THE ENGINEERING DESIGN GRAPHICS

Journal

Autumn 1986 Volume 50 Number 3

ENGINEERING DESIGN GRAPHICS DIVISION

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

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Knowledge is of two kinds:
We know a subject ourselves
or we know where we can
find infomation upon it.

Samuel Johnson

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PUBLICATION BOARD

CALENDAR OF EVENTS

ASEE ANNUAL CONFERENCES
1987 RENO hosted by The University of Nevada at Reno
1988 PORTLAND hosted by Portland State University

EDGD MIDYEAR MEETINGS
1986 AUSTIN hosted by The University of Texas at Austin
1987 LOUISVILLE hosted by The University of Louisville
1988 EVANSVILLE hosted by The University of Southern Indiana
1989 TUSCALOOSA hosted by The Universityof 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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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-September 15; WINTER-December 1; 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. SIX 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 to 4.25" in width. 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 cardboard to prevent bending.

Continued inside back cover.

VOLUME 50 NUMBER 3

THE ENGINEERING DESIGN GRAPHICS

Journal

ENGINEERING DESIGN GRAPHICS DIVISION

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Departments

Features

FROM THE DESK OF THE EDITOR

This appears to be the issue to share some reflections about engineering education and other things. I hope it gets you thinking, and reflecting.

Of Distant Lands

I just returned from the 1986 European Society for Engineering Education (SEFI) meeting in Edinburgh, Scotland with my eyes opened. Not the first time to Europe, it solidified my perceptions about the similarities and differences in what is done on the two sides of the Atlantic. First off, engineering education is vastly different in Europe from what we do here. Compared to them we are training not engineers, but scientists. Their version of engineering is more a blend of industrial design and engineering technology, producing a practicable generalist that is in great demand these days. Oddly enough, they worry about the U.S. and Japan, just as we worry about them and the Japanese. It points out that everybody is worrying about the Japanese. The speakers at the conference were generally talented orators, higher quality lecturers than one hears at ASEE meetings, possibly because the lecture is still their primary delivery tool. European professors are less harried than their U.S. counterparts—more gentile—probably due to a less competitive faculty structure. But then their status is only slightly above that of an itinerant music teacher.

Watch the Lips, Son

Computer mania has not yet hit Europe. Computers exist, they're used, but the cult status they've attained here appears to have passed them by. I have a list of possible explanations. The first is our predeliction to treat engineering and computing as sciences. They don't even call it "computer science" over there. It's INFORMICS, like electronics or mechanics. And remember, they knew what the "real" sciences were before we were even a gleam in Chris's eye. Second, personal computers are very expensive in relative terms over there so you have fewer digital sacophants. Since literally no one enters engineering studies at age 17 or 18, rather their typical engineering student is 20 or 21, the hacker / nerd syndrome has been broken by the harsh realities of the foundry. Lastly, computer companies, and by default I mean American computer companies, appear to treat European colleges and universities even more contemptuously than their state-side norm. We have learned that computer salesmen tell the truth only when their lips are not moving. Europeans can't even get them to talk.

When Right is Wrong

The Scots are lucky. Not only don't they have to worry about an armed populace (or armed police for that matter), they are forced by their substandard road system into a sophisticated process of give-and-go that keeps everyone moving, albeit quite slowly. They're also lucky to have access to some of the finest and most unusual motorcars available. They must have ten times the diversity of utility vehicles that have we. The thing that bugs me is that many are made by Ford and GM of Europe—clearly superior to their offerings here. If you think small vans are hot here you should see their diversity. Every thing from ones you could park in your closet to dozens of different models like our mini vans. Of course, the U.K. professors kidded me about us driving on the "wrong " side of the road...and car. I thought about it a lot. I figure if God had intended man to drive on the right side of a car, then the vast majority of humans would have been made left-handed. I'll take my gear selector at my right hand, thank you, even if my bonnet is dented, silencer worn out, dampners soggy, wings rusted, and my overriders have long since dropped off.

> "Americans are not impressed with the 55 mph speed limit one bit....."

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Midyear Meeting Attracts over 35 Papers

University of Texas/Austin Plays Host

The 1986/87 **ASEE/EDGD** Midyear Meeting scheduled for January 6-9, 1987 should be the focal point of interest for graphics and design educators throughout the country. Meeting facilities chairman Ron Barr states that a special highlight of the meeting is a Thursday afternoon panel session on "Industrial Requirements for Engineering Graphics in the Next Decade." Guest speakers have been invited from industry to present their viewpoints on how engineering graphics will change in practice as we proceed into the next century. They will hopefully provide us with insight on how we can better prepare our engineering graphics students for the future. This session, coupled with last year's educators' forum at the Midyear at Purdue, should provide valuable information.

Four technical sessions feature speakers from the United States, Canada, Europe, and Mexico, providing an "international flavor" to what will undoubtedly be a great conference.

Midyear at a Glance

January 6

- 2:00 – 6:00 Check-in and Registration
- 2:00 – 6:00 Vendor's Exhibits
- 3:00 – 6:00 Executive Committee
- 6:00 – 8:00 Dinner (on own)
- 8:00 – 10:00 Wine and Cheese Social

January 7

- 8:00 Registration
- 8:30 – 12:00 Introduction Technical Session I
- 9:00 – 5:00 Vendor's Exhibits
- 12:00 – 2:00 Lunch
- 2:00 – 5:00 Technical Session II
- 5:00 Dinner (on own)

January 8

- 9:00 – 12:00 Technical Session III-A
- 9:00 – 12:00 Technical Session III-B
- 12:00 – 1:00 Lunch (on Own)
- 1:00 – 4:00 Free Time
- 4:00 – 5:30 Industrial Panel Session
- 6:30 – 10:00 Social Hour and Awards Banquet

January 9

- 9:30 – 11:30 Tours of U.T Graphics Facilities
- 11:30 – 1:00 Lunch (on own)
- 1:00 – 5:00 Mini Workshop Holguin CAD (Special Registration Required)

Chairman

Continued from page 5

add activities in newly developing technologies. To this end, I have asked a small study group to meet with me in Austin to discuss things such as membership goals, committee structure, and our role within ASEE. I will bring any productive results from the study group to the Executive Committee for formal discussion and possible action.

What areas are most beneficial to the Division? I have some ideas and I know you do also. I will be discussing some of mine in upcoming messages from the chairman. I would like you to convey your ideas by letter or telephone to me so that I can bring them up to the study group in Austin. Best wishes for a successful year. I hope to see "you all" in Austin.

Rollie Jenison
Chairman, EDGD

chairman

A MESSAGE FROM THE CHAIRMAN

I am honored to be serving as your Chairman for the 1986-87 year. My thanks go to Bob Foster, the immediate past chairman, who kept me posted last year on the required activities of this position.

We will continue this year in a period of transition in engineering education. In our area of engineering design/graphics the changes over the past few years have been dramatic. Recent changes of ASEE and EDGD have reflected the rapid and profound changes taking place as the result of advances in computer graphics technology. Although I am certain we all agree the computer is a great engineering tool, many of us are struggling with the role of the computer in our educational endeavors. What about 2-D verses 3-D software. Microcomputers versus mainframes? The incorporation of CAD techniques in design instruction? The role of engineering graphics in today's curricula?

One of my responsibilities as Chairman will be to ensure that the Division continues to provide you, the membership, with opportunities to (1) hear new ideas and fresh approaches to teaching, (2) present your own experiences, and (3) have a voice, through ASEE, in matters that affect our nation's engineering education programs. The success of the Division will then depend on your participation in the many activities available.

The major activity, our Midyear Meeting, takes place January 6-9, 1987 in Austin Texas with Ron Barr and the University of Texas serving as hosts. The 37 papers scheduled for presentation indicate a growing interest in design/graphics. It looks like the Austin meeting will attract a large number of us and provide a significant amount of technical information. Ron Pare' has done an admirable job of organizing the program.

"perhaps we need to reduce our broad scope of activities and concentrate on strengthening areas of benefit...."

Under the direction of Edward (Dale) Galbraith as Program Chairman, and Josann Duane as Program Director, the 1987 ASEE Annual Meeting has been put together. There will be a session or two dealing with the use of CADD software in the teaching of graphics and a session on the status of freshman design. As you can see, these programs are planned 6 months to a year in advance. If you would like to be on a program, watch the Journal and the ASEE "News in Engineering Education" for calls for papers.

Your EDGJ has undergone a couple of changes which were discussed by editor Jon Duff in the Winter 1986 issue. A Review Board headed by Ron Barr is now governing the selection of technical papers. Also, interactive page composition software has shortened the assembly time for each Journal issue.

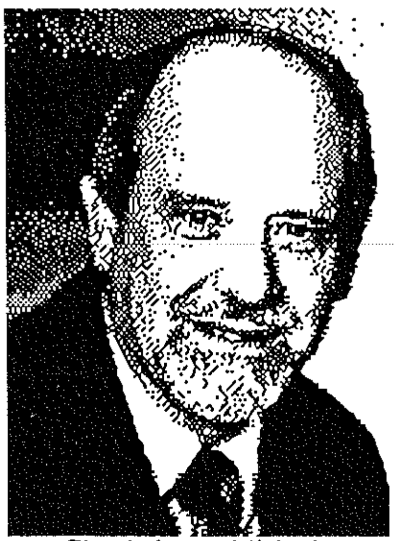
The Annual and Midyear Meetings along with the Journal provide the visibility for the Division among engineering educators. Many more activities occur behind the scenes. Our committees are addressing topics which involve liaison with other ASEE organizations and the technical activities of the Division. Other individuals and their assistants are developing future programs, managing publications, and organizing the Creative Engineering Design Display. You are encouraged to express your interests in one or more of these areas and become an active participant.

I perceive a need to look at the organization and activities of the Division in order to develop a firm sense of future direction. Perhaps we need to reduce our broad scope of activities and concentrate on strengthening those areas we feel will be most beneficial to our membership. Perhaps we need to

Continued on Page 6

1986 Distinguished Service Award

The Engineering Design Graphics Division bestowed its Distinguished Service Award for 1986 on **Claude Westfall** at the ASEE annual meeting June 24, 1986, in Cincinnati, Ohio. Claude has been an active member of the American Society for Engineering Education and the Engineering Design Graphics Division for more than 25 years. During that time he served on numerous Division and Society committees and was Campus Activity Coordinator for seven years. He was Secretary of the Division in 1971-72 and Division Chairman in 1974-75.



Claude has published problems books for engineering graphics, and texts on cartography, his area of specialty. He has sponsored a cartography workshop and received an NSF grant to develop a computer cartography laboratory.

For his dedicated service to the Division and engineering education, his devotion to students and colleagues, and as an expression of the admiration and respect by his professional peers, the Division proudly presented this award.

Editor

Continued from page 4

Things Closer to Home

Ten thousand, five hundred miles in my own Plymouth mini-van this summer brought me closer to the very heartbeat of our country. My overriding impression after this long and sometines posteriorally painful trek was that Americans are not impressed with the 55 mph speed limit one bit. The lame explanations that speed kills and that the 55 saves not only lives but mountains of fuel only impress those who don't drive (like Ralph Nader). If I had obeyed the 55, I'd still be on the road this day, my brain numbed into silly putty by 484 miles of Nebraska interstate that makes only two bends from Wyoming to Iowa. As engineers, you should avail yourselves of every opportunity to reestablish some sanity to what has become a national joke.

The trip also pointed out, beyond one family's limit in remembering every camp fire song learned since 1952, that in our country we don't have a population problem, we have a population distribution problem. We could relocate 20% of our population and they wouldn't make any impression at all on about six states. It would be well worth the $500 billion investment in bringing water and power to a hunderd sites and then offering free land and government support to grow jojoyba or some other sticky plant. Doesn't it seem ludicrous that 99% of our population lives on 5% of the land? What are the long-term social and political ramifications of this?

Nose Up to the Trough

It was disappointing to miss the ASEE annual in Cincinnati but the impetus for the earlier mentioned trip precluded my attendance: an ASEE/Navy Faculty Research Fellowship in San Diego that kept me busy for 12 weeks. At first I was honored, and then when I got there I was mad. At an informal brown-bag for the 12 Faculty Fellows I started to feel like the illegitimate child at a family reunion. Of the 12, I was the only ASEE member! Of the 12 I was the only one with an engineering/technology background! Wake up out there! Major dollars are being funneled through ASEE by the Navy to support not engineers, but psychologists, social scientists, and other fresh air outsiders. The next time the brochure comes out you can bet it will be circulated *en masse* to every humanities-type in need of support. You pay taxes too! Nose up to the trough.

IN MEMORIAM

Leon Billow, a faculty member at the Naval Academy for 26 years and long associated with the Engineering Design Graphics Division, died following a traffic accident July 13, 1986. Leon, who retired from The Academy in 1984, had recently completed a descriptive geometry text to be published by Holt, Rinehart, and Winston. He is survived by his wife Kathryn, who was injured in the accident. Our respects go to her, and to the many others whose lives were enriched by Leon's life-long devotion to teaching.

Paul speaks on wedding nights,atlantic salmon....page 8

Westfall's Comments

University of Maine Professor Awarded EDGD's Distinguished Service Award

"There are many happy people in Maine who are glad I am here tonight. As some of you know, I am an avid fisherman and spend considerable time angling for Atlantic salmon. My fellow club members have been trying to get me off the river for years during the height of the run and I guess they have you to thank for helping them.

April 10 is a day I remember very well. A few minutes before my 10 o'clock class, Arvid Eide telephoned and his first question was, "did I remember him?" How could I not remember one of the past chairmen who always impressed me as a polished, articulate, and well informed professional who has served the Division in many ways. He then informed me that I had been selected to receive the Distinguished Service Award of this Division for 1986 and asked if I would accept this award. It is not often an award is received from a group of very special friends in recognition of life-long work in an area one loves. I, of course, told Arvid yes to this unexpected surprise, and I can tell you here tonight that this is a very exciting and humbling experience. The only times I can recall being this excited and nervous were my wedding night, the first time I stood in front of a class of students eagerly awaiting their first lecture in what was then called engineering drawing, and my first Atlantic Salmon.

This award you have so generously presented to me has also been made to a number of outstanding individuals since 1950. I have known most of them and am equally proud and grateful of the Division to be included in this group."

Letters

Carving Out Some Space

Please allow a comment on Three Dimensional Graphic Modeling (Vol 50, No 2) by my good friends and former facultymates, Ron Barr and Davor Juricic.

Their paper is important in that it defines the relationships among basic terms beginning with Graphic Modeling. I suggest, however, along side the concept of 2-D and 3-D graphic modeling is another fundamental concept, 2-D graphics and 3-D graphics. The distinction between the two is clouded by the word "graphics" appearing in both terms; since "graphics" implies 2-D images how may 3-D graphics even exist?

I would pose the problem this way: What is the definitive difference between an axonometric pictorial and the same image produced in a secondary auxiliary by orthodirectional orthographic projection? I suggest the former is 2-D graphics while the latter is 3-D graphics.To be convinced we need to acknowledge that in order to accurately draw to scale the axes of an axonometric we must resort to "gimmicks" of geometry while for orthodirectional orthographic projection we do not to need to scale the axes at all, the foreshortening becomes automatic by virtue of the intrinsic qualities of the projection technique. When a pictorial is drawn we are using only the two dimensions of the sheet of paper—no matter what the image looks like. When we produce images by orthodirectional orthographic projection we are defining the locations of points of an object in 3-D space by their graphic representation. In 2-D graphics we have only the two dimensions of the paper and on which we artifically foreshorten the lines in order to actually achieve the appearance of an object. In 3-D graphics we are able to represent the automatic foreshortening of the three dimensions of space—not just lines of the object.

When we use 2-D software we may treat the CRT surface as we would a flat sheet of paper for either drawing pictorials or for projections. The latter requires trigonometry and a laborious (compared to manual) plotting of the orthodirectional orthographic images but, nevertheless, virtual space which is intrinsic to any orthodirectional orthographic projection may be created. However, the computer is capable of realizing virtual space properties of orthodirectional orthographic projection. Using 3-D software, once the object is defined within the virtual space of the computer, one may then produce any view by direct rotation (or nonorthodirectional orthographic projection).

Pat Kelso
Louisiana Tech University
Ruston, Louisiana

International Corrections

I am pleased and feel highly honored that my paper has appeared in the "milestone issue" of the EDGJ, Winter 1986, Volume 50, Number 1. However I was a little suprised when I found my paper in the Journal because I had not received any request or notice in advance. Although the paper had already been published in the (International Conference) proceedings, it is quite strange for me if it is your editorial policy. I believe it has occurred by a careless mistake or other unavoidable reasons.

