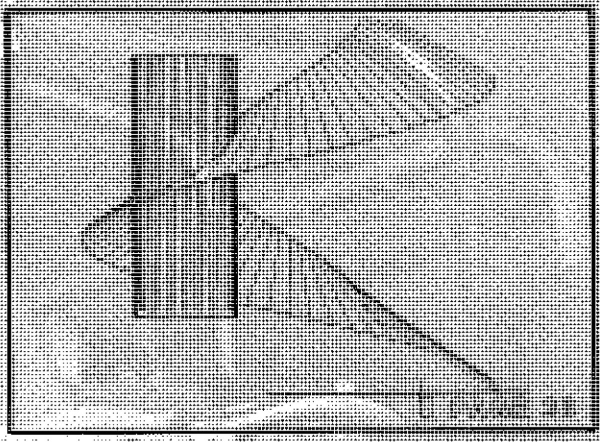
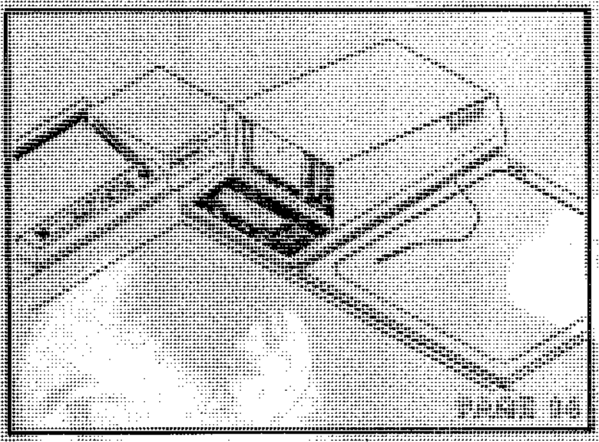
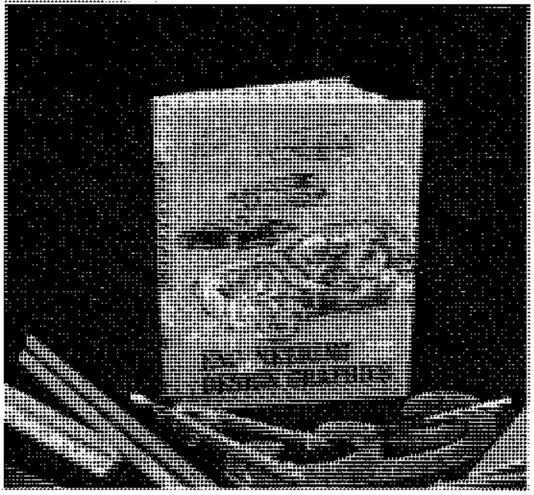




ENGINEERING DESIGN GRAPHICS JOURNAL

AUTUMN 1993 VOLUME 57 NUMBER 3

ENGINEERING DESIGN GRAPHICS DIVISION



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0-201-11318-X, Hardbound,
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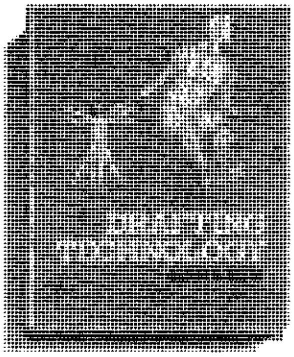

Drafting Technology James H. Earle, Texas A&M University
Appropriate for students in engineering technology programs, this text covers the basic principles of drafting, engineering drawing, and graphical problem solving. Advanced topics, such as design, descriptive geometry, specialty drafting, and computer graphics, are also discussed. 0-201-10233-1, Hardbound, 823 pp., 1982

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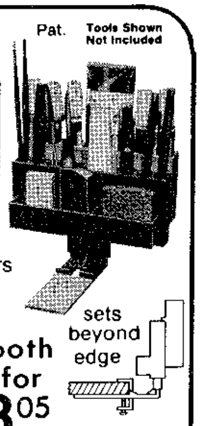

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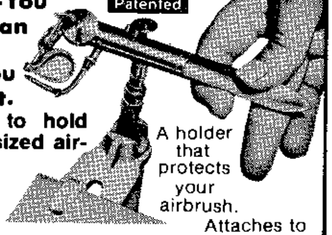

