can be written in parametric form separately:

$$x(t) = \sum_{i=0}^{n} x_i B_{i,n}(t) \qquad (2)$$

$$y(t) = \sum_{i=0}^{n} y_i B_{i,n}(t) \qquad (3)$$

The Computer Program

A listing of a two-dimensional Bezire program written in FORTRAN for a VAX-11/750 computer is shown. The user is prompted to input the number of control points n, and the number of points on each segment of a Bezire curve , m. The latter corresponds to the resolution of the lines plotted. The program begins by computing the blending function, $B_{i,n}(t)$, and proceeds to the calculation of the coordinates of the Bezire curve: see equations (2) and (3).

Some sample plots are shown in Figures 1 and 2. The crosses are the position of control points entered interactively. They can be removed before printing the final design. Curve I in Figure 1a shows the Bezire curve corresponding to control points C_1 to C_5. Curve II shows the effect of moving the control point C_3 to C'_3 position. Figures 3 and 4 show the application of Bezire curves in drawing rounds and corners. More interesting designs are shown in Figures 5 and 6. These are obtained by piecing together several sets of smooth Bezire curves, each containing an arbitrary number of control points.

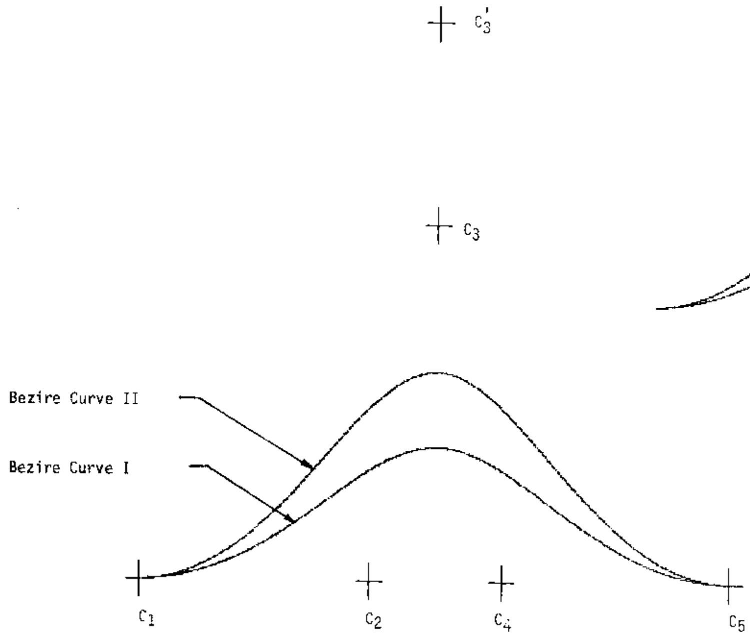


Figure 1a

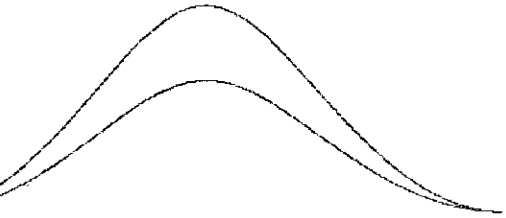


Figure 1b

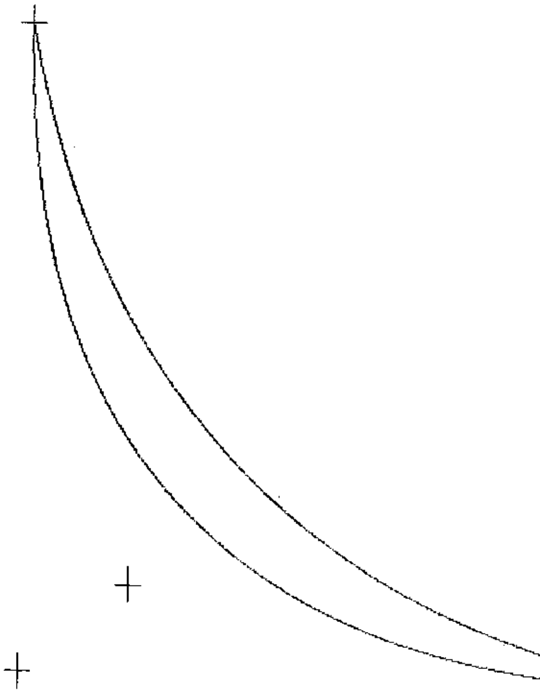


Figure 2a

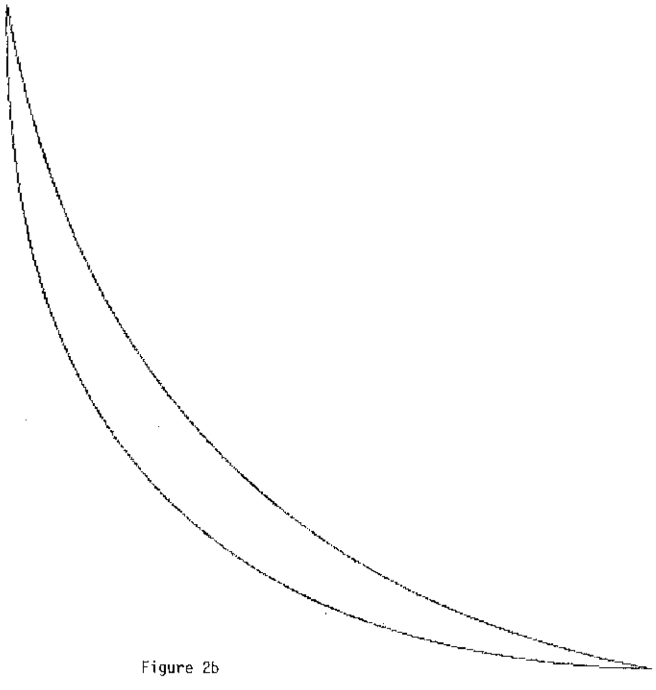


Figure 2b

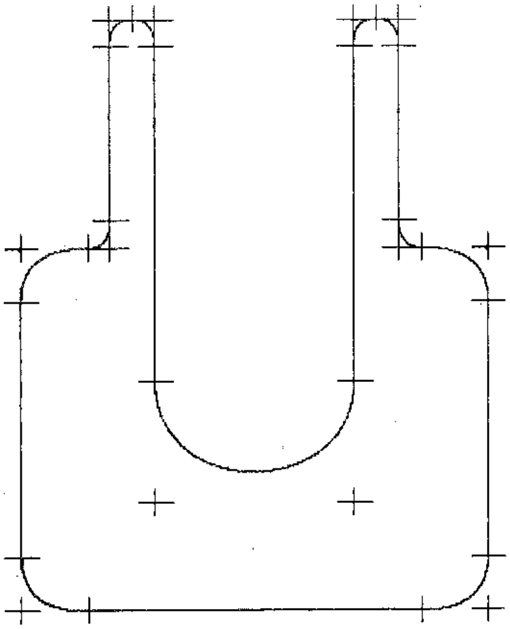


Figure 3a

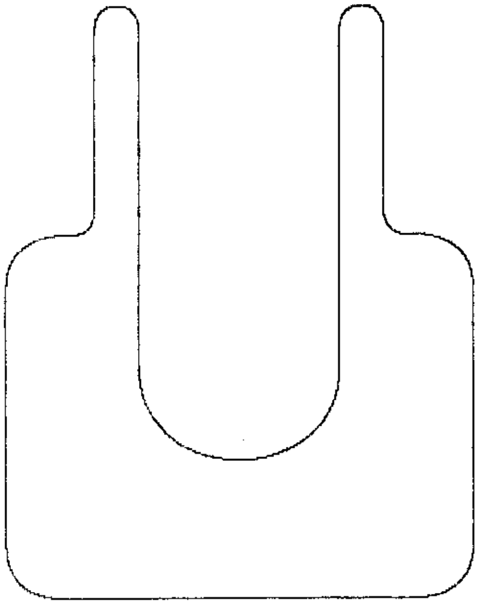