However, I hardly understand my own paper (as it) appeared in the Journal because it has so many errors in printing and bad quality of figures.

The Journal has published over the past several issues, selected papers from the proceedings of the International Conference. One of the criteria used was the quality of the figures since we did not have the originals. -ed

Continued on next page

Letters, continued

After sending an apology to the author with assurance that corrections would be printed, a return letter:

Thank you for your prompt response to my letter of July 3, 1986. I am very happy that you treated my request appropriately and offer an opportunity to inform the EDGJ of our activities here in Japan.

Kazuhiko Takayama
Kobe University
Kobe, Japan

In reference to Dr. Taayama's paper (Vol 50, Number 1, pp29-32), several regretable omissions occurred in the text. The EDGJ will provide a correct copy to interested readers. Since the equations form the basis of the paper, they are presented here.

(1) $c^2 = a^2 \sin^2\theta + b^2 \cos^2\theta$,

$d^2 = a^2 \cos^2\theta + b^2 \sin^2\theta$

(2) $\cos\gamma = (a^2 - b^2)\sin\theta\cos\theta / cd$,

$\sin\gamma = a\,b / cd$

(3) $\cos\phi = a\sin\theta / c$,

$\sin\phi = b\cos\theta / c$

(4) $$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

(5) $X = 2r^2 p / (r^2 - c^2)$,

$Y = (2r^2 q - 2rc^2) / (r^2 - c^2)$

where $p = d\cos\gamma$, $q = d\sin\gamma$

(6) $$x = \frac{(r^2 + c^2)(p\cos\phi + q\sin\phi) - 2rc^2\sin\phi}{r^2 - c^2},$$

$$y = \frac{(r^2 + c^2)(p\cos\phi - p\sin\phi) - 2rc^2\cos\phi}{r^2 - c^2}$$

(7) $$\frac{x^2}{(a^2 - b^2)\cos^2\theta} - \frac{y^2}{(a^2 - b^2)\sin^2\theta} = 1$$

(8) $y / x = \pm \tan\theta$

(9) $Y = (q \pm c) X / p \mp c$

EDGD NOTES

- Nominations for the 1987 Distinguished Service Award will be solicited by Larry Goss of The University of Southern Indiana....deadline March 15,1987 Watch for a mailing early in 1987
- The International Descriptive and Computer Graphics Conference scheduled for summer of 1988 in Vienna is still on!
- A novel session is being planned for the ASEE Annual Conference in Reno. The same graphics problem will be solved by individuals on several different CADD systems. It should be interesting, Dale.
- Look for a piece on the **Japan Society of Graphic Science** in an upcoming issue.

EDGD Elections

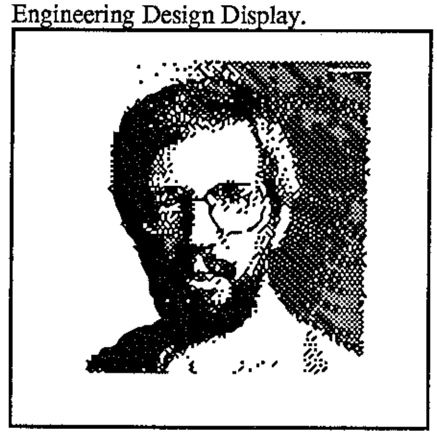
Merwin Weed Penn State University

Merwin is Assoc Prof of Engineering at PSU-McKeesport and program chair for MET in the PSU system. Active in EDGD for many years in committee, midyear, and authoring.

Vice Chairman

John Jensen Marquette University

Jon is Assoc Prof and Asst Dean of the College of Engineering at MU. As Director of Engineering Programs he has taught graphics for 10 years. Active in ASEE since 1978 in the Creative Engineering Design Display.



Vera Anand Clemson University

Vera is Assoc Prof and Coordinator of the Engineering Graphics program at CU. Active in ASEE and EDGD by presenting papers at meetings and serving as session and program moderator.

Director of Technical and Professional

Del Bowers Arizona State University

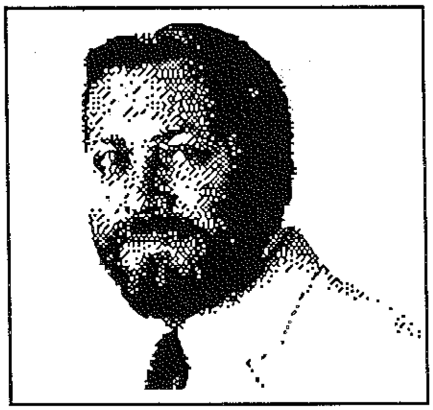
Del is Assoc Prof of computer graphics and coordinator of freshman engineering graphics. He has presented technical papers at ASEE conferences and contributed to graphics workbooks

In March, ballots will be sent out to the membership of the EDGD for the election of Vice Chairman, Director of Technical and Professional, Journal Advertising Manager, and Director of Zones. These highly qualified candidates warrent your attention. Make sure you return your ballot in March and exercise your right to vote.

Journal Advertising Manager

Jerry Smith Purdue University

Jerry has taught at PU/Lafayette for 26 years as is currently department chairman. Active in ASEE program chairman position as well as laboratory development.



William Ross North Carolina State University

Bill is Lecturer in graphics at NC State. Active in ASEE as an author, he serves as a consultant and trainer for industrial companies.

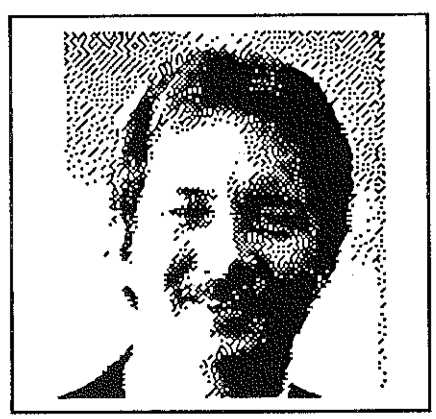
Director of Zones

Steve Mikelson Iowa State University

Steve is Asst Prof in Freshman Engineering at ISU coming from Sundstrand. A new member of ASEE, he has attended local and national meetings

Billy Wood University of Texas/Austin

Billy is a Teaching Specialist in the ME department at UT, an active author in computer graphics and CADD, and registration chairman for the 1987 Midyear meeting.



VOLUME 50 NUMBER 3

division

NEWS OF THE ENGINEERING DESIGN GRAPHICS DIVISION

Results of Questionnaire to All Members of the Engineering Design Graphics Division Regarding Computer Graphics Use

Bob Lang
Northeastern University

About this Report

This report summarizes the responses to a Questionnaire designed by Professor Robert Lang, Director of Technical and Professional Committees, Engineering Design Graphics Division, American Society for Engineering Education. It was directed to faculty involved with engineering graphics at various colleges and universities in the United States. A total of 130 responses were received. The objective of this study was to gather information regarding engineering graphics as it pertains to course structure, computer graphics usage, and hardware/software used. In addition, interest in the various committees of the Engineering Design Graphics Division was also assessed.

The Study

During the academic year 85-86, every member of the Design Graphics Division of ASEE received a questionnaire regarding his interest and willingness to serve on the committee now constituted and for suggestions on any new committees that might be needed. This was an effort to evaluate members' opinions and possibly eliminate or revise those existing committees that have been moribund and create or strengthen those that are vital.

Since computer graphics is the topic that is so ubiquitous and pervading our profession, it was decided to determine how and to what extent we as faculty are committed to it.

To the one hundred and thirty respondents please accept my thanks for your cooperation. The following are the results I promised you, along with some conclusions of my own.

Questions

1. What is the allotted time to teach graphics to engineering students; to non-engineering students?

2. Computer Graphics is what part of your Engineering Graphics Course(s)?

3. Do you teach graphics to non-engineers and if so, what percentage is computer graphics?

4. What hardware is used in your course?

5. What is the number of students per workstation? What is the desired ratio?

6. What software is used in teaching?

7. It is anticipated that computer graphics will be what part of the course by 1990?

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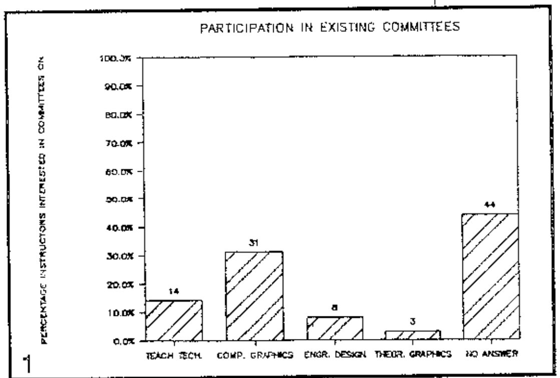
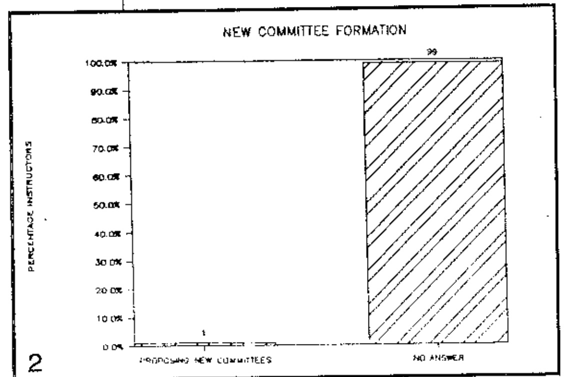
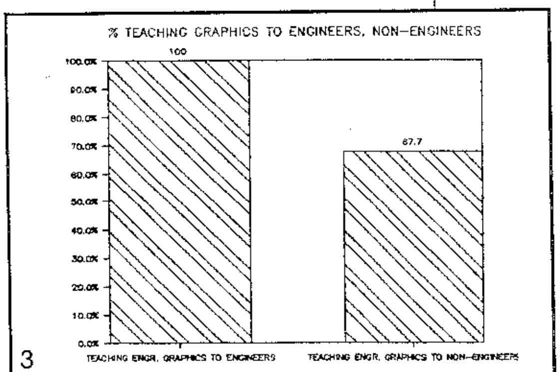

PARTICIPATION IN EXISTING COMMITTEES
PERCENTAGE INSTRUCTORS INTERESTED IN COMMITTEES ON
14
31
8
3
44
TEACH TECH.
COMP. GRAPHICS
ENGR. DESIGN
THEOR. GRAPHICS
NO ANSWER

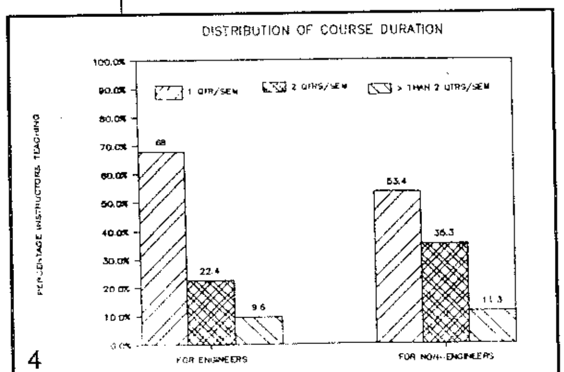
1


NEW COMMITTEE FORMATION
PERCENTAGE INSTRUCTORS
1
99
NO ANSWER

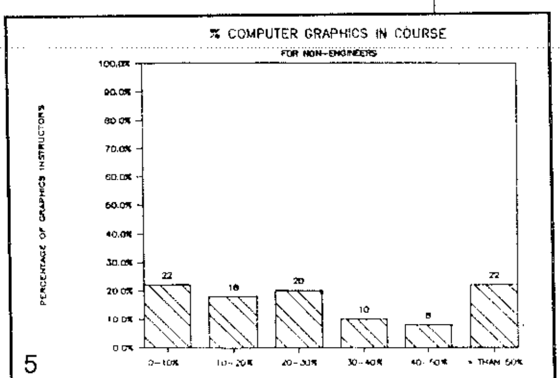
2


% TEACHING GRAPHICS TO ENGINEERS, NON-ENGINEERS
100
67.7
TEACHING ENGR. GRAPHICS TO ENGINEERS
TEACHING ENGR. GRAPHICS TO NON-ENGINEERS

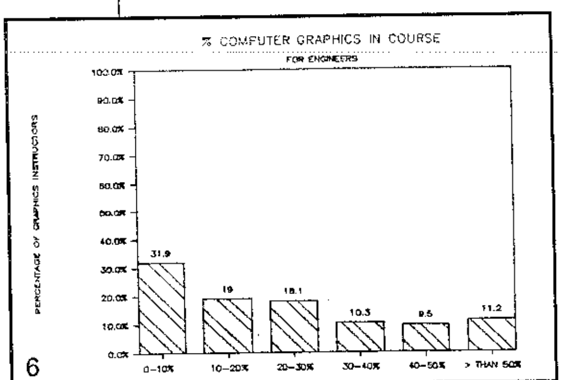
3


DISTRIBUTION OF COURSE DURATION
68
22.4
9.6
53.4
36.3
11.3
FOR ENGINEERS
FOR NON-ENGINEERS

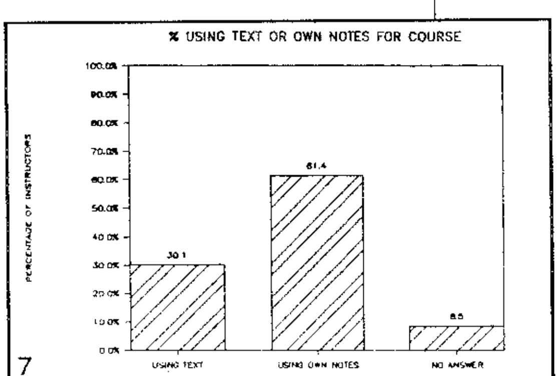
4


% COMPUTER GRAPHICS IN COURSE
FOR NON-ENGINEERS
PERCENTAGE OF GRAPHICS INSTRUCTORS
22
18
20
10
8
22
> THAN 50%

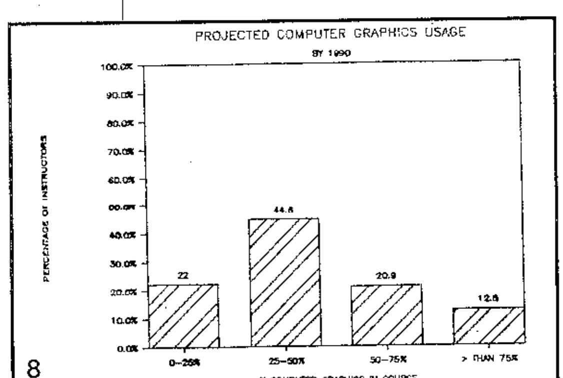
5


% COMPUTER GRAPHICS IN COURSE
FOR ENGINEERS
PERCENTAGE OF GRAPHICS INSTRUCTORS
31.9
19
18.1
10.3
9.5
11.2
0-10%
10-20%
20-30%
30-40%
40-50%
> THAN 50%

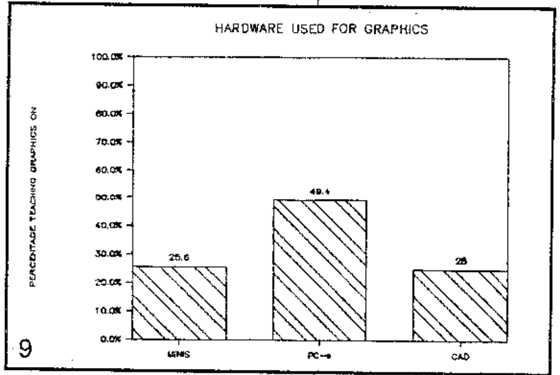
6


% USING TEXT OR OWN NOTES FOR COURSE
PERCENTAGE OF INSTRUCTORS
30.1
61.4
8.5
USING TEXT
USING OWN NOTES
NO ANSWER

7


PROJECTED COMPUTER GRAPHICS USAGE
BY 1990
PERCENTAGE OF INSTRUCTORS
22
44.8
20.9
12.8
0-25%
25-50%
50-75%
> THAN 75%
% COMPUTER GRAPHICS IN COURSE

8



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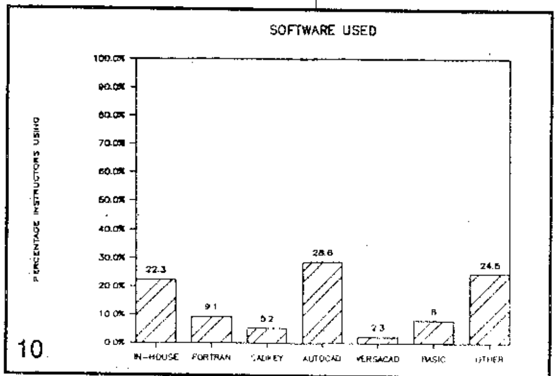