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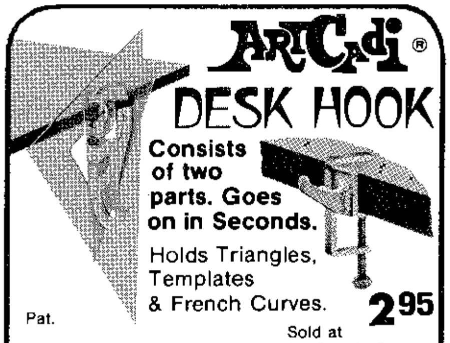

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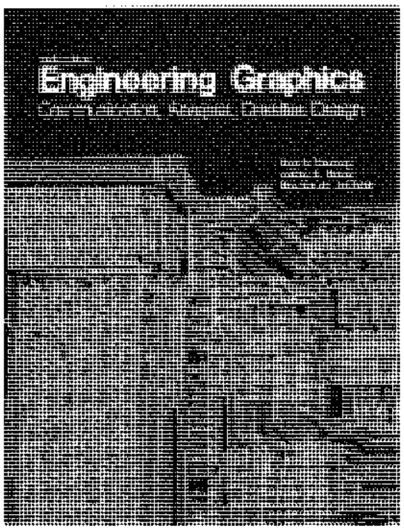

ENGINEERING GRAPHICS:

Communication, Analysis, Creative Design, Sixth Edition

by Paul S. DeJong, James S. Rising, and
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EDGD MID-YEAR MEETINGS

1984 - Pittsburg, Pennsylvania

1985 - Kansas City, Missouri

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The views and opinions expressed by the individual authors do not necessarily reflect the editorial policy of the ENGINEERING DESIGN GRAPHICS JOURNAL or of the Engineering Design Graphics Division of the ASEE. The editors make a reasonable effort to verify the technical content of the material published; however, final responsibility for opinions and technical accuracy rests entirely upon the author.

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The objectives of the JOURNAL are:

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

DEADLINES FOR AUTHORS AND ADVERTISERS

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

Fall	September 15
Winter	December 1
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STYLE GUIDE FOR JOURNAL AUTHORS:

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

1. All copy is to be typed, double spaced, on one side only, on white paper, using a black ribbon.
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8. All articles shall be written using Metric-SI units. Common measurements are permissible only at the discretion of the editorial staff.
9. Send all material, in one mailing to: Jon M. Duff, Editor, Department of Engineering Graphics, The Ohio State University, 2070 Neil Avenue, Columbus, Ohio 43210.

REVIEW OF ARTICLES

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

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ENGINEERING DESIGN GRAPHICS JOURNAL

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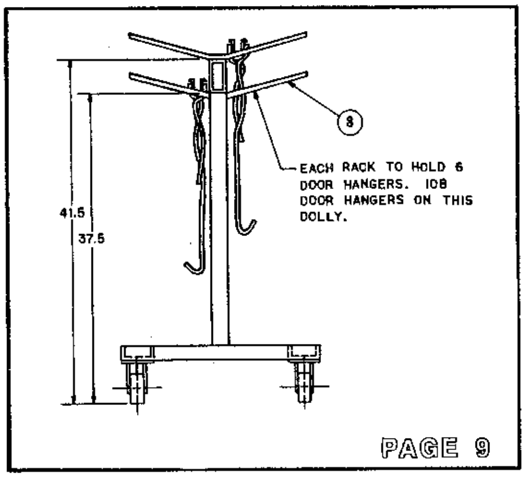

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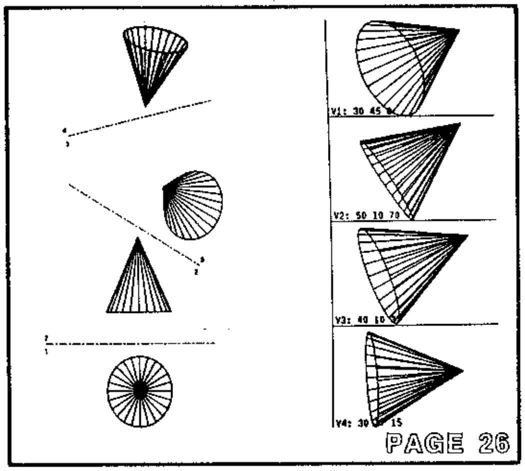