Figure 3b

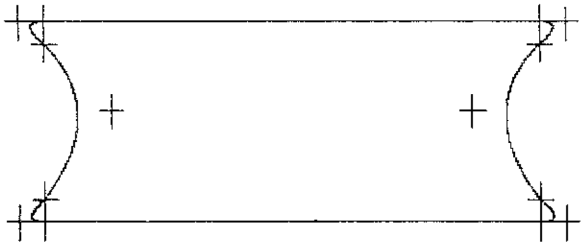


Figure 4a

Figure 4b

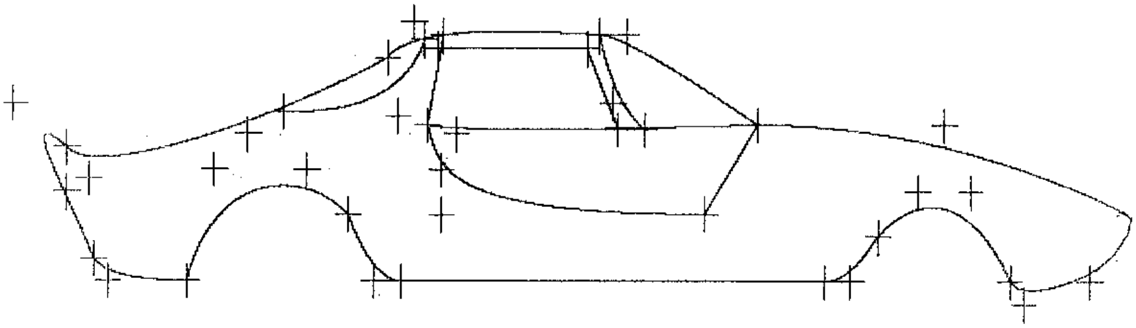


Figure 5a

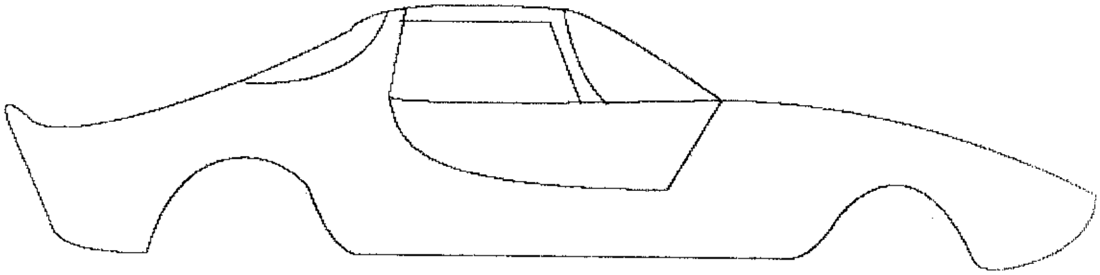


Figure 5b

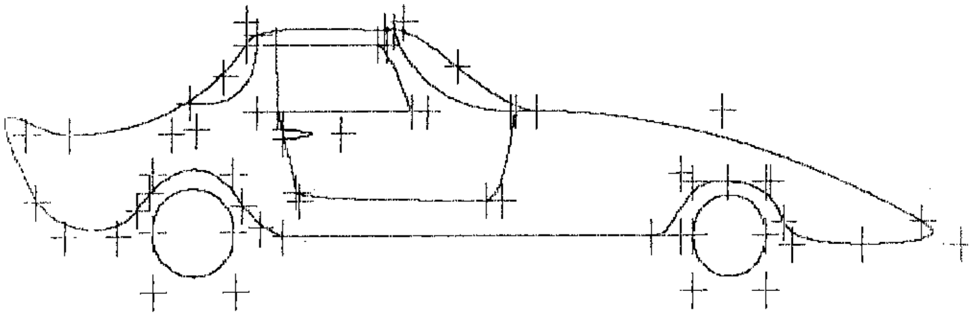


Figure 6a

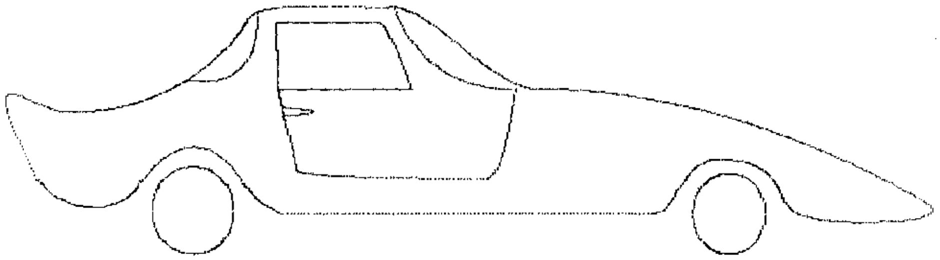


Figure 6b

Application in Interactive Design

Interactive design is in general an iterative process since the "best fit" is not known apriori. The program can be made more practicable by allowing the CAD designer to make several tries before he/she finds the desired shape. This is implemented so that the program questions the user if any modification is to be done on a portion of the plot. If the response is positive, the program will prompt the user with instructions for revisions.