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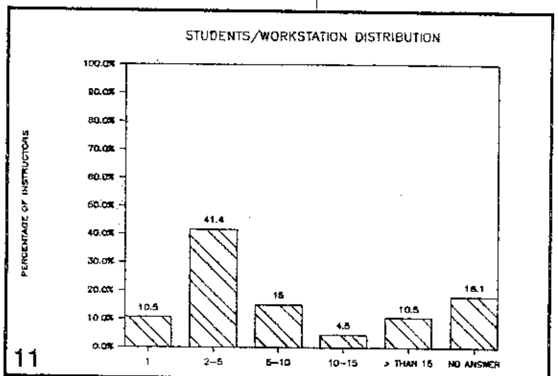

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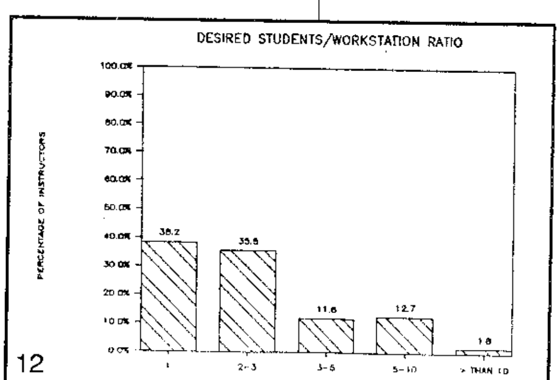

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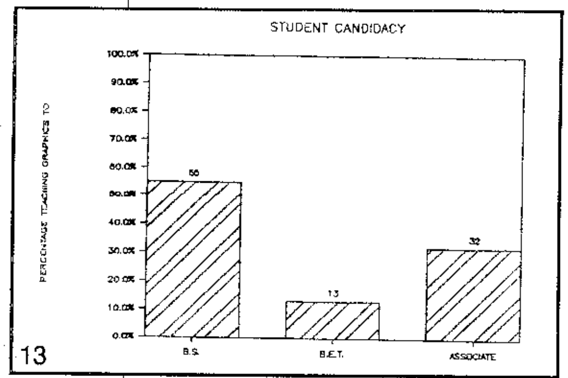

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Results

The results are shown in the following charts and present some pretty obvious conclusions such as:

A. One semester or quarter is the prevailing allotted time we have to teach the subject. If anything substantive is to be accomplished our teaching must be very efficient and address the graphics of the future and not of the past.

B. There is a suprising amount of teaching of graphics to non-engineers. Maybe we should be thinking of new opportunities to service this market.

C. While computer graphics now is 26% of our course content for engineering, 78% of faculties predict it will be up to 50% or more by 1990. As micro-based CAD improves in drawing and geometric modeling ability and increasingly provides for engineering analysis and post processing, this factor is sure to rise.

D. Due no doubt to the variety of software used and the comparative novelty of the subject matter, most faculty are resorting to use their own notes in place of a text.

E. Most people are not interested in serving on any committee or think any new ones are necessary. As could be predicted, computer graphics evoked the greatest interest.

COGNITIVE PROCESSING AND THE TEACHING OF ENGINEERING GRAPHICS

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ABSTRACT

Cerebral asymmetries and cognitive processing have constituted a major area of psychological research in the past several decades. The brain appears to process different kinds of information in different ways. Language and symbolic information appear to be processed in a mode ascribed to the left side of the brain, while spatial and visual information is processed in an opposing mode, or by the right-side of the brain.

Western culture in general and engineering education in particular seem to encourage development and rapid maturation of the left-mode processing techniques at the expense of balanced development and the maturation of right-mode processing strategies.

Implications of this research for the teaching of engineering graphics are numerous. Some have held that left-mode processing actually inhibits visual and spatial cognitive processing and interferes with the learning process in these areas. Special laboratory techniques may be needed to avoid this cognitive dissonance and to facilitate the teaching of drawing and spatial visualization to engineering students.

Such a program is underway at Arizona State University. This paper presents the approach parameters, techniques and observations of two semesters of experience with the teaching of engineering graphics to freshmen engineering students based upon cerebral lateralization and cognitive processing theory.

A two-course sequence is employed which combines the teaching of representational drawing and visualization techniques with computer graphics and applications software such as spread sheets and equation solvers for engineering analysis and design.

INTRODUCTION

A major area of psychological research in the last several decades has been cerebral asymmetries and cognitive processing. This fundamental research has been popularized in numerous books and articles as the right-brain, left-brain theory (1).

Starting with research on brain-damaged subjects, or those with surgical separation of the two hemispheres of the brain, studies have shown dramatic differences between cerebral hemispheres in the way in which the brain deals with information. For example, experimental subjects have demonstrated that the left brain is verbal, can attach names to perceived objects, while the right brain cannot. Although it can recognize familiar objects equally well, the right brain apparently cannot use symbols in its information processing.

Early research seemed to indicate that the left hemisphere is logical, analytic, symbolic, temporal and sequential, while the right hemisphere is intuitive, holistic, spatial and non-temporal. This gave rise to intriguing speculation about a physiological basis to the age old duality of man's nature: good and evil, yin and yang, scientific and artistic.

Unfortunately for those who like simplistic answers, recent research has pointed to numerous uncontrolled variables in earlier work, and many instances of behavior inconsistant with cerebral lateralization theory (2). We would be wise to proceed with caution and avoid overly broad generalizations about cerebral lateralization.

"we have introduced them to systems of projection and a great deal of arcane terminology"

COGNITIVE PROCESSING

Most researchers do seem to agree, however, that there are two distinct styles of cognitive processing. Kaufmann speaks of *parallel* versus *sequential* information processing (3) while Bever introduces the terms *unitary* and *relational* (2). We can use the term "left-mode" to stand for sequential analytic and language-oriented processing, while the term "right-mode" can be used for holistic, spatial, and intuitive, processing. We are thus talking about types of information processing, rather than specific physical brain structures.

Introspection of mental processes during problem-solving usually reveals a tidy, logical step by step process when the individual is processing in the left mode. The algorithm for solving a mathematical problem is a good example.

Right mode processing does not reveal itself to such analysis. Persons using right mode processing are not aware of sequence. The "answer" to the problem seems to come in a moment of insight. There are no "steps". Instead, the whole problem is considered at once.

While we all use both types of cognitive processing, Western culture seems very dependent upon the left-mode. Modern society itself seems very structured and time conscious. We sort people and events into labeled groups to better understand them.

Our educational system stresses left-mode strategies, such as problem solving through algorithm, sequenced curricula, and symbolic modeling. Engineering students, in particular, are products of an extremely left-mode curriculum, heavy with math and science courses.

A number of authors have suggested that our right-mode processing techniques are less developed, less mature than left-mode techniques, among them, Edwards (4), Lockard (5), and McKim (6).

These authors, and others, have pointed out that drawing and spatial visualization are essentially right-mode activities, and in order to learn to draw and to visualize spatial concepts, effective right-mode processing techniques must be developed.

LEARNING TO DRAW

Learning to draw through direct observation of nature has been a tenet of art education since the renaissance. Many artists and observers of art and art education have held that learning to see is the secret to learning to draw (7).

Betty Edwards, in her 1979 book "Drawing on the Right Side of the Brain" (4) reiterated the claim that learning to draw. But Dr. Edwards' contribution has been to employ cognitive processing theory in support of her methods of drawing instruction for art students. She contends that left-mode processing techniques actively inhibit learning to see correctly and therefore learning to draw.

The problem is that left-mode processing is analytic and symbolic. We have developed techniques of "shorting out" our information gathering senses to avoid overloading the brain with unnecessary information. When we "recognize" something, we quit gathering more sensory information about it and categorize the object with a name, or label and substitute a visual symbol for its actual appearance.

Drawing attempts by persons untrained in direct observation of form substitute symbolic shapes for the actual forms of nature. Educated persons in our culture who do this are observant enough to realize that their drawings are not representational, and do not "look like" the objects they depict, but they do not know why, and come to believe that they simply "cannot draw".

This belief occurs in most of us at ages around ten or eleven. Before this stage of development, children are not concerned with realism in their drawings. After the disillusionment of discovering that we cannot make drawings that look like nature, most of us give up and turn to other pursuits. Engineering students in particular, being adept at math, logic, and science, often turn their backs on "art", deriving satisfaction from more technical pursuits.

ENGINEERING DRAWING

Traditionally, when these students have come to us to learn about "engineering drawing", we have taught them in a very symbolic and analytic way. We have introduced them to "systems of projection", including a great deal of arcane terminology. We have asked them to attempt to form a mental image of an object by combining abstract views and symbols. We have counseled the many who are frustrated by our approach with the declaration that visualization is an important skill well worth the effort to acquire, and asked them to follow the procedures regardless of the fact that they did not understand what they were drawing. In short, traditional efforts to teach visualization have been based upon left-mode strategies. We have further held that "engineering drawing" was somehow different from representational drawing as understood by artists.

But Leonardo daVinci, the great Italian renaissance artist, inventor architect and engineer drew everything with the same techniques, from portraits, cadaver disections, to mechanical devises, buildings and fortifications. He did not shift mental gears to make artist's drawings one time and technical drawings at another. His drawings are clear, lucid and immediately understandable by anyone.

Examination of Leonardo's notebooks makes clear that he used drawing on several levels. Of course, he could express himself artistically, as he did with "The Last Supper" and the "Mona Lisa", world famous paintings. But he also used drawing as a means of formulating his ideas, as visual note-taking, and to communicate his mechanical and architectural designs to others.

DEVELOPING THE CONCEPT

Engineers may not have a primary vocational interest in drawing for artistic expression, but every engineer deals with problem-solving, with idea development, and with communication. More importantly, drawing serves as a way to understand form and space, that is, to visualize. Many studies have rated this ability as extremely important in problem solving, especially when dealing with complex problems with many variables (8). Many scientists have revealed that mental imagery is very important to their work. Could techniques used to teach art students how to draw be used effectively for engineering students? Could an engineering graphics faculty accept and employ those techniques effectively? We at Arizona State University did not know the answers to these questions, but we were determined to find out. In the fall of 1984, we partitioned our freshman engineering students into an experimental group and a control group. The control group was introduced to engineering graphics in the traditional way, while the experimental group was taught with techniques based upon right-mode cognitive processing and drawing from observation.

Data collected during this period show a remarkable growth in drawing skills in the experimental group, up to 35 percent better than improvement shown by the traditionally taught students (9). We were convinced that we had found a workable approach. The techniques employed in that fall 1984 semester are the basis of graphics instruction in our current introductory course, ECE 105, Languages of Engineering.

language, taught in the traditional manner. The three hour grphics lab is given to freehand drawing and visualization based upon techniques we have developed (10).

The second course, ECE 106, devotes its lecture and recitation portions to creativity, the design process and computer aided analysis using Supercalc 3™, and TK! solver™. The graphics laboratory portion of ECE 106 deals with graphic ideation sketching and graphic documentation using AutoCAD™ version 2.17. What are the characteristics of the method we have developed for the introductory course? First, we create a positive learning environment. We convince our incoming students that if they sign their name, they will be able to learn to draw. All that is necessary is to follow our instruction and to practice.

An atmosphere of deferred evaluation is also important. We do not criticize student drawings in the early weeks of instruction. Each student is allowed to proceed at their own pace.

"engineering drawing" was somehow different from representational drawing as understood by artists.

A two course sequence, ECE 105 and ECE 106, Introduction to Computer Aided Engineering, form part of the engineering core at Arizona State University. Each course includes one hour of lecture per week, two hours of recitation, and three hours of graphic lab.

The lecture and recitation portions of the first course, ECE 105 are devoted to Fortran 77, a computer

Students are encouraged to experience and utilize the cognitive shift to right-mode processing. During the act of drawing, students must avoid verbalization, analysis, and symbolization. They are encouraged to avoid naming of parts of the subject they are drawing, concentrating only on the form and the visual information in front of them.

Technical terminology is also avoided during this first fifteen week course. We do not discuss systems of projection, the "glass box" analogy of multi-view drawing, or other analytic approaches to technical drawing. In fact, "Technical Drawing" is not discussed at all.

Our goal is to help the students to develop mature visualization skills and confidence in their own abilities before introducing the concepts of engineering documentation drawing in the second course, ECE 105.

In this second course, we continue freehand drawing exercises, but shift the emphasis from drawing from observation to drawing from mental images. Graphic ideation, or visual note-taking is stressed. At the same time, we introduce the concepts of graphic documentation using the computer.

ECE 106 culminates in a design project where the students are required to develop their own design concepts starting with idea sketches and carrying them through the documentation phase on the computer CAD system.

Graphics are integrated with analysis and the students work in a computer intensive environment, using spreadsheets, equation solvers word processing and computer aided design packages to preform analysis, optimization, design documentation and presentation of their findings in an engineering report.

We have found that the visualization skills acquired in ECE 105 allows the students to understand and acquire the concepts of engineering documentation much more rapidly. The students leave the second course with a good understanding of the importance of the computer in an engineering environment and the tools to facilitate their progress in the rest of the engineering curriculum.

STUDENT RESPONSE

An important benefit of the approach is in student attitudes and motivation. Our student evaluations are overwhelmingly positive. Students are excited about the courses and about engineering. They feel that they have had a taste of what engineering is about and feel good about themselves and their growth. Many express that they never thought they could learn to draw and that drawing opens up whole new vistas to their personal development. We don't reach all of our freshmen engineering students with our approach. A few neglect to follow the program or do the work required. Learning to draw does require work and dedication. We can honestly tell incoming classes, however, that those who follow our program and do the drawings will show improvement, often dramatically. Our students tell us that they rate these courses as important educational experiences. One student stated: *"It (ECE 105) has improved my drawing skills tremendously. I felt that I couldn't draw at all before I came here. Now, I feel that I can draw almost anything. THANKS!!"*

And another student stated: *"I found the course an invaluable aid in the field of drawing. I could not really draw well before the course, and now, I feel that my perception and drawing skills have improved. I recommend that the course be kept for all engineers."*

And a third student: *"This course gives a good knowledge of drawing. I feel I have much more command of my hand to do drawings in physics, statics and some other courses that require sketches, diagrams, etc."*

Does our method work because it is based upon sound psychological principles? Perhaps. We don't really know for sure. But our observations of three semesters of experience convince us that we are on the right path. The fact that our students are motivated and enthusiastic may be enough in itself to produce measurable improvement in visualization and drawing skills. We at Arizona State University feel that the results we have obtained meet the needs of our engineering programs.

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DESIGN ANALYSIS IN THE FRESHMAN ENGINEERING PROBLEMS COURSE

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INTRODUCTION

The Freshman Engineering Department at Iowa State University has employed color graphics terminals in classroom settings for four years. Various uses of the computer as a tool for instruction as well as a tool for problem solving have been explored. One such use, as a tool for solving a design problem in an introductory problems course, will be explored in this paper.

DEPARTMENT AND PROBLEMS COURSE OVERVIEW

In December 1981 the Department of Freshman Engineering installed 25 color graphics terminals (DEC - "GiGi's") in a classroom and began using computer aided instruction (CAI) techniques to teach freshmen engineers. In the summer of 1985 the "GiGi's" were replaced and the system expanded to eight classrooms with color graphics terminals (DEC - VT241's). The expansion included a central processor (DEC VAX 11/785) dedicated to Freshman Engineering and VT241's for all instructor's offices (1).

These classrooms are used for the two primary course offerings of the department; Engineering Graphics with Design (Fr E. 170) and Engineering Problems with FORTRAN (Fr.E. 160). The Graphics course is approximately one-third design oriented with students working in engineering teams to study, research, and make oral and written presentations (2). The subject of this paper is the design effort that has begun in the Engineering Problems course.

The Engineering Problems course has experienced rapid changes in the last four years. The introduction of the digital computer via the FORTRAN language and interactive color graphics terminals has helped to meet the demands of 1200 engineering problem students each year. Twenty-six computer based lessons have been locally developed for use in the problems course at Iowa State. These lessons may be used as an "electronic blackboard" from which to teach during the class periods. They may also be accessed from the students' computer accounts during lab hours. At least one coverage of topics is as follows:

DESIGN IN THE PROBLEMS COURSE

The Engineering Problems course has traditionally been a place where freshman learn to solve problems and present their results using the so-called engineering method. Typically "textbook problems" have been assigned for practice in honing presentation skills. These problems however fall short of synthesis as defined by Bloom's scale (3), (4). A great deal of emphasis has been placed on design in engineering curricula by ABET (5). The "knowledge" (Bloom's scale) or "textbook" problems used so often in an engineering problems course provide excellent practice for presentation skills but do not adequately prepare engineers for the thought process necessary to solve a design problem and, therefore, do not adequately integrate the skills developed in the problems course into the whole of a design based engineering curriculum and profession.