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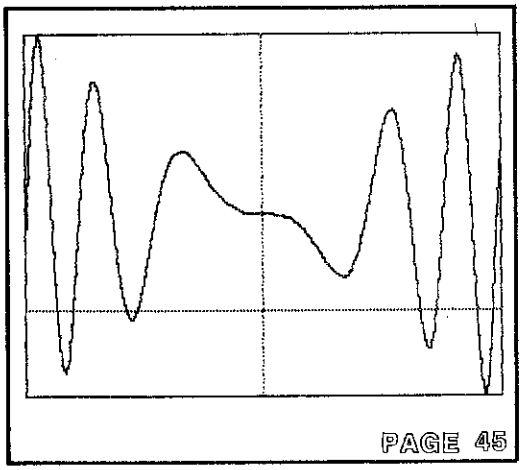

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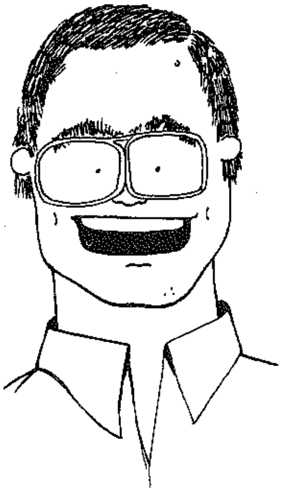


WHAT PRICE GRAPHICS?

Eyebrow deep in another school year, I find myself wondering about the state of our teaching and what we are doing to ourselves and to our students. There was a time that graphics coursework depended on a suitable work surface, a text, some paper, and $25.00 worth of drawing tools. One could almost guarantee that on a given day, graphics instruction would be given. But that is no longer the case in these times of the electrified graphics lab. At any time our ability to deliver graphics instruction can be interrupted by system crashes, disk failures, terminal down-time, system maintenance, software updates, hacker students, broken air conditioning, etc. It points out that the very nature of our subject has changed and by that, the nature of what and how we teach.

I wonder what it would have been like had we had the same problems in the era of manual graphics, and if we would have put up with it.

STUDENT: Professor Ouff, I can't get my paper to tape down to the drawing table.

PROFESSOR: Well, have you updated your tape to RSX15/a, and are you applying it in the command sequence outlined in the Adhesive Data Manual (ADM)?

STUDENT: Sure, I knew that the desk surface was changed last week from compound asphalt/rubber to the ANSI standard silicon polymar laminate.

PROFESSOR: How are you aligning your paper?

STUDENT: Just as you showed us with the 2.0 version of the B-24 T-Square and using the smoothing routines you suggested.

PROFESSOR: Do you have a double-sided double density head on the T-Square?

STUDENT: Why no, mine is formatted single sided!

PROFESSOR: That's it then! We had an update on our table edges this morning. They are all double-sided now as dictated by the Bureau of Undergraduate Regional Programs (BURP) so you will have to get a new unit.

STUDENT: Gee, just when I thought I understood this course.

PROFESSOR: Also, don't forget that all next week the drawing tables will be down while we install new software seating on the stools. Our systems people assure us that it will really increase our throughput of students across the stools.

Of course this sounds silly, or does it? If you are involved at all in graphics instruction using computers then much of the dialogue should sound familiar. I don't think any of us would stand for so much "educational noise" in a manual drawing environment. Why is this situation then a problem?

1. Graphics instruction in times past was subject-matter dependent, it is now equipment and technology dependent.
2. This graphics instruction was not and is not regarded as having intrinsic value. What is valued by the powers to be (Deans) is the technology.
3. Never before has graphics instruction been so dependent on non-graphics people to run smoothly.
4. Never before was graphics so non-transportable. That is, what is required to do graphics one place can now be totally different from that which is required somewhere else.
5. Never before has it taken such an outlay of funds to teach graphics.

Where does this all lead? We should be careful when we rush to adopt a given technology. Are we teaching graphics or are we teaching the technology? Obviously there is a place for both - but it would seem that in many instances we have confused the two. We should strive to reduce this "noise" that only adds to the problems of teaching graphics. Non-graphics people (systems types, programmers, computer scientists) should be kept away from the curricula, and given only limited access to graphics equipment.

Yet the solution is not to have graphics faculty intimately involved in the day-to-day operation of computer graphics systems, or in the intricate nuances of programming or systems. I assure you, a graphics teacher cannot serve two masters (and you can quote me on that.) Either you are a teacher of the subject, or a teacher of the technology. Look around yourself, at the young and old graphics teachers. What do you think?