control points tend to "absorb" the curve toward themselves

Conclusions

A two-dimensional Bezire curve is proposed to be an effective educational tool for computer graphics courses. The Bezire scheme offers a smooth representation of a curve that approximates a given set of data. The blending function is the Bezire curve algorithm based on the Bernstein polynomial approximation. Being in parametric in form, it can easily be extended to three-dimensional cases for the design of surfaces. This would make another project for an advanced class in graphics programming. The interested reader is referred to the following references:

1. Giloi,W., Interactive Computer Graphics, Prentice Hall, 1978.
2. Juricic,D., Barr,R., Deen,W., and M. Knox, Engineering Computer Graphics, The University of Texas Publication, October, 1981.
3. Artwick, B., Applied Concepts in Microcomputer Graphics, Prentice Hall, 1984.
4. Newman, W. and Sproull, R, Principle of Interactive Computer Graphics, McGraw-Hill, 1979.

```
C
C
C     ***************************************************************
C     ***************************************************************
C     **                                                           **
C     **       INTERACTIVE DESIGN USING THE TWO-DIMENSIONAL        **
C     **                       BEZIER CURVE                        **
C     **                                                           **
C     ** THIS PROGRAM IS DESIGN TO MAKE IT EASY FOR THE USER TO    **
C     ** MAKE BEZIER CURVES.  THE CONTROL POINTS ARE STORE IN A    **
C     ** DATA FILE FOR LATER USE.                                  **
C     **                                                           **
C     ***************************************************************
C     ***************************************************************
C
C
      EXTERNAL FACT,CURVE,MOD
      CHARACTER*14 FILE
      INTEGER FAC(0:50),P,I,A
      REAL    SUM(2),XY(2,0:50),S,T,N,N1,N2
      CALL INITT(960)
      CALL TERM
      CALL VWPORT(0,1024,0,960)
      CALL WINDOW(0.,1024.,0.,960.)
      CALL MOVABS(0,BOO)
      WRITE(6,*)
      WRITE(6,*)'THIS PROGRAH IS TO ENABLE THE USER TO CREATE MANY'
      WRITE(6,*)'CURVE BY USING CONTROL POINTS. THE CONTROL POINTS'
      WRITE(6,*)'ARE ENTER BY USING THE CURSER CONTROL AND PRESSING'
      WRITE(6,*)'THE SPACE BAR TO ENTER THE LOCATION.'
      WRITE(6,*)
      WRITE(6,10)
 10   FORMAT(1X,'INPUT A FILE NAME WHERE THE DATA CAN BE STORED ?',$)
      READ(5,20)FILE
 20   FORMAT(A14)
      FILE=FILE//'.DAT'
      OPEN (UNIT=1,NAME=FILE,STATUS='NEW')
      CALL ERASE
      CALL SETGRA
      A=0
      N=1
C
C      A WHILE LOOP IS NEEDED SO MANY CURVES CAN PUT TOGETHER TO
C      GET DESIRED IMAGE.
C
      DO WHILE(N.NE.0.)
      CALL MOVABS(0,0)
      CALL ANMODE
      WRITE(6,30)
C
C      THE INPUT FOR THE NUMBER OF POINTS AND INCREMENT CONSTANT
C      MAKE IT POSSIBLE TO GET A DESIRED SHAPE.
C
 30   FORMAT(1X,'INPUT THE NUMBER OF POINTS AND INCREMENT CONSTANT ?',$)
      READ(5,*)N,N2
      CALL DARK
      DO 40 I=2,36
       CALL POINTA(1.,FLOAT(I))
       CALL DRAWA(900.,FLOAT(I))
 40   CONTINUE
      CALL LIGHT
      IF (N.NE.0 ) THEN
      IF (N2.NE.0 ) THEN
       N1=1/N2
      END IF
      N=N-1
      FAC(0)=1
C
C      THE FOLLOWING DO LOOP SOLVES FOR THE POLYNOMIAL CONTANTS.
C
      DO 50 I=1,N-1