For this reason we have chosen to introduce the role of analysis in design into the engineering problems course. We do this by devoting one class period out of

FRE 160 Coverage

Topic	Class Periods
Design	2
Engineering Fundamentals (Grading, approximations, units, etc)	6
Engineering Problems Topics (Statics, economy, balances, etc.)	7
FORTRAN	13
Testing	2

Figure 1

30 to a lesson introducing the engineer's place in the company, his participation in the design cycle, and the role of analysis in design. A printout of this lesson is included in the appendix of this paper. We attempt to inform the student that design engineers interface and communicate (both written and oral forms) with a broad spectrum of people in the company. We also explain the iterative nature of design by showing a flowchart introducing the design cycle and the"CAD loop".

The major thrust of this lesson, and the small part of the design process that we emphasize in this course, is then presented as we discuss the difference between analysis and synthesis and present an example of a design performed by repeated analysis. Throughout the remainder of the semester this lesson is reinforced by choosing appropriate "design-by-repeated-analysis" problems.

An example of a simple trigonometry problem which has been turned into a "design-by-repeated-analysis" problem is as follows.

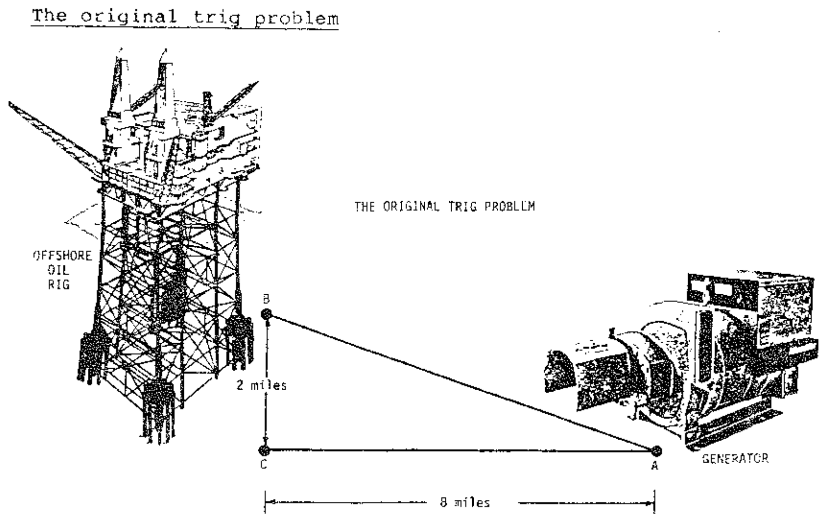

Figure 2

A utility company ran a power line from point A (the generator) to point B (the off-shore oil rig located 2 miles off shore from point C that is 8 miles down the coast from point A. If installation of the cable costs $1000 per mile, what is the total cost?

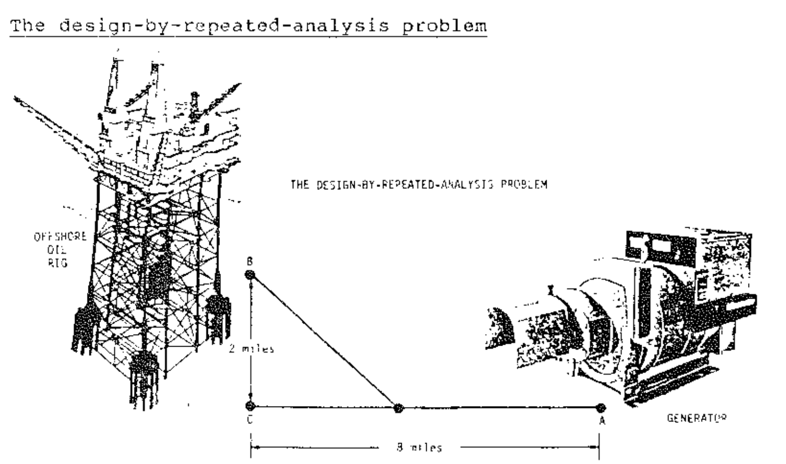

Figure 3

A utility company wants to run a power line from point A (the generator) along the shore to point D (somewhere between A and C) and then underwater to point B. Point B is 2 miles off shore from point C which is 8 miles down the coast from A. It costs $1000 per mile for cabling under water and $800 per mile for cabling on shore.

(a) derive the cost as a function of the distance from C to D.

(b) create a table of values and a plot of cost versus distance.

(c) by choosing smaller and smaller refinements of the distance value (nearest mile, tenth of a mile, etc.) find the distance which minimizes cost to the nearest penny.

(d) check your calculations by using calculus.

This type of problem allows the freshman student to immediately apply repeated analysis to a meaningful engineering problem with a scenario that he can easily comprehend. Problems introduced later in the course reinforce this principle in more complicated scenarios. Since this course also introduces the computer and FORTRAN language, many of these later problems employ the computer as an analysis tool to perform the repetitious calculations. An example of the type of problem assigned to freshmen which incorporates the computer is as follows.

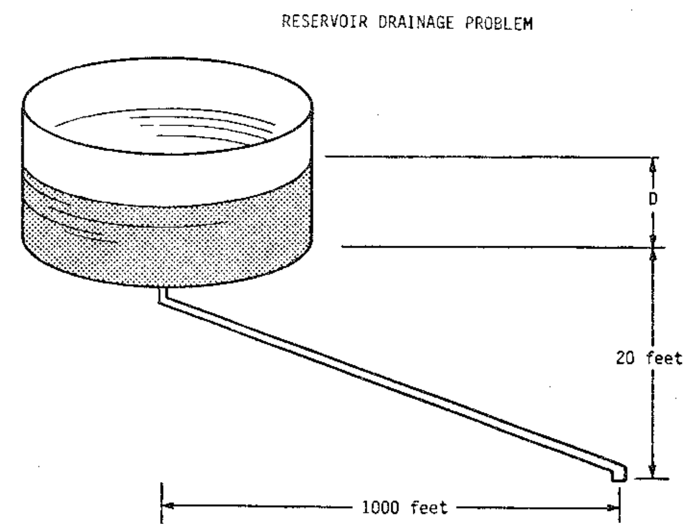

Figure 4

There are several formulas that have been developed experimentally to determine the velocity of flow of fluids through pipes. The *Manning Formula* is stated:

$$V = \frac{1.486}{N} R^{2/3} S^{1/2} \text{ where}$$

V=velocity in feet per second
N=roughness coefficient

$$R = \text{hydraulic radius} = \frac{\text{cross-sectional area, FT}^2}{\text{wetted perimeter, FT}}$$

$$S = \text{slope of the energy gradient} = \frac{d + 20}{1000}$$

The rate of fluid flow, Q, is equal to the cross-sectional area (of the pipe) multiplied by the velocity.

There is a cylindrical reservoir with radius=30.0 feet and height=40.0 feet which is filled and emptied by a 12 inch diameter pipe. The pipe is 1000.0 feet long and discharges at an elevation 20.0 feet lower than the bottom of the reservoir. The pipe has been tested and has a roughness factor, N, of 0.0130.

Part I

a) Calculate the rate of flow through the pipe when the reservoir is full.

b) Assuming a constant flow rate, how much water will be withdrawn in five minutes?

c) What will then be the depth of water in the reservoir.

d) Determine the flow rate when the reservoir is half empty and when it is empty.

e) Estimate the length of time required to empty the reservoir if it is filled to overflow.

Part II

Write a computer program that will determine the length of time to empty the full reservoir by calculating the flow rate at five minute intervals, assuming a constant flow rate for the five minute period, and continuing until the reservoir is empty. Output the time required to empty and the depth of water in the reservoir at the beginning of each five minute period.

Part III

Suggest a method to improve the accuracy of your program in Part II.

CONCLUSION

The design lesson now included in the Engineering Problems course and the more thought-provoking problems which have been assigned have provided two benefits for out students. For one thing they are better prepared for further engineering courses where they will face similar problems. For another, the students' interest in the assignments has been greatly increased. We no longer assign endless rote memorization of techniques and formulas for application to problems for homework. The availability of interactive graphics terminals has allowed our students to, in a small way, enter the design loop as a practicing engineer might and has enhanced our curriculum greatly.

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STUDY OF JOURNAL BEARING DYNAMICS USING THREE-DIMENSIONAL MOTION PICTURE GRAPHICS

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Lewis Research Center

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Lewis Research Center

ABSTRACT

Computer-generated motion pictures of three-dimensional graphics are being used to analyze journal bearings under dynamically loaded conditions. The motion pictures simultaneously present the motion of the journal and the pressures predicted to develop within the fluid film of the bearing as they evolve in time. The correct prediction of these fluid film pressures can be complicated by the development of cavitation within the fluid. The numerical model that is used predicts the formation of the cavitaiton bubble and its growth, downstream movement, and subsequent collapse. A complete physical picture is created in the motion picture as the journal traverses through the entire dynamic cycle.

INTRODUCTION

Computer graphics is becoming increasingly valuable to the engineer. It can play a vital role in analyzing complex problems by providing quick insight and understanding to an otherwise overwhelming task. The ability to output data in the form of color three-dimensional graphics to a motion picture device adds still greater versatiliy, especially for transient phenomena.

Computer motion pictures are being used at the NASA Lewis Research Center to study journal bearings subjected to dynamic loading. Under these conditions cavitation in the fluid film must be considered since it has an effect on load capacity, stiffness, damping, and power loss. Our particular concern thus far has been with the numerical modeling of the cavitation boundary conditions and the fluid film pressures as they evolve in time. The prescribed motion of a journal whirling in a circular path was chosen for the dynamic cycle so that comparisons could be made with concurrent experimental work. In this study each frame of the motion picture portrays the position of the journal relative to the housing at each instant in time. Accompanying each positional configuration is a three-dimensional pressure distribution that was determined from the numerical calculations. The formation, growth, and collapse of the bubble in response to the dynamic conditions are shown. A complete physical picture is created as the journal spins about its own axis and makes its journey through one complete orbit. In this way computer graphics makes it possible to obtain a more complete understanding of the complicated dynamics that may be encountered.

JOURNAL POSITION AND MOTION

The position of the journal relative to the housing is shown in the upper left corner in each frame of figure 1. The outline of the journal surface is represented by the dotted circle and its center by the smaller "+" symbol. The bearing housing inner surface is represented by the solid circle and its center by the larger "+" symbol.

The prescribed motion of the journal center was in a clockwise circular orbit about a point fixed in space relative to the bearing center. The journal spun in the counterclockwise direction about its own axis, which was considered parallel to the axis of the bearing housing. The net result for this motion was that the fluid entrainment velocity was in the counterclockwise direction. In this particular case a complete orbit took 66.7 ms.

THREE-DIMENSIONAL PRESSURE PROFILE

Accompanying each positional configuration of the journal and housing is a three-dimensional pressure distribution that was determined from the numerical calculations. This plot represents the pressures both axially and circumferentially within the clearance between the journal and the housing. A cylindrical representation has been transformed into a Cartesian representation by making a cut in the housing (journal) surface at the maximum film position and unwrapping it end to end. This position was determined by extending the line of centers through the largest clearance space. Note that the three-dimensional plot is in a moving coordinate system that is fixed to the minimum film position (located diametrically opposite the maximum film position). The positive pressures shown in the three-dimensional plots were generated in the fluid flow inlet (converging clearance) region adjacent to the minimum film line. In the direction of rotation the pressures became negative in the outlet (diverging clearance) region. The occurrence of vapor cavitation is made possible when these negative pressures lead to tensile stresses that exceed the tensile strength of the oil or the binding of the oil to the surface.

TRACKING PRESSURES THROUGH ONE CYCLE

The figure illustrates the pressure changes as they occurred throughout the entire orbit. Part (a) represents the position of the journal within the housing and the associated pressure distribution at the initial instant in time. The pressure buildup due to the combined squeezing and sliding motion of the journal is shown for the first half of the cycle in parts (a) to (d).

The onset of cavitation occurred between parts (c) and (d), 27 ms into the cycle. The extent of cavitation is shown by the outline of asterisks in the three-dimensional plot of part (d). The upstream and downstream menisci of the cavitation boundary are outlined in the diverging clearance region in the accompanying bearing configuration.

Graphically the menisci are represented by a pair of parenthetical symbols. The orientation, size, and position of the parentheses were based on the geometry of the journal and housing at a particular moment in time. During that part of the orbit in which cavitation was present, the orientation, size and position were constantly changing and had to be redetermined to comply with the geometry changes and the extent of the bubble.

Proceeding from (d) to (e) shows the journal (near the minimum film line) separating from the bearing. The initial stages of separation created a suction effect, causing the pressure hump to dissipate and the vapor bubble to expand. As the journal continued to pull away from the housing, the side flow became dominant because of the increased clearance. This resulted in the collapse of the bubble. In this particular case the bubble drifted downstream and crossed the maximum film line (part (f)) before collapsing. Thus figure 1, and particularly the motion picture, created a complete physical picture of the fluid film behavior as the journal spun about its own axis and journeyed through one complete orbit.

CONCLUDING REMARKS

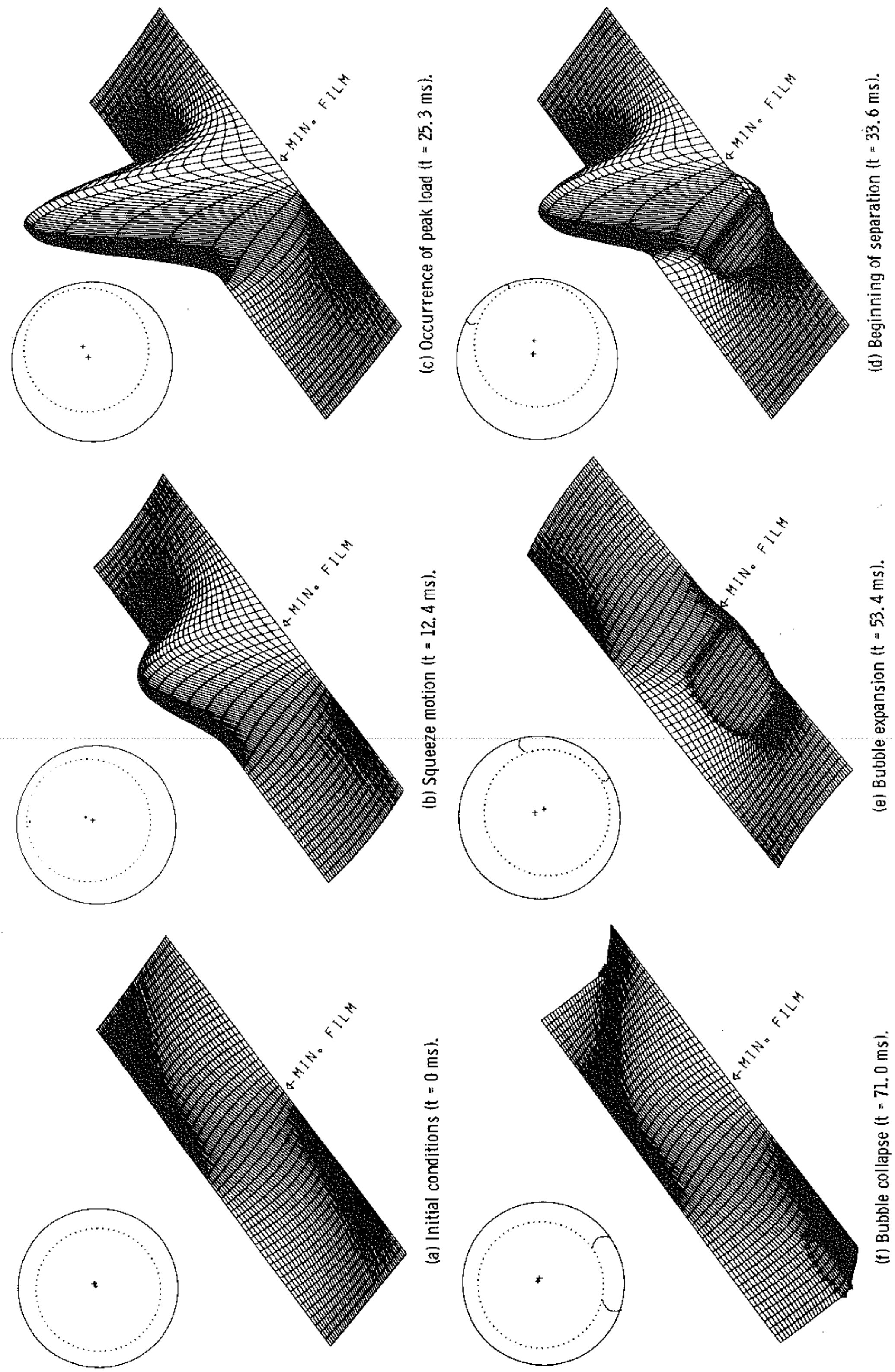
Three-dimensional graphics has been an extremely useful tool in analyzing journal bearings subjected to dynamic loading. Furthermore the capability to output the graphics to a motion picture device enables one to effectively and efficiently analyze transient phenomena resulting from dynamic loading. This motion picture afforded a visual recording of the motion simultaneous with the pressure map, which depicted the formation, growth, and subsequent collapse of the cavitation bubble. As a result a complete physical picture was created as the journal traversed the entire dynamic cycle.