ACCEPTANCE STATEMENT FOR DISTINGUISHED SERVICE AWARD

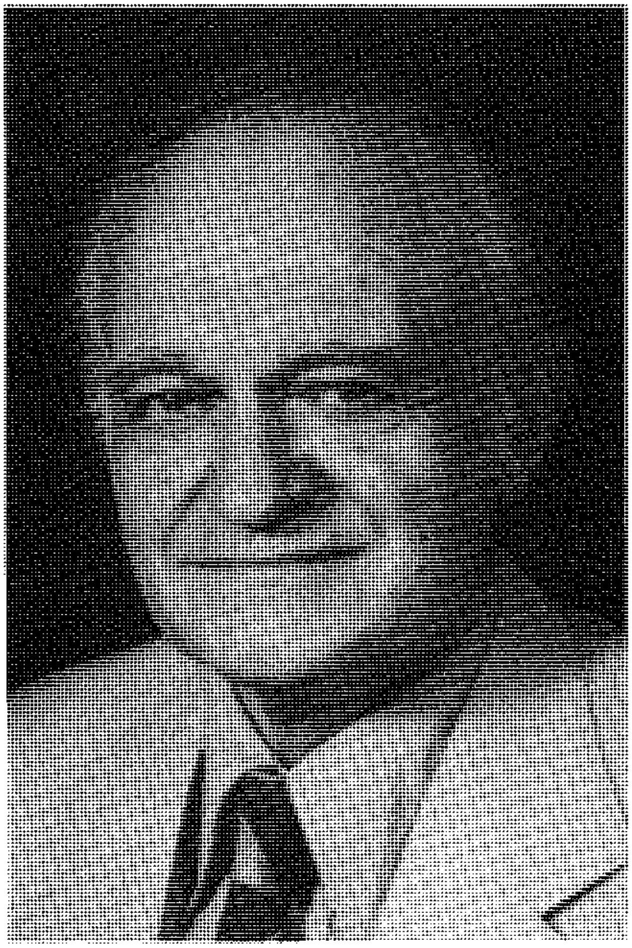
Steve M. Slaby

How does a person react when given a prestigious honor by his peers, his friends and colleagues? My reaction is one of humility and thankfulness. Humility in the recognition that our work is based on a foundation laid down by the giants in our field which include people like: Frank Heacock, Jim Rising, Al Levens, Paul Reinhard, Steve Coons, John Rule, Bill Street, Mary Blade, Dave Brisson, Luisa Bonfiglioli, Percy Hill, Ernesto Lindgren, Gene Pare, Jim Earle, and many others from our division. Also Fritz Hohenberg of Austria and last but not least the father of our field - Gaspard Monge.

I am thankful to have been a member of our division for these many years - a division comprised of a very special group of teachers - scholars - practitioners. A group of people who are constantly searching for better ways to teach their material to students while simultaneously researching at the frontiers of their respective specialties. A group of people who encourage self criticism and who do this in a spirit of friendship and unity. A group of people who are concerned about the human condition in our world and work to improve it for all.

Our integrated field of Engineering Graphics and Descriptive Geometry is more critical than ever to the field of design and plays a pivotal role in the developing areas of computer-aided design and computer-aided manufacturing (CADCAM/CADAM). The fundamentals in our field are the bed rock on which design and manufacturing rest. And the heart and soul of our fundamentals is geometry!

A few weeks ago an IBM specialist came to Princeton to demonstrate the power of the latest industrial version of a CADAM system which recently has been installed at our Interactive Computer Graphics Laboratory at the School of Engineering and Applied Science. I asked him how anyone could meaningfully use this state of the art system without having studied Engineering Graphics and Descriptive Geometry. He answered, "Oh, IBM is teaching Descriptive Geometry to its people working in the CADAM area." Well, this answer to my question made my day. Finally, our field is getting attention, without fanfare, as never before from certain segments of industry. Now we may have a better chance to help our college and university deans and faculty become enlightened sufficiently to catch up with this realization.



The future for our field is wide open. The area of theoretical graphics offers immense opportunities for creative research and teaching. The marriage of descriptive geometry, graphics and the computer has taken place - but this marriage has a long way to go before the relationship matures and is developed to the ultimate in user friendliness - a free form friendliness which liberates the designer from laborious detailed drawing and from the inhibiting strictures of the computer machine and the parameters within which it binds up the user.

The International Conference on Engineering Graphics and Computer-Aided Design which is being sponsored by our Engineering Design Graphics Division and the China Engineering Graphics Society in Peking, China between August 27 - September 1, 1984, is another manifestation of the strength and scope of our field. At this conference we expect participants from all over the world, including Australia, Japan, Germany, the Soviet Union, England, France, Austria, Vietnam and of course very strong representation from the United States. I strongly urge that we have the widest and fullest participation from our Division. This conference is in actuality the Second International conference we have sponsored - the first taking place in Vancouver, Canada in 1978 - beautifully and extremely successfully organized and implemented by our own Clarence Hall and Inogene DeVaney.