       FAC(I)=FACT(N)/(FACT(FLOAT(I))*FACT(N-FLOAT(I)))
 50   CONTINUE
      FAC(N)=1
C
C      THE WRITE STATEMENT STORES THE NUMBER OF POINTS AND THE
C      INCREMENT CONSTANT IN A DATA FILE.
C
      WRITE(1,53)N,N2
 53   FORMAT(1X,F5.0,F5.0)
      CALL BELL
C
C      THIS LOOP LETS THE USER INTERACT WITH THE SCREEN.  A
C      CURSOR WILL BE ON THE SCREEN AND THE USE OF THE "ARROW"
C      KEYS WILL MOVE IT. PRESSING THE SPACE BAR WILL ENTER THE
C      CURSOR LOCATION AS A CONTROL POINT.
C
      DO 60 I=0,N
       CALL MOVABS(0,930)
       CALL ANMODE
       CALL VCURBR(A,XY(1,I),XY(2,I))
       CALL POINTA(XY(1,I)-9,XY(2,I))
       CALL DRAWA(XY(1,I)+11,XY(2,I))
       CALL POINTA(XY(1,I),XY(2,I)-16)
       CALL DRAWA(XY(1,I),XY(2,I)+16)
 60   CONTINUE
      CALL PCOLOR(7,0)
C
C      CALL SUBROUTINE TO DRAW BEZIER CURVE.
C
      CALL CURVE(N1,N,XY,FAC)
      FILE='Y'
      DO WHILE(FILE(1:1).EQ.'Y')
      CALL MOVABS(0,0)
      CALL ANMODE
      WRITE(6,65)
C
C      INPUT TO FIND OUT IF THE USER WANTS TO MODIFY THE CURVE
C      DRAWN.
C
 65   FORMAT(1X,'DO YOU WANT TO CHANGE THE CURVE ?',$)
      READ(5,68)FILE
 68   FORMAT(A6)
      CALL DARK
      DO 66 I=2,36
       CALL POINTA(1,FLOAT(I))
       CALL DRAWA(900.,FLOAT(I))
 66   CONTINUE
      CALL LIGHT
      CALL BELL
C
C      CALL MOD SUBROUTINE TO MODIFY CURVE.


C
      IF (FILE(1:1).EQ.'Y') CALL MOD(N1,N,XY,FAC)
      END DO
      DO 69 I=0,N
C
C      WRITE STATEMENT IS TO STORE THE FINAL CONTROL POINTS IN
C      A DATA FILE.
C
       WRITE(1,72)XY(1,I),XY(2,I)
 72    FORMAT(1X,F5.0,F5.0)
 69   CONTINUE
      END IF
C
C      LOOP BACK TO THE BEGINNING SO A NEW CURVE CAN BE ADDED.
C
      END DO
      CALL FINITT(0,0)
      END
C
C
C
C
C
C
C
C
      REAL FUNCTION FACT(H)
C
C
C     ***************************************************************
C     ***************************************************************
C     **                                                           **
C     ** SIMPLE FUNCTION TO COMPUTE FACTORALS WHICH ARE NEEDED FOR **
C     ** SOLVING THE POLYNOMIAL CONSTANTS.                         **
C     **                                                           **
C     ***************************************************************
C     ***************************************************************
C
C
      REAL H,FACT1
      INTEGER I
      FACT1=1.
      IF (H.GT.1) THEN
       DO 10 I=1,H
        FACT1=FACT1*I
 10    CONTINUE
       END IF
      FACT=FACT1
      RETURN
      END
```

```
      SUBROUTINE CURVE(N1,N,XY,FAC)
C
C
C     ****************************************************************
C     ****************************************************************
C     **                                                            **
C     ** THIS SUBROUTINE IS THE PART OF THE PROGRAM THAT ACTUALLY   **
C     ** COMPUTES AND DRAWS THE BEZIER CURVE.                       **
C     **                                                            **
C     ****************************************************************
C     ****************************************************************
C
C
      INTEGER FAC(0:50),P,I,A
      REAL N1,N,XY(2,0:50),T,S,SUM(2)
      DO 20 I=0,N
       CALL POINTA(XY(1,I)-9,XY(2,I))
       CALL DRAWA(XY(1,I)+11,XY(2,I))
       CALL POINTA(XY(1,I),XY(2,I)-16)
       CALL DRAWA(XY(1,I),XY(2,I)+16)