APPENDIX - GRAPHICS SYSTEM OVERVIEW

The computer graphics presented herein were generated by NASA Lewis' interactive three-dimensional graphics system known as GRAPH3D. This system, developed entirely in-house at NASA Lewis, is a large-scale, general-purpose graphics package based on the ACM Siggraph core specifications with several unique features added. Among these features are (1) a versatile interface that allows a user to create graphics either from Fortran or directly from command language; (2) one-command, device-to-device switching at any point; (3) alternative hidden-line, hidden-surface, or shaded renderings obtained with a single command and without reexecution of user code; and (4) a rich family of higher level primitives so that complex plots may be constructed in relatively few graphics calls or commands. In addition GRAPH3D makes available special tools to aid the scientific and engineering graphics application.

Currently GRAPH3D runs on a IBM 370/3033 operating IBM's TSS (Time Sharing System) and on an Amdahl 5840 running VM/CMS. At the moment more than a dozen different devices, ranging from an off-line Zeta pen-plotter to high-performance interactive terminals such as the IBM 5080 are supported. During prime hours GRAPH3D system usage averages 20 to 30 simultaneous users. Applications include standard two- and three-dimensional vector and point

Continued on Page 48



(a) Initial conditions (t = 0 ms).

(b) Squeeze motion (t = 12.4 ms).

(c) Occurrence of peak load (t = 25.3 ms).

(d) Beginning of separation (t = 33.6 ms).

(e) Bubble expansion (t = 53.4 ms).

(f) Bubble collapse (t = 71.0 ms).

Figure 1. - Pressure distribution and bearing configuration for a full period of shaft whirl. Figures (a) to (f) viewed in clockwise order are consecutive in time.

KALEIDOSCOPE: A GRAPHIC ARTS AND DESIGN SYSTEM

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INTRODUCTION

Kaleidoscope is a comprehensive computer graphics program for artists, designers, engineers and architects. Kaleidoscope combines a highly effective user interface with a wide range of tools for manipulating two-dimensional design elements and color. Full color, computer generated images can be reproduced in the form of high resolution slides.

DEVELOPMENT

Kaleidoscope is the result of an experimental class offered at the University of Michigan in the spring of 1984. The class consisted of thirty students. Fifteen were senior level art students, mostly graphic designers, having little or no experience with computers. The remaining fifteen were senior level engineering students, all having two or more semesters of computer graphics. In the first two lectures the artists were introduced to the computing system from a user's point of view. They were taught some of the vocabulary and terminology necessary for communicating with the engineers about the system. The engineers were provided with technical manuals and introduced to the specific requirements of the system. Simple assignments were made to each group to bring them up to speed on the new system.

HARDWARE

Kaleidoscope is written for a Raster Technologies Model One workstation. The Model One color graphic display controller forms the heart of the workstation. It includes three 8-bit programmable Look-Up-Tables, allowing over 16 million simultaneously displayed colors. Images are displayed on a Raster Technologies high resolution (512x512) color video display monitor.

A digitizing tablet, complete with stylus and puck provide the main tools for interfacing with the system. The digitizing tablet provides a one-to-one mapping to each pixel (picture element) of the display monitor. The stylus and puck can be used in conjunction with the tablet to address pixels on the display. The stylus has a retractable tip. As the stylus is moved across the tablet, a cross-hair tracks the screen. When the tip of the stylus is depressed, an interrupt is generated and the coordinate location of the stylus is saved. This provides an excellent tool for sketching. The puck has a small window with a cross-hair in it for orientation and sixteen programmable function buttons. Each button can be programmed to execute a different function when pressed.

Two cameras are available to provide visual outputs. One produces Polaroid prints for immediate reproduction. The second produces high resolution (1500x1500) 34mm color slides.

A keyboard and monochrome CRT are also provided as a means for communicating with the host computer, bringing up the system and providing a help screen for users.

DESIGN PHASE

The design phase of Kaleidoscope was very interesting from an educational point of view. The class was divided into three groups: User Interface, Display Management and Tools. Each group consisted of an equal number of artists and engineers. A broad description of the responsibilities of each group was provided, but the specifics of the system design were left to each group.

> "a highly effective user interface"

The user interface group was responsible for the design of menus and describing how the various pieces of hardware (the stylus, puck and digitizing tablet) were to be utilized.

Display Management was responsible for the design of the data-base and for coordinating the transfer of information from the various code modules.

The tools group was responsible for typography and the design of all the drawing methods, and special effects.

The groups met during class and outside of class to generate and discuss ideas. The artists told the engineers what features they would like the design system to have and how they would like these features to operate. The engineers determined which of these features could be implemented. As the various aspects of the system were implemented, the artists tested them and made suggestions for redesign when necessary.

A formal presentation of the intermediate design was given at midterm.

RESULTS

Kaleidoscope's user interface is entirely menu driven. Icons are used to represent the available commands. An icon editor is available to generate icons on the computer. The icons can be stored and recalled for menu display. Along the left margin of the display screen is a command area containing icons. This region is referred to as the main menu. Pull-down menus containing icons are available across the top of the screen. Icons can be moved from the pull-down menus to the main menu area allowing the user to create a custom menu. The stylus is used in conjunction with a digitizing tablet to select an icon. The icon that is currently selected is displayed in the current icon box located at the bottom of the main menu. Below the main menu is a parameter box that displays the options available within the current command.

A color control area is provided along the bottom margin of the screen. A palette of twelve colors is available to make selections from. Two methods for color mixing are also provided, color interpolation and hue, saturation and value mixing. Color interpolation allows the user to select two colors. The result is a gradual change of one color to the other color along the interpolation bar. Any color along the interpolation bar can be selected as the current color. Hue, saturation and value mixing are controlled by three sliders. The top slider changes the hue of the current color, the middle slider changes the saturation of the current color and the bottom slider changes the value of the current color. The Raster Tech uses an additive system of red, green and blue for color mixing. An algorithm for HSV to RGB conversion is provided in appendix A.

The database design for Kaleidoscope includes two databases. One database is stored locally on the Raster Tech and is referred to as the local database. The other is kept on secondary storage and is referred to as the secondary data base.

Polygonal definitions are stored in both databases along with information required for color and special functions.The local database is necessary for polygon manipulations such as copying, moving and deleting. Each of these manipulations requires efficient coordinate matching for polygon selection. Coordinate matching is accomplished by examining the convex hull of each polygon. The opposite corners of the convex hull are stored for each polygon.

A wide variety of tools are available. Two-dimensional figures including circles, rectangles, polygons, lines and curves are provided. Numerous painting and sketching styles are available and many special effects, including smear paint and posterization. Both smear paint and posterization use a process known as pixel averaging. The eight neighboring pixels of a selected pixel are examined. Their color values are averaged and the selected pixel is replaced with the average value of its eight neighbors. When pixel averaging is used as a painting style, such as smear paint, a smeared effect is achieved. The user can create the effect of wet paint on a canvas. The posterization tool produces a uniform smoothing or blurring of an image.

"a versatile graphics system for use in design, both technical and artistic."

The local database contains a temporary storage area. Each function performed writes data to the temporary storage area. When a new function is selected, data stored in the temporary area is written to the secondary database and to the local database and the temporary storage area is cleared. In the event that the newly selected function is an UNDO, the temporary storage area is cleared without being written to either the local or secondary database. The provision of the UNDO function allows the user to easily correct a mistake.

```
procedure HSV_TO_RGB(var r,g,b:real;h,s,v:real);
  {Given:h in [0,360] or undefined, s and v in [0,1]}
  {Desired:r,g,b, each in [0,1]}
begin
  if s = 0
     then                          {achromatic color: there is no hue}
       if h = undefined
          then
            begin                  {this is the achromatic case}
              r:=v;
              g:=v;
              b:=v
            end
          else ERROR               {error if s = 0 and h has a value}
      else                         {chromatic color: there is a hue}
        begin
          if h = 360 then h = 0;
          h:=h/60;                 {h is now in [0,6)}
          i:=FLOOR(h);             {largest integer <=h}
          f:=h - i;                {fractional part of h}
          p:=v*(1 - s);
          q:=v*(1 - (s*f));
          t:=v*(1 - (s*(1 - f)));
          case i of
            0:(r,g,b):=(v,t,p);    {triplet assignment}
            1:(r,g,b):=(q,v,p);
            2:(r,g,b):=(p,v,t);
            3:(r,g,b):=(p,q,v);
            4:(r,g,b):=(t,p,v);
            5:(r,g,b):=(v,p,q);
          end    {case}
          r=r*255
          g=g*255
          b=b*255
        end    {hue}
end   {HSV_TO_RGB}
```

A formal presentation of the kaleidoscope system was given at the end of the semester. Selected members of the business community and the university were invited. A user's manual for Kaleidoscope was prepared and a copy was provided for each person attending the presentation.

CONCLUSIONS

Many hours went into the design of Kaleidoscope. The cooperative efforts of artists and engineers was a key factor in producing a versatile graphics system for use in design, both technical and artistic.

ACKNOWLEDGMENTS

I wish to express my gratitude to Professor Richard Phillips for allowing me to assist him in the instruction of this course and to Iowa State University for supporting the preparation of this paper.

REFERENCES

J.D. Foley and Van Dam, A., Fundamentals of Interactive Computer Graphics, Addison-Wesley Publishing Company, Reading, MA, 1982.

Icons of the Kaleidoscope system are presented on the following pages.

Appendix A

Opaque Paint

By moving the brush across the tablet this causes the current color to be painted on the screen. Parameters: There are many brushes available to paint with.

Weird Paint

Allows you to experiment with an unpredictable painting style. You can create unique effects using a variety of defined and undefined brushes.

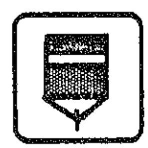
Smear Paint

Gives a wet paint effect by smearing an image. Parameters: You can choose the size of the smear brush.

Spray Paint

Allows you to create a special effect that resembles an airbrush painting technique. Parameters: You can choose brush sizes and weighting.

Pencil Paint



Allows you to draw a freehand opaque line.

Tint Paint

Creates a transparent wash of color over the existing color on the screen to blend and create a third color. Parameters: You can choose brush sizes.

Hue Paint

As the brush moves across the image, the hue of the colors on the screen will be changed to the hue of the current color. The saturation and value will not change.

Value Paint

As the brush moves across the image, the value of the colors on the screen will be changed to the value of the current color. The hue and saturation of all colors will not change. Parameters: You can choose brush sizes.

Saturation Paint

As the brush moves across the image, the saturation of the colors on the screen will be changed to the saturation of the current color. The hue and value will not change. Parameters: You can choose brush sizes.

Fill 1

Allows you to fill a shape with the current color to the nearest boundary.

Fill 2

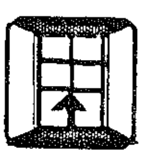
Allows you to define a shape using a certain color that may extend over a boundary that is a different color.

Posterization

A rectangular area of the screen image is selected to be posterized. Each pixel is enlarged resulting in a blocky looking image.

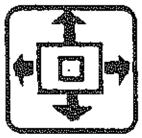
Rubber Stamp

Allows you to duplicate a rectangular area of the screen and place the duplicate in any other area of the screen. Parameters: Direction.



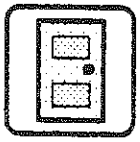
Set Window

Creates an enclosed area in which you want to work in. The remaining areas of the screen will then act as a mask.



Zoom

Allows you to select an area to be magnified. Parameters: You may magnify area 2,4 or 8 times its normal size.



Exit

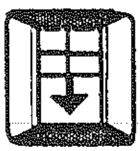
Takes you out of Kaleidoscope. Stops the program.

Get Color

Allows you to pick a color anywhere on the screen and use it as the current color.

Sketch Pad Clear

Clears the sketch pad.

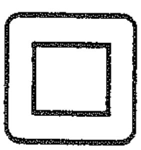


Reset Window

Allows you to remove the masked area and work on the whole screen again.

Circle

Allows you to choose a circle of any desired radius.

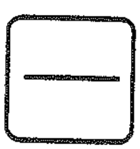


Rectangle

Allows you to choose a rectangle to any desired shape and size.

Polygon

Allows you to form any hard-edged, enclosed shape you wish with up to 49 sides.



Line

Allows you to define a straight line of any length from one point to another.

• see Ingber, inside back cover •

COMPUTER GRAPHICS: A WAY TO TEACH CNC PROGRAMMING WITH OR WITHOUT MACHINE TOOLS

Teruo Fuji and Robert Speckert
Miami University

ABSTRACT

The students in Manufacturing Engineering and Engineering Technology at Miami University are beginning to use computer graphics which simulate actual machine-shop techniques to provide a better way for them to gain a stronger understanding of manufacturing tools in a shorter period of time and with close to zero scrap-machined parts.

At Miami University, the use of inexpensive personal computers to teach computer-aided manufacturing (CAM) has made the hands-on student utilization of computer numerical control (CNC) equipment affordable. The key to using such personal computers as the IBM-PC or the Apple II (series) for CNC program generation is a software system which makes it easy for the students to create a new program or to edit an existing one.

These CNC programs can be given a trial run on the screen of the computer monitor in the form of graphics simulation. During this process, the student can safely observe a motion picture in color of the actual tool motion that would take place on the machine tool. If an error is detected, the software system provides an easy method for correcting through editing the program.

Once the student has attained a successful graphics simulation, a high-resolution plotter can be used to depict tool paths on hard copy (paper). This hard-copy plot and a program listing from a computer printer can be submitted for grading.

INTRODUCTION

Ever since the industrial revolution, man has manipulated symbols more and more, and things less and less. Even manufacturing processes have changed a great deal. Automated assembly lines with robots accomplishing the fitting, fastening and welding can work 24 hours per day and quite often in total darkness. Computer Numerical Control (CNC) machine tools turn out perfect parts often without human intervention.

To man, information is becoming a more valuable asset than material things. At one time, the education of manufacturing engineers meant long hours in machine-shop laboratories where students produced machined parts which turned out to be mostly scrap. At Miami University, the use of computer graphics which simulate actual machine-shop techniques is providing a better way for engineering students to gain a stronger understanding of manufacturing tools in a shorter period of time and with close-to-no scrap machined parts.

NUMERICAL CONTROL (NC)

The beginning of the modern machine tool industry started when John Wilkinson constructed his metal-cutting coring machine in the 1700's. This eighteenth-century machine marked the genesis of some two centuries of evolution which climaxed with the hydraulic trace-controlled copy milling machines and engine lathes.

Then came automation. It began with fixed-assembly line automation, which became popular as the automobile-assembly line. Process-control automation followed, which became popular in the manufacture of chemicals and food products and in the beneficiation processes in the minerals industry. Finally, data processing automation resulted from the development of the electronic digital computer.

After World War II, it became apparent that the metal-cutting industry was not able to meet the requirements imposed by either the consumer public or the United States Government. A U.S. Government study determined that the combined resources of the entire United States metal-cutting industry of 1947 did not have the ability to meet the needs of the U.S. Air Force, let alone anyone else.

In response to this dilemma, the U.S. Air Force commissioned the Parson's Corporation to develop a better, more flexible manufacturing system for small-to-medium production runs. In 1951, the development of the critical machine-tool control system was subcontracted by the Parson's Corporation to the Massachusetts Institute of

Technology (MIT). MIT fulfilled its contract by developing a control to drive a slide-lead screw through an interface as instructed by a programmed list of steps. Using instructions programmed onto a punched-paper tape, MIT engineers successfully controlled a Cincinnati Hydrotel milling machine in 1952. Since that time, nearly every machine-tool manufacturer in the Western Hemisphere has converted their products to this control system. This system was named Numerical Control (NC).