I am optimistic for the future of our field and our Division. We have a continuous supply of young fresh-creative minds entering our ranks and we should make available every opportunity for them to play key roles in the life of our Division and encourage and support them in the development of innovative ideas devoted to excellence in teaching-scholarship and implementation. They are our future and as long as our immediate and ultimate goal is to improve the human condition on this earth - we have nothing to fear.

I thank you for this very special and extraordinary honor which you have given me. It will be a part of my life for the rest of my life - I will never forget it - I will never forget the people - past and present - who have made our Division such a special human-educational organization.

Steve M. Slaby

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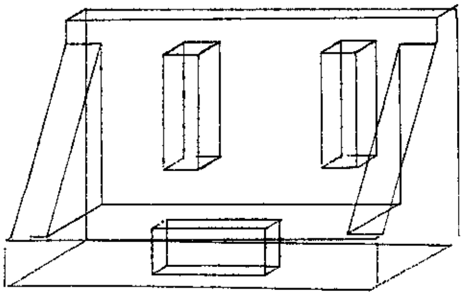
continued from p.9

The computer graphics test was given three times. First, it was used as a pre-test. After the students had completed all assignments used in this study, the test was again given as a post-test during the seventh week of the semester. To measure long-term retention, it was given again during the last week of the semester at the same time the comprehensive exam was administered.

Findings

Appropriate forms of analysis of variance were used to evaluate the data collected. Regarding the short-term retention of graphic principles as measured by the weekly quizzes, there was no significant difference between the control and treatment groups. The overall retention of graphic principles as measured by the comprehensive exam did show a significant interaction in favor of the treatment group. As expected, the computer graphics test produced a significant difference in favor of the treatment group regarding both their knowledge of simple computer graphics and their attitude toward using computer graphics. Also as expected, the time spent by the treatment group was far less than the time spent by the control group (5.2 minutes versus 42.0 minutes). Figure 8 summarizes these results. Simple comparisions of the means of the treatment and control groups were also more favorable to different extents for the treatment group on all four measurements as shown in Figures 9, 10, 11, and 12.



Oblique Drawing

FIGURE 6

Conclusions

The results indicated that the students who were taught engineering graphics through a combination of manual graphics followed immediately by user-oriented interactive computer graphics for each separate topic presented benefitted more in several ways than the students who were taught graphic principles using only the traditional methods. Based on the data analysis, the following conclusions are made:

1. The treatment had no significant short-term effect on the learning of engineering graphics principles by either the treatment or control groups.
2. The application of the treatment favorably affected the overall retention of engineering graphic principles by the students who did receive the treatment.
3. The application of the treatment caused the students who received the treatment to learn more of the basic principles of computer graphics than the students who did not receive the treatment. This was as hoped and expected, because the treatment group had learned some computer graphics at the same time they were learning engineering graphics.
4. The application of the treatment caused the students who received the treatment to improve their attitude toward the use of computer graphics.
5. In terms of the time required to complete related exercises, the treatment was a much more efficient method to teach engineering graphics. Since computers are well known for their speed, this was not a surprising result, but it is a strong advantage.
6. To summarize the conclusions, the treatment group accomplished the task of learning engineering graphics as well or better than the control group

continued on p.21

VICE-CHAIR, 1984-85

BOB FOSTER
Pennsylvania State University

Bob is Professor and Chair of Engineering Graphics at Penn State and has been active in EDGD since 1969. Within the Division he has been Associate Editor of the Journal, Secretary-Treasurer, and Chair of the midyear meeting at Arizona State in 1976. For the past three years he has been Chair of the Creative Engineering Design Display and is currently Awards Chair. He has written several articles for the Journal and is an author with McGraw-Hill.