 20   CONTINUE
C
C      THIS LOOP IS CONTROLED BY THE INCREMENT CONSTANT.  THE
C      INCREMENT CONTROLS HOW MANY POINTS WILL BE PLOTTED FOR A
C      SINGLE CURVE.
C
      DO 90 T=0,1,N1
       SUM(1)=0.
       SUM(2)=0.
       DO 80 P=1,2
        I=0
        IF (AINT(T).NE.1.) THEN
        SUM(P)=XY(P,I)*((1-T)**N)
C
C      THIS DO LOOP DOES THE ACTUAL SUMMATION OF THE BEZIER
C      EQUATION.
C
        DO 70 I=1,N-1
         S=FAC(I)*(T**FLOAT(I))*((1-T)**(N-I))
         SUM(P)=SUM(P)+(XY(P,I)*S)
 70     CONTINUE
       END IF
        SUM(P)=SUM(P)+(XY(P,N)*(T**N))
 80    CONTINUE
C
C      THE FOLLOWING STATEMENT PLOTS THE SOLVED POINT.
C
       CALL POINTA(SUM(1),SUM(2))
 90   CONTINUE
      RETURN
      END

      SUBROUTINE MOD(N1,N,XY,FAC)
C
C
C     ****************************************************************
C     ****************************************************************
C     **                                                            **
C     ** THIS SUBROUTINE IS TO HELP THE USER MODIFY A CURVE.        **
C     **                                                            **
C     ****************************************************************
C     ****************************************************************
C
C
      INTEGER FAC(0:50),I,J,A
      REAL XY(2,0:50),XY1(2,0:50),N,N1,N2
      N2=N1
      OD 40 I=0,N
C
C      THE NEXT FIVE STATEMENTS CAUSE THE CONTROL POINTS TO
C      BLINK.
C
       CALL PCOLOR(7,1)
       CALL POINTA(XY(1,I),XY(2,I)-16)
       CALL DRAWA(XY(1,I),XY(2,I)+16)
       CALL POINTA(XY(1,I)-9,XY(2,I))
       CALL DRAWA(XY(1,I)+11,XY(2,I))
       CALL MOVABS(0,930)
       CALL ANMODE
C
C      THE CALL VCURSOR SETS UP THE CURSOR WHICH IS MOVED BY THE
C      "ARROW" KEYS.
C
       CALL VCURSR(A,B,C)
       CALL PCOLOR(7,0)
C
C      IF A "M" IS INPUT THROUGH THE CURSOR, THE PROGRAM WILL
C      ASK FOR A NEW INCREMENT CONSTANT.
C
       IF (A.EQ.77) THEN
        CALL MOVABS(0,0)
        CALL ANMODE
        WRITE(6,35)
 35     FORMAT(1X,'INPUT NEW INCREMENT CONSTANT ?',$)
        READ(6,*)N2
        CALL DARK
        DO 36 J=2,36
         CALL POINTA(1.,FLOAT(J))
         CALL DRAWA(900.,FLOAT(J))
 36     CONTINUE
        CALL LIGHT
        N2=1/N2
        CALL MOVABS(0,930)
        CALL ANMODE
        CALL VCURSR(A,B,C)
        END IF
       CALL POINTA(XY(1,I),XY(2,I)-16)
       CALL DRAWA(XY(1,I),XY(2,I)+16)
       CALL POINTA(XY(1,I)-9,XY(2,I))
       CALL DRAWA(XY(1,I)+11,XY(2,I))
C
C      IF "I" IS INPUT THROUGH THE CURSOR THE OLD LOCATION IS
C      TRANSFER TO TEMPORARY STORAGE.  A SPACE BAR WILL TAKE A
C      NEW LOCATION AND TRANSFER IT TO TEMPORARY STORAGE.
C
       IF (A.NE.73) THEN
        CALL POINTA(B,C-16)
        CALL DRAWA(B,C+16)
        CALL POINTA(B-9,C)
        CALL DRAWA(B+11,C)
        XY1(1,I)=B
        XY1(2,I)=C
        ELSE
        XY1(1,I)=XY(1,I)
        XY1(2,I)=XY(2,I)
        END IF
 40   CONTINUE
C
C      THE FOLLOWING TWO STATEMENTS ERASE THE OLD CURVE AND THE
C      NEXT TWO STATEMENTS DRAW THE NEW ONE.
C
      CALL PCOLOR(0,0)
      CALL CURVE(N1,N,XY,FAC)
      CALL PCOLOR(7,0)
      CALL CURVE(N2,N,XY1,FAC)
C
C      THIS DO LOOP TRANSFER THE TEMPARORY STORAGE TO STORAGE
C      TO BE PASSED BACK TO THE MAIN PROGRAM.
C
      DO 50 I=0,N
       XY(1,I)=XY1(1,I)
       XY(2,I)=XY1(2,I)
 50   CONTINUE
      RETURN
      END
```