COMPUTER-NUMERICAL CONTROL

The evolution of Numerical Control (NC) rapidly gained momentum as the state-of-the-art electric and electronic circuit systems advanced. Beginning with electrical relays and vacuum tubes, the state of the art progressed through discrete transistor circuits and into integrated circuits. With rapidly advancing integrated circuits (IC's) came low-cost computers. This lead to Computer Numerical Control (CNC) which was successfully adapted not only to machine tools, but to practically every manufacturing process from arc welding to zeroing.

DIFFICULTIES IN TEACHING CNC PROGRAMMING

Teaching CNC programming has not been without some serious disadvantages. When a student is manually operating an engine lathe, it is easy for him or her to see that the cutting tool is about to cut through the entire part being machined or the chuck of the lathe itself. Common sense, or lacking that, self preservation will cause the student to at least stop advancing the tool toward terrible destruction. However, when a pre-programmed set of instructions is controlling the motion of the cutting tool and especially if the student is shielded from the event taking place by a heavy plate of transparent-but-durable plastic, the student is often slow to react; and the accident is over before the student has responded.

Some schemes have been devised to circumvent such problems. One method is to use inexpensive materials in place of steel for the material being worked. Such materials are also less dense and cause a lot less difficulty when the rotating work is accidentally cut through. However, if the cutting toiol is aimed at the chuck of the lathe, the difference in the density of the material being worked does not help.

At Miami University, the student actually uses CNC lathes to work real metals. But before the student is allowed to work the CNC lathes with his or her project, the student is reasonably certain that the machining will be completely successful.

COMPUTER GRAPHICS SIMULATION PROVIDES ANSWER TO CNC

With the cost of microcomputers dropping, teaching techniques which were once considered too expensive are now becoming affordable. At Miami University, the use of inexpensive personal computers to teach computer-aided manufacturing (CAM) has made the equipment affordable. The key to using these personal computers for CNC program generation is a software system called **LINK-UP/BCX™**.

The student can use **LINK-UP/BCX™** to write and store programs for CNC. As a precautionary measure, these programs can be given a trial run on the computer's screen in the form of a graphics simulation. During this process, the student can safely observe a color motion picture of the actual tool path. If an error is detected, the software system provides an easy method for correction through editing the program.

Once the student has attained a successful graphics simulation, a high-resolution plotter can be used to depict tool paths on paper. This hard-copy plot and a CNC program listing can be submitted for grading.

AN EXAMPLE USING LINK-UP/BCX™ SOFTWARE

By using **LINK-UP/BCX™**, the student can accomplish any of eight tasks which can be selected from the Main Menu as shown in Figure 1. This menu appears on the screen of the computer after loading the system software into random-access memory.

The data disk is simply a 5.25-inch soft-sectored diskette which has been formatted (initialized) for use in a particular make and model microcomputer. After the student has assigned a new CNC program number or has selected an existing program, he or she may select any of the other eight choices from the Main Menu.

The actual programming is quick, easy and powerful. No first or second-generation computer language such as FORTRAN or BASIC is required for the programming with **LINK-UP/BCX™** since it is more like programming with a software such as APT ™ which has been used with large computers since the early days of the NC machines. Such easy but powerful software enables the student to start programming quickly without having to learn countless idiosyncrasies of languages such as FORTRAN or BASIC.

```
MIAMI                                                          040201

ACTIVE CNC PROGRAM #                                           ENGLISH UNITS

              THIS IS THE MAIN MENU FOR THE SYSTEM.
              FROM THIS MENU YOU CAN:

              1 - ASSIGN OR SELECT A CNC PROGRAM NUMBER
              2 - ENTER A NEW CNC PROGRAM
              3 - EDIT THIS CNC PROGRAM - LIST TO SCREEN
              4 - SIMULATE THIS CNC PROGRAM ON THE COMPUTER
              5 - PLOT THIS CNC PROGRAM ON THE PLOTTER
              6 - PRINT A LISTING OF THIS CNC PROGRAM (PRINTER)
              7 - SEND THIS CNC PROGRAM TO THE EMCO LATHE
              8 - RECEIVE THIS CNC PROGRAM FROM THE EMCO LATHE
              9 - END THIS TRAINING SESSION

CHOOSE  1,2,3,4,5,6,7,8 OR 9
```

Figure 1

The **LINK-UP/BCX**™ actually generates standard G-codes for controlling EMCO CNC 5 training lathes. However, since the ultimate machine process is preceded by the programming, editing simulation, plotting, and listing steps--only a few training lathes need to be connected to microcomputers in the machine shop. All of the steps which come before the actual machining can be accomplished in a microcomputer laboratory. Such a separated programming-environment/machine-shop-environment situation makes it possible for a large number of students to utilize very few training lathes. A sample listing of the G-codes for the first few instructions for a CNC lather are shown in Figure 2.

A graphics simulation run of the program is an actual motion picture of the computer monitor. A color-graphics monitor shows clearer definition of various objects which are depicted in various colors. Selected frames of the motion picture for a particular program demonstration are shown in Figures 3, 4, 5 and 6. The simulation is complete with appropriate sound effects which are generated in the computer.

A more accurate graphics simulation is obtained by plotting the CNC program on a plotter such as the IBM 7371 or 7372. The plotting can usually be accomplished in two colors. The original plot was depicted in red and black. After all of these steps have been successfully accomplished and the hard copies have been approved by the instructor, the student is ready to take his or her data disk into the machine shop to machine the actual part perfectly on the very first attempt.

ADVANTAGES OF USING COMPUTER GRAPHICS

The computer simulation and graphics method of teaching CNC programming offers the following advantages:

1. It is safer. An actual wreck, such as the cutting tool colliding with the chuck of an engine lathe, would provide a genuine hazard to a student trying out his or her CNC program. With computer simulation and graphics, the wreck is not real. It is only a picture of the cutting tool impacting the chuck. To give feedback to the student that something is terribly wrong, the computer plays a "sad song".

2. It is economical. Besides saving all of the scrap work that would have been produced in the actual situation, computer simulation and graphics allow the limited few training machine tools to be utilized among a far larger number of students.

3. It is psychologically more satisfying. The sweet smell of success is unbeatable in

N	G	X	Z	F	S	T
000	84	-125	-290	90	1200	1
001	84	-150	-275	95	1200	1
002	84	-175	-260	100	1200	1
003	84	-190	-225	100	1200	1
004	84	-210	-160	100	1200	1
005	84	-235	-115	100	1200	1
006	01	-100	-450	199	1200	1
007	84	-25	-1100	90	1200	1
008	01	-25	-50	199	1200	1
009	84	-25	-1025	94	1200	1
010	01	-25	-50	199	1200	1
011	84	-25	-950	98	1200	1
012	01	-25	-50	199	1200	1
013	84	-25	-895	102	1200	1
014	01	-25	-50	199	1200	1
015	84	-25	-845	104	1200	1
016	01	-25	-50	199	1200	1
017	84	-25	-795	106	1200	1
018	01	-25	-50	199	1200	1
019	84	-25	-745	108	1200	1

TO CONTINUE LISTING PRESS C.
TO EDIT THIS PAGE PRESS E.

Figure 2

be utilized among a far larger number of students.

3. It is psychologically more satisfying. The sweet smell of success is unbeatable in teaching and learning. To think that every time that a student uses the training-machine tools, that he or she will produce a successful product is a dream come true.

4. It makes better engineers of the students. Most schools now have microcomputer laboratories. With a graphics-simulation package, the student can be using such microcomputer facilities to learn CNC programming. Then, with the trial-and-error situations already encountered and corrected, the student can actually machine his or her part successfully and with confidence. After all, isn't that what CNC is really all about?

The major advantage of using this system of program generation and testing is that all of the trial and error is confined to the microcomputer laboratory and that the scarce CNC training machines are utilized as a final step with a successfully-tested program.

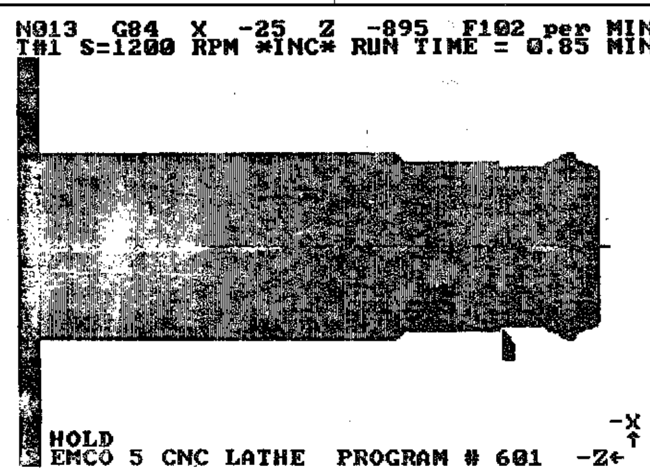
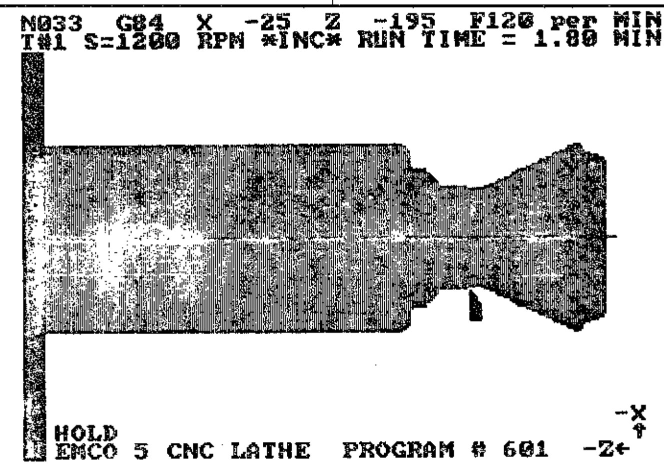


Figure 3



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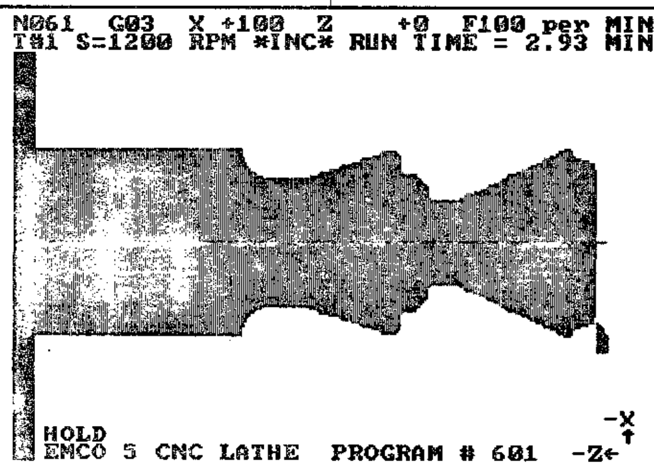

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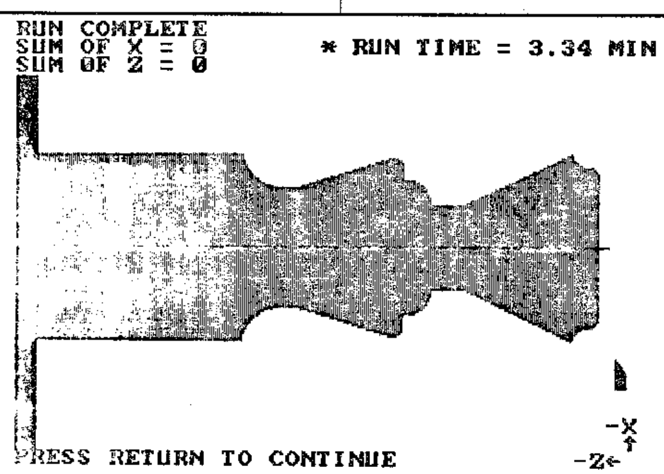

Figure 6

For schools which still do not have CNC machine tools, the same system can be used with computer-graphics simulation alone. The same software system can be used; and if such a curriculum is augmented with student work on conventional hand-crank-control machine tools, only a slight disadvantage will exist during the interim before the desired CNC machine tool becomes feasible. If the enthusiasm for CNC programming at Miami University is any indicator, any such interim of operating with an actual CNC machine tool should be mercifully short.

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ELECTRONIC GENERATION OF HIGHER PLANE CURVES AND THE CONCEPT OF DIGITAL UNLOADING

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INTRODUCTION

A complement to an earlier work by the author (Karayanakis, 1985), this article expands on the aspects of using analog computation methods in generating mathematical functions. The techniques shown are based on the direct electronic mechanization of an equation or a system of equations that represent(s) a given problem.

The analog/hybrid approach represents an ideal vehicle for the integration of electronics, mathematics and graphics. Analog signal processing peripheral to the digital computer can also make life easier for people engaged in graphics or simulation. Preprocessing of signals in the analog form is the ideal vehicle to unloading a predominantly digital system from ill-suited computational tasks. Often, unloading is requisite to handling complex problems with digital systems of finite capabilities. Yet, there is little popular understanding of the available techniques. In an attempt to fill the void, we continue here the discussion on designing and implementing mathematical function circuits.

The Hypocycloid

Hypocycloids are special cases of the cyclic curve, which is a higher plane curve. The hypocycloid can be described as the trace of a point fixed within a circle of radius b rolling around the inside of a fixed circle of radius a. The generalized hypocycloid is described by the following system of parametric equations:

$$X = (a - b) \cos t + b \cos [(a - b) t/b]$$

$$Y = (a - b) \sin t - b \sin [(a - b) t/b]$$

..................(1)

Different values for a and b will yield special cases, like those of the asteroid and the deltoid, both of which are discussed below.

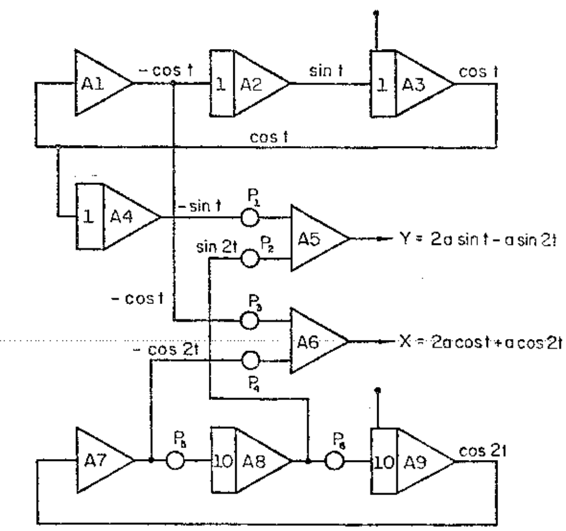

Figure 1

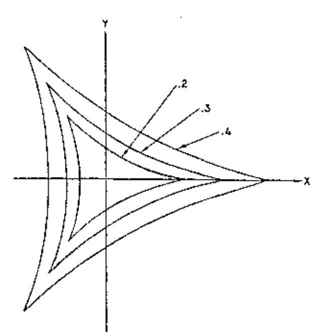

Figure 2

The Deltoid

A deltoid is a hypocycloid of three cusps formed when $\alpha = 36$. It is described by the following system of parametric equations:

$$X = a(2 \cos t + \cos 2t)$$

$$Y = a(2 \sin t - \sin 2t)$$

................(2)

The analog computer setup is shown in Figure 1. Figure 2 represents the deltoid solution with a as a parameter which can be varied by adjusting potentiometers P1, P2, P3 and P4. Care should be taken when adjusting P5 and P6 so that the coefficients on A8 and A9 are identical. If the coefficients on A8 and A9 are not the same, a phase angle is introduced into the sinusoid thereby influencing the argument so it is not an integral t-multiple and resulting in an open tracing after a complete cycle.

The Hypocycloid of Four Cusps

This is a special case of the hypocycloid curve. A hypocycloid of four cusps is formed when the radius of the fixed circle is four times that of the one rolling inside, or a = 4b. It is described by the system of parametric equations:

$$X = (a - b) \cos t + C \cos [(a - b) t/b]$$

$$Y = (a - b) \sin t - C \sin [(a - b) t/b] \quad \text{.................(3)}$$

When C > b, *a prolate hypocycloid* is generated, like those of Figures 3 and 4. When b = c, the cusps of the cycloid will be inscribed inside the fixed circle. When C < b, a *curtate hypocycloid* will appear, as shown in Figure 5. Again, care should be taken to avoid unequal settings on P5 and P6. Unequal potentiometer settings will contribute to a nonintegral relationship between circumferences, making the generation of a continuous curve per revolution impossible. Figures 3 and 4 are X-Y plotter outputs for well-matched P5 and P6 settings.