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POINT OF VIEW

THE PROBLEM OF ABANDONING FUNDAMENTALS IN ACADEMIA

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While there are few propositions about which there is universal agreement at the university, that would appear to be the case for the proposition that undergraduate students learn something other than fundamentals, at least to the extent that reading articles in Engineering Education would reveal. Exceptions appear in the form of those few recommendations oriented towards placing engineers experienced in industry in the classroom rather than engineers who have been students all their life. Another exception might be the acceptance of instruction in applications at the graduate level. In either case, it is not likely that proposals such as these would point out a significant reduction in the instruction of fundamentals.

The arrival of computers has changed society as much as any other modern development, creating a problem of identifying what is fundamental in a rapidly changing field. The lack of discussion on this point may not be motivated as much by the perception there is no problem as much as by the idea of having to question the "scared cow" of teaching fundamentals. There appears to be a complete absence of insistence that instruction in computer language start with the fundamental machine assembly language, rather than say, application languages. Is it possible that the label "scientific" language, as assigned to Fortran, is intended to create the illusion that applications are fundamental?

Indeed, it would be exactly appropriate that academia boldly proclaim this (that applications are fundamental) on the applications side of the campus, such as engineering, who apply science and business with concern for economics. If this rational proposition cannot be accepted because of the inertia and habits of the past, then it may be impossible to find a way to react when the problem reappears under other labels -- such as computer graphics, computer aided design, computer aided manufacturing, numerical control, or robotics. Academia is frantically trying to catch up to industry and government in these areas to be able to supply useful employees. There seems to be no attempt however to establish an acceptable philosophical approach for a proper education in these areas of urgent need. It may be that an academic Pert chart cannot be used to establish philosophic agreement prior to reaching the goal of the best engineering education. Such a Pert chart, so highly touted as a method of accomplishing objectives, is not known to exist. Most institutions establish programs as permitted by resources made available by government and industry.

In the instance of computer graphics, there is agreement that conventional graphics is the fundamental approach. Or is this only the consensus of those who teach engineering graphics?[2] Suppose, in the on-going evolution of curriculum, there are not enough hours for undergraduate engineers to take both computer graphics and conventional graphics and that there are sufficient resources for computer graphics for all undergraduates. This situation is becoming commonplace. While other courses such as thermodynamics and circuits might be alternatives to cutting, the "smart" money is on the removal of conventional graphics. There would be some sentimental money placed elsewhere by those who teach engineering graphics. The "smart" money would have no difficulty creating the (perhaps wrong) conviction that high schools are providing the fundamental graphics needed.

We should recognize what is fundamental in computers. There is already agreement about what is fundamental in graphics, be it taught at university or secondary school. Many schools are teaching both, but the approach is quite different. Which is fundamental, manual or computer graphics? The answer must be neither if machine language is not learned. There have been no descriptions given in the Engineering Design Graphics Journal of schools that use machine language so there will likely be no attempt to pretend that fundamentals are being taught in the computer area outside of electrical or computer engineering. The acceptance of this is important to institutions like Auburn University that use powerful canned programs (there are more respectable names like software) in their undergraduate instruction; the approach is a fundamental norm.

Those who insist that the fundamental approach is by programming, even if not by machine language, must tell why the "wheel must be designed over" and over forever. Who can or should employ the man-years that an IBM or an Atomic Energy Commission took to create graphical programs that erase hidden lines and draw stereograms? If this makes good practicable sense, educators could agree that what is fundamental has a lot to do with the type of engineer being trained and the resources of time and equipment available.

the chances are, nowadays, that industry or government has already written the desired program and the university community is about to reinvent the wheel

For civil, mechanical, chemical, aeronautical, industrial and mining engineers who want to be able to create a drawing with a computer and have only limited hours available to find out how it can be done, canned programs are fundamental. Those that feel they need better programs that produce dynamic graphics on powerful computers will have to turn to the possibilities of writing their own graphic routine. The various approaches of the University of Texas (2), Triton College (3) and Princeton University (4) may all be accepted as fundamental, even if Princeton does use its canned programs to illustrate the application of matrices to graphics. That is, students from each school know how drawings can be made with existing programs. The fact that the University of Texas students do not require programming skills (5) requires no apology nor does the recommendation that programming be integrated in the program. There is no need to consume the time of all students for the sake of those that have special interactive needs. The chances are, nowadays, that industry or government has already written the desired program and the university community is about to reinvent the wheel.