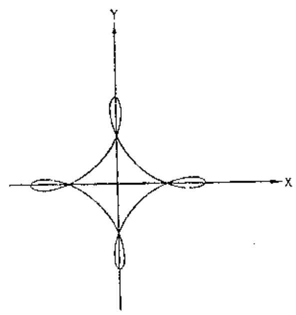

Figure 3

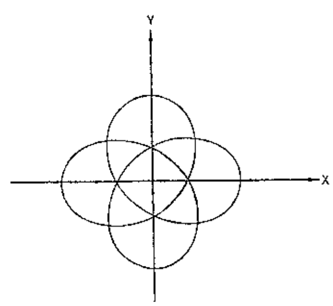

Figure 4

The Asteroid

The asteroid is also a hypocycloid of four cusps, formed when a = 4b. In this case, the generalized hypocycloid equations become

$$X = (a/4)\ (3 \cos t + \cos 3t)$$

$$Y = (a/4)\ (3 \sin t - \sin 3t) \quad \text{...............(4)}$$

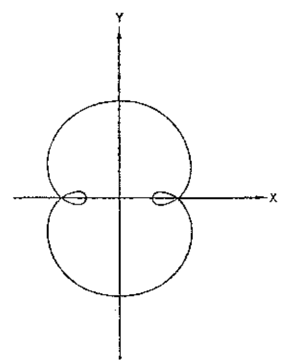

Figure 5

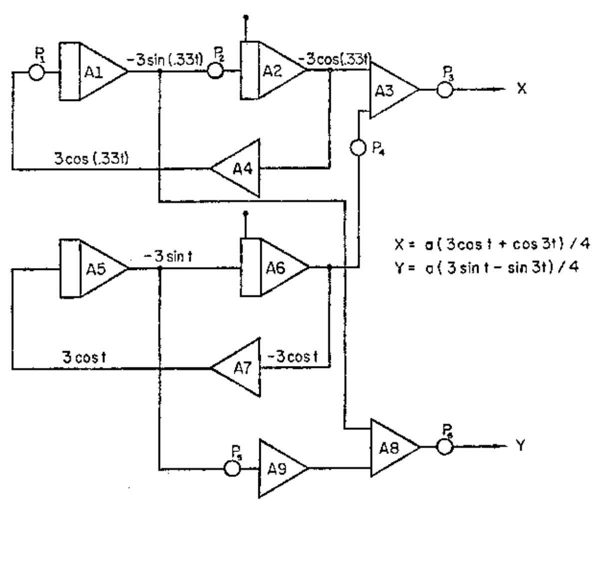

Figure 6

The analog computer setup for generating the asteroid is shown in Figure 6. The size of the output trace can be controlled by varying either the initial conditions of A2 and A6 or by the setting of potentiometers P3 and P4 which control the factor a/4. Figure 7 shows asteroids generated with initial conditions of 0.5V and

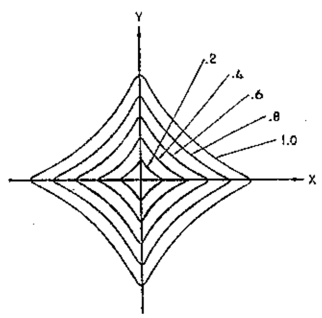

Figure 7

settings on both potentiometers P3 and P6 of 0.2, 0.4, 0.6, 0.8 and 1.0.

Hypocycloids of More Than Four Cusps

Theoretically, a hypocycloid having any number of cusps can be generated by applying the generalized Equation (1) and Equation (2). A case in point is

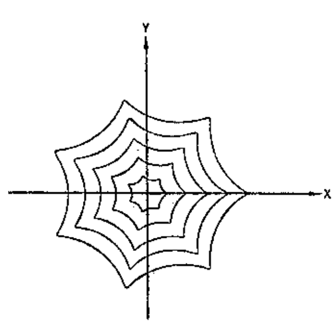

Figure 8

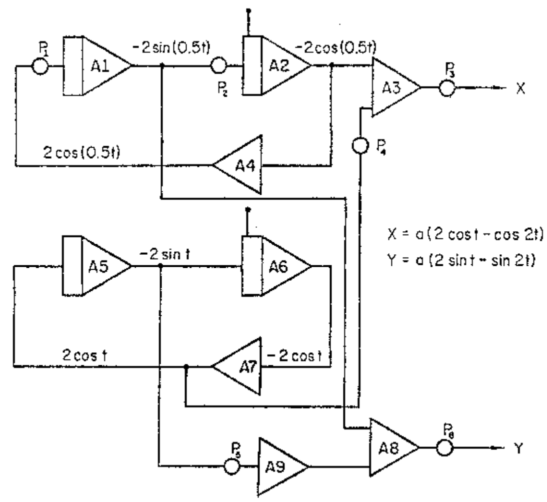

Figure 9

offered by the seven-cusp trace of Figure 8 which was generated by the computer setup of Figure 6.

The Epicycloid

Like hypocycloids, epicycloids are special cases of the cyclic curve. Epicycloids are formed when a circle of radius *b* rolls around the <u>outside</u> of a fixed circle of radius *a* and a point on the circumference of the moving circle traces out the curve. The generalized epicycloid is described by the following system of parametric equations:

$$Y = (a + b) \cos t - b \cos [(a + b)\ t/b]$$

$$X = (a + b) \sin t - b \sin [(a + b)\ t/b] \qquad \text{.............(5)}$$

Different values for a and b will yield special cases like those of the *cartioid* and the *nephroid*. In the case where the tracing point is located along a radial line of the moving circle and at a distance c from the center, if c is larger than the diameter the epicycloid can be described by the system of parametric equations

$$X = (a + b) \sin t - c \sin (a + b/b)$$

$$Y = (a + b) \cos t - c \cos (a + b/b) \qquad \text{................(6)}$$

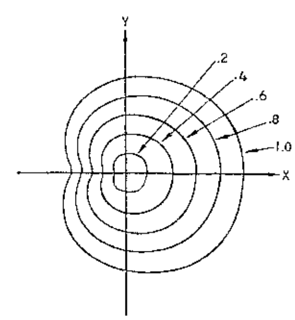

Figure 10

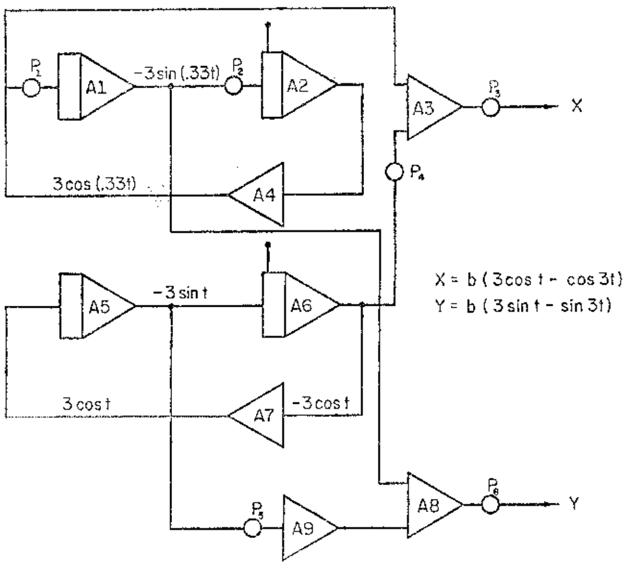

Figure 11

The Cardioid

The cardioid is an epicycloid of one cusp and is formed when a = b. It is described by the system of parametric equations

$$X = a(2 \cos t - \cos 2t)$$

$$Y = a(2 \sin t - \sin 2t) \qquad \text{..................(7)}$$

The system can be implemented on the analog computer as shown in Figure 9. Figure 10 shows cardioids generated with initial conditions of 5.6V and settings on both potentiometers P3 and P6 of 0.2, 0.4, 0.6, 0.8 and 1.0.

And Finally, the Nephroid

The *nephroid* is an epicycloid of two cusps and is formed when a = 2b. It is described by the system of parametric equations

$$X = b\,(3 \cos t - \cos 3t)$$

$$Y = b\,(3 \sin t - \sin 3t) \qquad \text{................(8)}$$

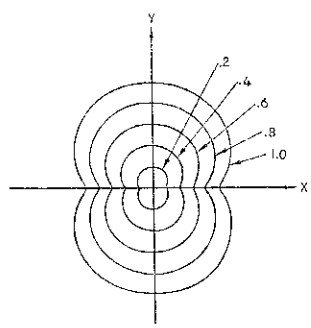

Figure 12

The analog computer implementation of this system is shown in Figure 11. A series of nephroids generated with initial conditions of 5V and a variety of b coefficients is shown in Figure 12.

CONCLUSIONS

By now, it should be obvious to anyone who managed to get to this point that straight electronic mechanization of mathematical functions is indeed another way to 'skin the cat.' To reiterate, the author has not uncovered a way to undermine the digital machine, but rather the means to augment its capabilities. It is proposed here that analog signal preprocessing is a viable way to cope with multivariate problems and help the digital computer perform to its full potential.

In the future, I hope to show that practical analog preprocessing can be real, inexpensive, and very useful.

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International Conference
Beijing, PRC

AN ATTEMPT AT COMPUTER GRAPHICS EDUCATION

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Hiroshi Isoda
University of Tokyo

INTRODUCTION

In "Graphic science" courses of Japanese universities, descriptive geometry (intersection of mechanical design and perspective views) is mainly taught in architectural fields. Recently, three dimensional geometrical processing can be automatically operated with the computer, such as computer graphics, CAD/CAM, CAE and so forth. Computer graphics and CAD education are currently taught at several universities[1-5]. We attempted to create a course in computer graphics and CAD education at our institution.

At first, to implement the experimental course, we developed **Three-Dimensional Graphics Software for Educational Use (TGSE).** This program has many functions: creation of objects such as a cube, prism, cylinder, cone, and so on; display of objects with perspective or axonometric view, including hidden line elimination; calculation of cutting line of an object and a plane; calculation of intersection line of two objects; and shading and shadow of objects. All objects are represented by approximate polyhedron with boundary-representation. By using TGSE, three dimensional geometrical processing in the former "graphic science" could be accomplished with a computer. This program's size is about 1,500 lines of FORTRAN language. In the education, TGSE was used as a geometrical processing language.

Namely, the educational aim of our program is to teach (1) how to represent or memorize figures or shapes inside the computer, and (2) how to operate or treat these geometrical data, such as in display or intersection. Thirdly, how to use these geometrical data for various application like CAD/CAM. By using this developed software as a graphic

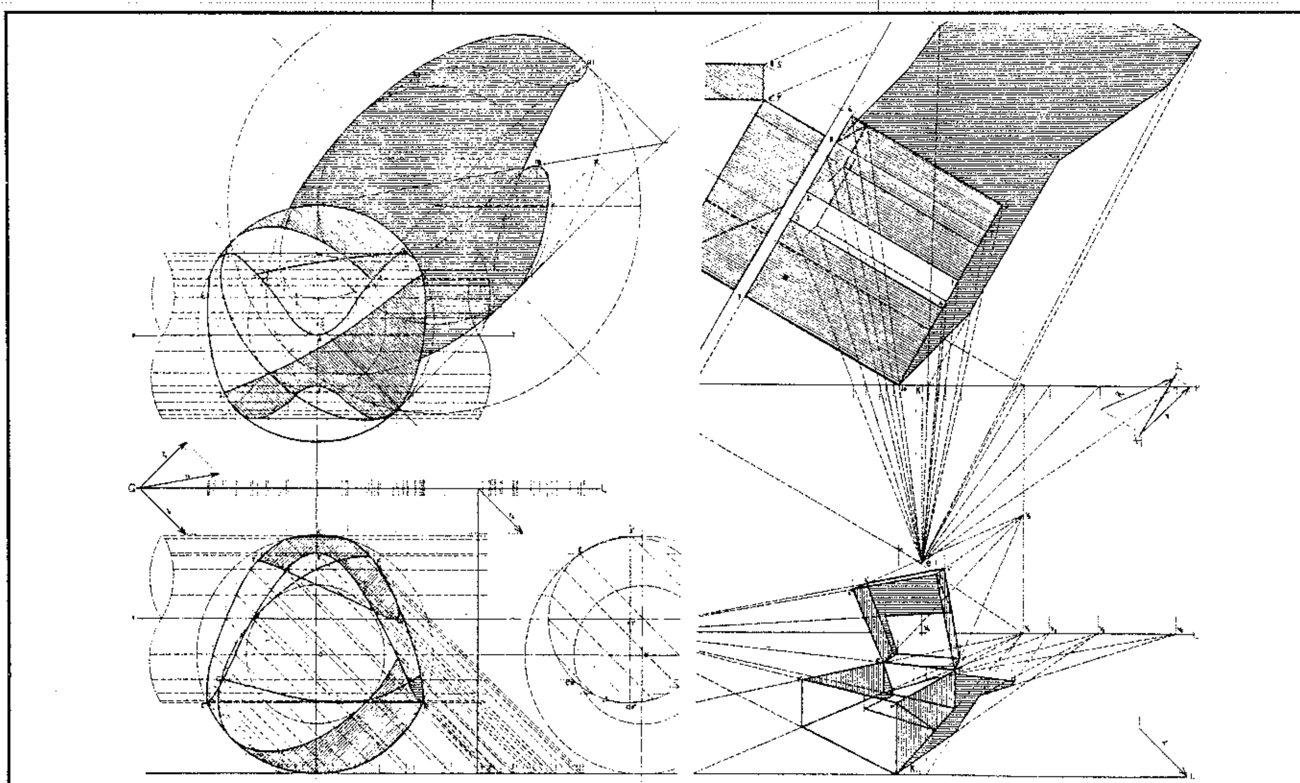

Figure 1

language, students without programming skills could create computer graphics easily. This consequently resulted in positive educational effects.

In such education, specific mechanical parts or two-dimensional figures are generally treated. But in respect to the value of geometric models in CAD/CAM or solids in descriptive geometry, it is important to conceptualize three-dimensional graphics.

geometrical processing, CAD/CAM and so on. We also present the educational contents of computer graphics in the "graphic science" course.

Contents of "graphic science" course

At first, we try to review the contents of descriptive geometry in former "graphic science" courses.

"using a graphic language was welcomed by many computer-allergic students"

We would like to present how this teaching was done and what results were derived. In the first part of the course the content of computer graphics was presented. In particular, this was decided with respect to content of the former descriptive geometry course, computer graphics and CAD/CAM, and the length of time of course and a grade of students' ability. After this the operation of TGSE was explained. Operational methods were explained in relation to the graphic processing language.

CONSIDERATION OF THE CONTENTS OF COMPUTER GRAPHICS EDUCATION

In this, we enumerate articles about three-dimensional graphics,

(1) Representation of Figures
Projection (first and third-angle projection, top, front and side views), representation of point, line, plane, and object .

(2) Operation of Figures
True form of normal projection, rabattement, intersection of a line and a plane, cutting and interpenetration of objects, development of surface, touching, shading, and shadow

(3) Single Projection
Axonometric, perspective, and oblique projections. In descriptive geometry, exactness, beauty of drawing and skills in the usage of drawing tools are often stressed. Examples of intersection, shadows and perspective view in the descriptive geometry are shown in Fig. 1.

Classifications of computer graphics contents by titles

Next, we try to roughly classify computer graphics by titles. We mostly take such titles out from three-dimensional graphics.

(1) Generation Technique
Data base, data structure, representation of objects (wire-frame, surface, solid/CSG, B-reps.), curves and surfaces (Bezier, Coons, B-spline), fractals.

(2) Processing Technique
Set operation of objects (union, subtract, and intersection), local operation (partial modification of geometrical shapes), section of objects, development of surfaces.

(3) Analysis Technique
Calculation of volume, weights, center of gravity, area of surfaces, area of sections, structural analysis by Finite Element Methods (calculation of displacement, stress, heat flow).

(4) Display Technique
Axonometric and perspective views, hidden line and hidden surface elimination, color, shading, luster, reflection, shadows, crystal (transparent and semi-transparent display), texture mapping.

(5) Application Technique
Drawing, numerical control, manufacturing, structural analysis, measurement, design, robotics. These are used in machine, automobile, boat, aircraft, architecture, plant, vessel, press, and mold fields.

Classification of computer graphics contents by fields of study

In this, we review fields of study in computer graphics theory. By doing this, we determine if the educational materials are being understood by students.

(1) Mathematics

*Analytic Geometry
Major part of computer graphics based on the analytic geometry, for example, coordinates, vectors, expression of point, line, plane.