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EDGD ELECTIONS

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Ronald C. Pare' is associate professor of Mechanical Engineering Technology at the University of Houston. A member of ASEE since 1968, he has been active at the section level. Ron has served on the Creative Design Committee, Vice Chairman of the Engineering Technology Division, program chairman for the mid-year meeting, and has published in the field of engineering and technology education.

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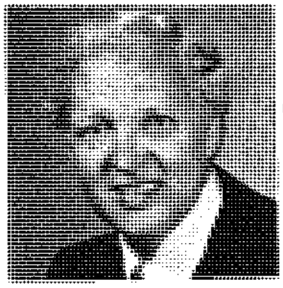

Rollie Jenison is Professor of Freshman Engineering at Iowa State University and has been a member of ASEE since 1974. He has been Program Director and Annual Meeting Program Chairman for EDGD and currently chairs the Design Education Committee. He received the Oppenheimer Award in '83 and '84. Rollie has been active in both presenting papers at EDGD meetings as well as writing articles for The Journal.

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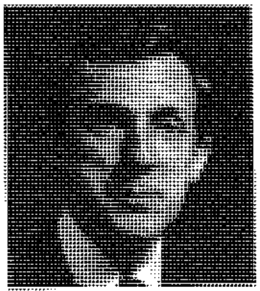
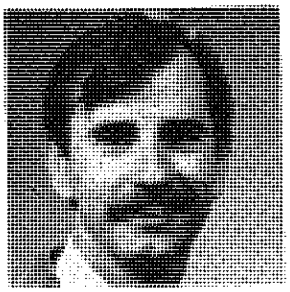


Barry Crittenden is Assistant professor in the Division of Engineering Fundamentals at Virginia Polytechnic Institute and State University. He has been an organizer for meetings in the Southeast section of ASEE and served as program chairman for a EDGD midyear meeting. Barry is active with professional engineering and scientific organizations in Virginia an has received a NASA-ASEE summer fellowship to work at the Langley Research Center.



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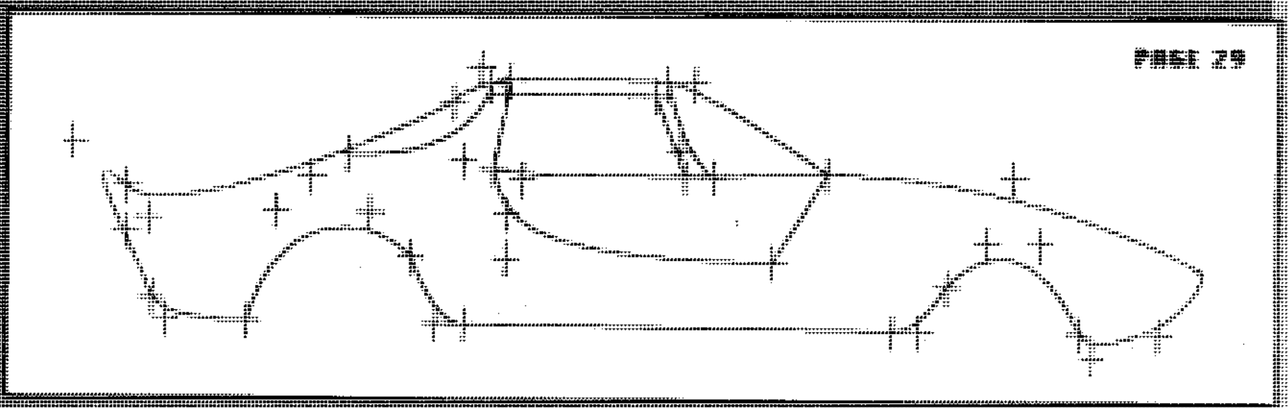

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