*Algebra
Interference of figures. For example, intersection of a torus and a straight line becomes a biquadratic equation.

*Linear Algebra
Axonometric transformation for display, important transformation of figure, such as parallel translation, rotation. Linear equations are used for smooth curve generation.

*Differential Geometry
Tangent and curvature of curves, tangent plane, normal vector, mean curvature, and Gaussian curvature of surfaces.

*Topological Geometry
Euler's polyhedron theorem, fractals.

(2) Information Science, Others

*Information Science
Software science (implementation of graphic processing algorithms), data base (representation of figure's information), numerical calculation.

*Material and Color Science
Expression of realistic images, for example passing and reflection of the beam on the surface.

*Mechanical and Electrical Science
Applications of CAD/CAM, hardware of graphic devices.

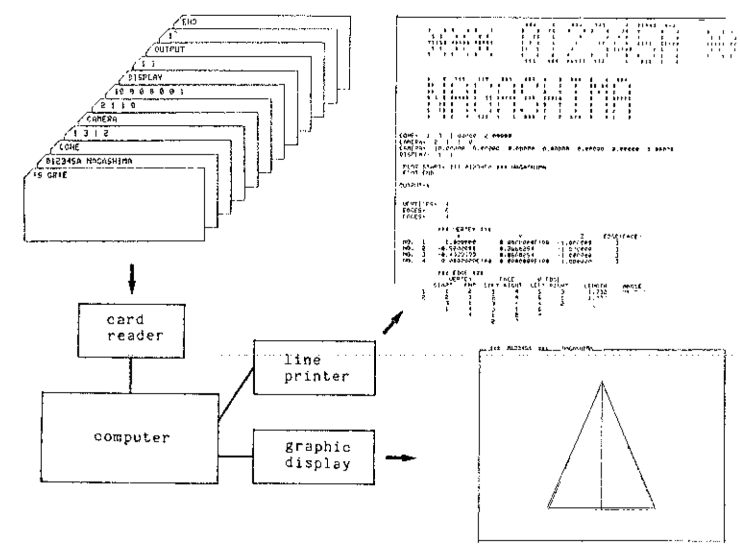

Figure 2

CONTENTS OF COMPUTER GRAPHICS EDUCATION

Some 1,000 students will be expected to enroll in computer graphics education in the future at their second year of university study. The experimental course was held with 82 students. They have already taken a course in descriptive geometry for one year, and there are some students who have programming skills for BASIC or FORTRAN language. Since the period for computer graphics education is very short, we cannot teach computer language programming. We developed this TGSE, and we use it as a graphic language instead. In place of making graphic processing in a black-box, we decided to make students describe the theory of graphic processing by writing or in an expression. We concluded that student performance depends on the level of practice and the degree of understanding of theory as written in their reports.

We presented the various articles of computer graphics as described above, but since the time is limited, we decided to take up creation, display, intersection and application of simple polyhedra. Ultimately, we divided contents of computer graphics into three subjects: (1) representation, (2) operation, (3) application of geometrical information with a computer. Detailed explanations are listed below.

(1) Representation of Figures
Educational aim of this subject is to teach how to represent or recognize figures or shapes inside the computer. In the **TGSE**, B-reps (boundary representation) which defines an object by dividing it into vertices, edges and faces. Next, students study linear transformation of figures, types of transformations and change of geometric information. Students had already

studied about transformation in general complex linear space, which includes rotation of Euler's angle, and rotation about an arbitrary axis. In this, creation and transformation of a simple polyhedra are practiced by TGSE.

(2) Operation of Figures

This subject is to study how to operate or treat these geometric data. In three-dimensional geometry, importance is placed on display or interference such as intersection and touching. A display is a matter of orthogonal and perspective transformation, and intersection is application of the analytic and topological geometry. Here, intersection of two simple polyhedra is practiced by **TGSE.**

(3) Application of Figures

This subject is to study how to use these geometrical data for various applications like CAD/CAM. In this, to understand the set operation of objects in CAD/CAM, computer practice is performed by students in freely creating desired shape model by combining some basic objects. This is realized by hidden line elimination of some basic objects of TGSE's function. Students imagine and describe figures stored in the computer.

TGSE (Three-Dimensional Graphics Software for Educational Use)

This software is comprised of several basic geometrical algorithms, realizing simple generation and processing of solid models of polyhedral representation. In consideration of "graphic science" fundamentals, the software performs the creation, display, cutting, intesection and shading of objects. Furthermore, this software is simple and small so that students can understand processes or algorithms when they read this program.

The example of this program for educational use is shown in Fig 2. Geometric processing commands and data are read from the card reader, results of processing is printed on the line printer, graphic output is drawn on the storage display and hard copy is automatically made.

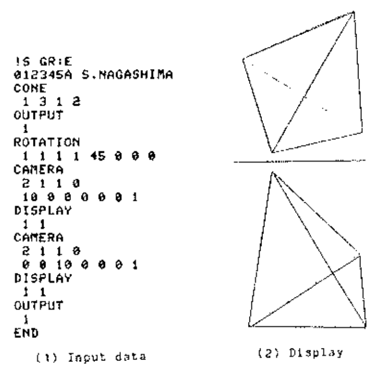

Figure 3

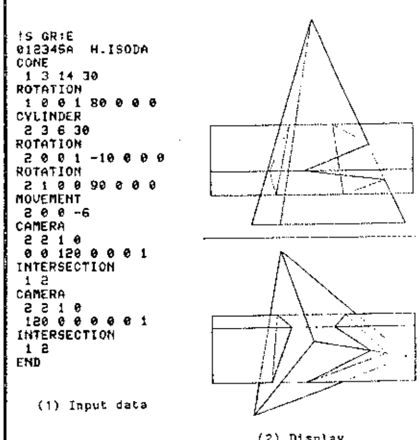

Figure 4

(1) Input and Output of Geometrical Data

"INPUT" . . .Generation of three-dimensional model from each set of coordinates of vertices. "OUTPUT" . . .Print-out of geometrical and topological data of the object.

(2) Creation of Basic Objects

"CUBE", "CYLINDER", "CONE", "SPHERE" . . Creation of three-dimensional models of a cube, cylinder, cone and sphere with approximate polyhedron. "PRISM", "PYRAMID", "REVOLUTION".. Creation of solids of general prism, pyramid and revolution.

(3) Transformation

"ROTATION", "MOVEMENT" . . .Performance of rotation and parallel translation to objects (change of the location and the situation). "AFFINE" . . Performance of affine transformation to objects (extension, contraction and shearing transformation).

(4) Display

"CAMERA" . . .Setting of eye point's location, indication of parallel or center projection, indication of hidden line elimination. "DISPLAY" .... Display of some objects, according to CAMERA parameters.

(5) Cutting and Intersection
"CUTTING" . . Calculation and display of intersection line of a plane and an object. "INTERSECTION" . . Calculation and display of intersection line of two objects.

(6) Shading and Shadows
"SHADING" . . . Shape and situation of the old object are copied to the new one. "END" . . Termination of the execution.

(7) Others
"COPY" . . .Making of a new object from another object. Shape and situation of the old object are copied to the new one. "END" . . .Termination of the execution.

AN ATTEMPT AT COMPUTER GRAPHICS EDUCATION

According to the educational contents discussed above, a computer graphics course in "graphic science" was started. We gave three subjects to students concerning to (1) representation, (2) operation, (3) application of figures with a computer. For each subject, we first explained the contents, for example, analytic geometry, graphic processing algorithms, and operational method of TGSE. Next, we gave some questions concerning computer graphics processing. Students made reports which included answers to the questions, results, and an explanation of computer practice.

This computer practice was done using the **TGSE**. Students made cards of commands and data of this graphics language. In addition to this, graphic display terminal was provided which allowed some students to practice interactively.

The First Subject

This subject contains property of polyhedra, representation of figures, and transformation of figures. In this, the following questions were presented.

(1) Expression and Property of a Straight Line and a Plane
Review of senior high school mathematics concerning straight lines and planes which constructs polyhedra.

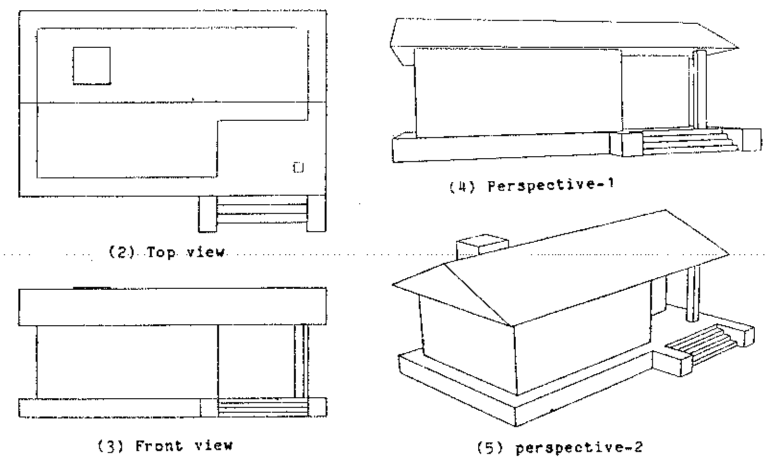

Figure 5

(2) Data Structure for Figure Representation

Study of Concrete representative method of geometric information inside the computer.

(3) Kinds and Property of Linear Transformations

Study of important transformation of figures, parallel translation, rotation.

(4) Computer Practice

An exercise of computer practice is shown in Fig. 3. This is an example of generation and transformation of figures. Creation of tetrahedron, printing of its inner data, rotation of the objects, and printing of transformed inner data and display of the object with front and top views are accomplished. Geometrical data such as coordinates of vertices or normal vectors of faces, topological data such as edge lists of the object, precision and error of numeric data, changing of data between former and latter transformations can be studied.

The Second Subject

This subject contains concrete geometrical processing such as intersection and display.

(1) Intersection Point of a Straight Line and a Plane

This is an application problem of analytic geometry. It appears in descriptive geometry very often, and it is needed in intersection of polyhedron.

(2) Judgment of Region of Figure

The judgment concerning if the point exists on the plane or not is studied. Usually infinite planes are used in the analytic geometry, but finite planes are used to represent objects.

(3) Display of Polyhedra

This display is used often in computer graphics. Local visibility of edges is treated. This question calculates the inner product of normal vector of faces.

(4) Computer Practice

Computer practice is on intersection of objects shown as in Fig. 4. Generation of a prism and a pyramid, transformation of these objects, situation, and calculation of intersection line.

The Third Subject

This is a subject to study how the figures are defined inside the computer.

(1) Applications of geometric models
In this, students must answer questions concerning the application of geometric models inside the computer bylooking at documents or by their own ideas. Examples of CAD/CAM were introduced beforehand.

(2) Computer Practice
This practice creates objects holding some kind of a meaning by combining basic objects (union operation). Fig. 5 was shown to students. We showed that when a model was made, object display such as its top, front or perspective views could be derived.

RESULTS

The content of this computer graphics course was easily learned by many students. They could understand the contents very well, such as the example theory or rough algorithms of graphic processing. For the computer practice, students performed well.

Computer practice on the third subject was very popular among students, so it required much work from the faculty side. The work of students is shown in Fig. 6. The total number of projects submitted was 118, since some students submitted more than one. In this practice, as they have experienced modeling the objects, they had many requests or questions concerning the shape of free-form surfaces, subtract operations, and so on.

Using a graphics language instead of general computer languages was welcomed by many computer-allergic students. As for the result, students without programming skills could practice computer graphics easily. Many positive educational effects could be described as being better than we expected.

The major part of processing by students was accomplished with a MELCCM COSMO-700III computer, TEKTRO-04010 graphic display and NEC PC-8801 micro computer used as a graphic display terminal. DEC VAX-11/780 computer and TEKTRO-4014 graphic display were also used for complex processing.

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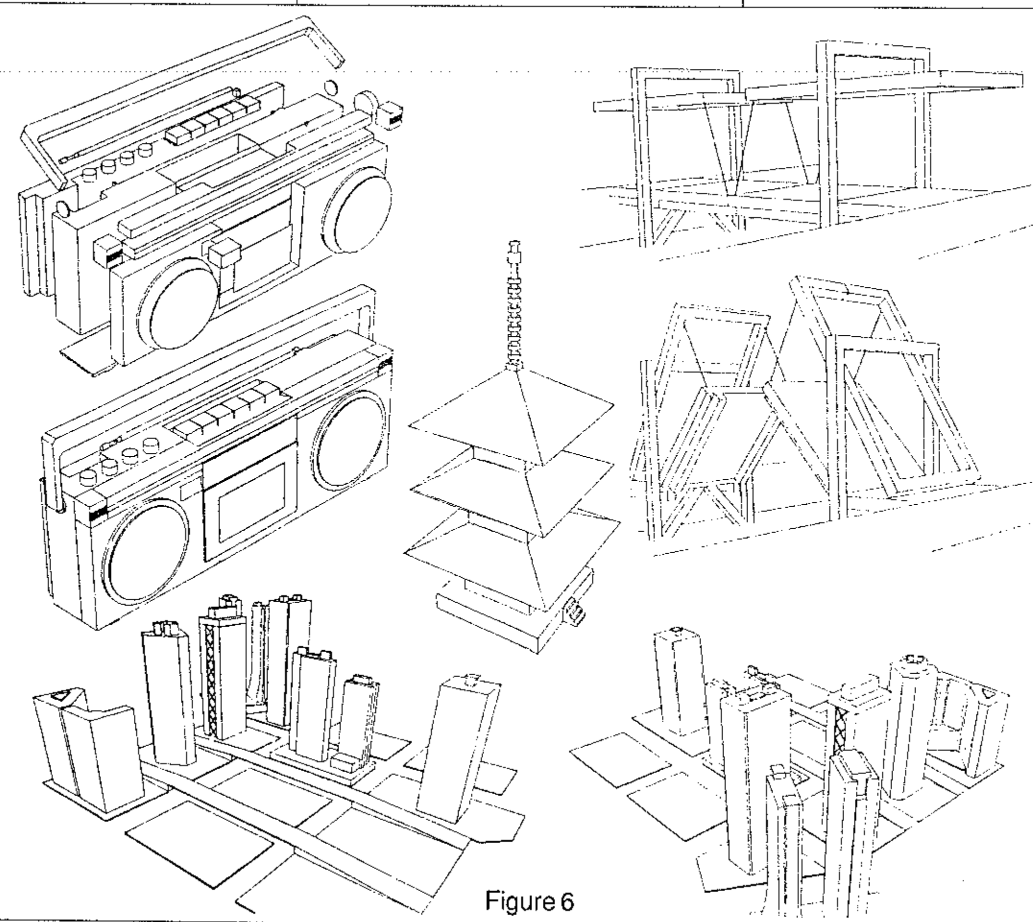

Figure 6

ACKNOWLEDGEMENT

We wish to thank Professor T. Sata and Professor F. Kimura, Department of Precision Machinery, Faculty of Engineering, University of Tokyo.

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Editor's Note: This paper was published originally in the proceedings of the International Conference on Engineering and Computer Graphics and included detailed program listings of the TGSE command language which unfortunately could not be reproduced here.The paper was edited but not refereed for the EDGJ.

Brewe

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plots, contour plots, surface and solids modeling, continuous-color (psuedo image processing) data representation as well as interactive chart creation and plot enhancement for presentation and report generation.

For the work presented herein four devices were primarily used. An Envision 230, a medium-resolution color raster device, was used as the primary development scope. The slides were obtained from negatives produced by a Matrix 3000 film recorder attached to a high-resolution Ramtek 9400 color raster workstation. Finally the color motion picture was generated on a Dicomed D48 recorder system. Approximately 390 CPU minutes were required to generate the graphics for the color motion picture.

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.

The Journal reserves the right to refuse letters to the editor due to space constraints, because the material is potentially libelous, because the issues discussed are no longer of a timely nature, or because of a large number of similar letters on the same topic. Letters may be edited for spelling, punctuation, and style, and may be shortened or abstracted although meaning and tone will not be changed.

Ingber

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Curves

Allows you to define a curve or loop using up to 50 points which the curve will pass through for desired size and shape.

Texure Fill

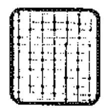
Allows you to fill an enclosed shape or background with a texture.

Polygon Interpolation

Allows you to pick a starting and target polygon and produce middle images at specified intervals along a specified pathway. Parameters: Rate, rotation and number of steps.

Perspective Grid

Allows you to use a perspective grid which can be used as a guide for creating three-dimensional looking objects.



Standard Grid

Allows you to use a grid with equal sized units that you specify.

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