VICE-CHAIR, 1984-85

FRANCIS MOSILLO
University of Illinois, Chicago

Francis is a graduate of IIT, and has been teaching at the U of I since 1955. He has also held positions in the university administration and has industrial experience as an engineer. In conjunction with his teaching he has published several papers on design graphics and computer graphics as well as a workbook-text in engineering drawing, descriptive geometry, design, and computer graphics. He has been an active member of ASEE and EDGD since 1955 and served as Chair of both the Division's Computer Graphics Committee and Zone II Committee. photo unavailable

JOURNAL ADVERTISING MANAGER (84-87)

FRANK M. CROFT
University of Louisville

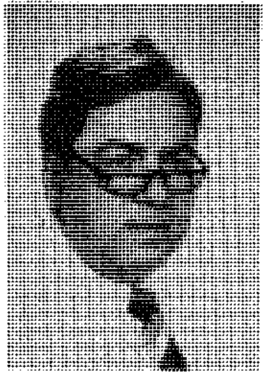
Frank holds a B.S. in aerospace engineering, an M.S. in civil engineering, and expects to complete his Ph.D. coursework in transportation engineering at Clemson University soon. He will then return to U of L, where he is Assistant Professor of Engineering Graphics and Civil Technology. He is a Registered Professional Engineer with industrial and consulting experience in engineering and graphic arts. Frank has been an active member of ASEE and EDGD since 1973. He has written and presented papers at midyear and annual meetings and has served as JOURNAL Associate Editor and is currently completing a term as Advertising manager. photo unavailable

DIRECTOR-TECH & PROF COMMITTEES (84-87)

ROBERT LANG
Northeastern University

Bob is an Associate Professor of Design Graphics, Department of Industrial Engineering and Information Systems at Northeastern. He has been a member of the Design Graphics Division for 28 years, during which he has served in many ways. He has presented papers at several conferences, and has served on the Computer Graphics Committee and as Chair of the Educational Relations Committee. He is also the author of a graphics textbook and problems book.

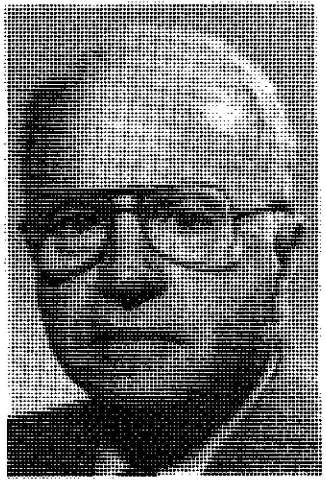

Bob Foster


Pat Kelso

JOURNAL ADVERTISING MANAGER (84-87)

ROBERT P. ("Pat") KELSO
Louisiana Tech University, Ruston

Pat left business for teaching in 1973, and is an Associate Professor of Industrial Engineering at Louisiana Tech. Pat holds a B.A. in physics and math, and an M.A. in art. His teaching experience covers ten different graphics courses, several of which he has developed personally. He is active in basic graphics research and has several original contributions to his credit. He has had numerous articles published in the EDG JOURNAL and was Assistant Editor for several years, when among other things he produced the "Puzzle Corner". Pat has received several grants, and reviews texts and periodical articles in addition to outside consulting. He is recipient of the Distinguished Engineering Service Award from the Louisiana Tech Engineering Foundation.


Robert Lang

Nominees continued on p. 13

Combination of Manual and Computer Graphics

Retha E. Groom, Ph.D.,
Assistant Professor
Engineering Design Graphics Department
Texas A & M University

Computer graphics and engineering graphics have been linked together numerous times for logical reasons. But can computer graphics be used unobtrusively to teach beginning engineering graphics? If so, the students would learn to accept the computer as one more tool available for graphical communication. A professional study was recently completd in the Engineering Design Graphics (EDG) Department at Texas A&M University to determine if the use of a combination of traditional manual drawing and user-oriented interactive computer graphics was an efficient method to teach engineering graphics and serve as an introduction to computer graphics for first semester engineering graphics students.

Review of Literature

A review of related literature indicated several prominent ideas.

1. Students should be taught the basics of graphics through traditional manual drawing before using the computer to draw (Hall, 1972; LaRue, 1981; Myers, 1981).
2. The course most often suggested to facilitate the introduction of computer graphics is engineering graphics (Barr, 1980, 1982; Coppinger, 1974; Demel, Kent, & Zaggle, 1979; Hall, 1972; Hartman, 1981).
3. Computer graphics can be thought of as a tool. It can be a teaching tool for the educator, a drawing tool for the draftsperson, and a drawing and analytical tool for the engineer (Slaby, 1976; Earle, 1977; Goestch, 1981; Hall, 1972; DeJong, 1981).
4. Educators do not agree regarding how much programming should be used when computer graphics is introduced (Barr, 1980; Demel, Kent, & Zaggle, 1979; Wilke & Demel, 1980; Juricic, 1980; LaRue, 1980; Ryan, 1980; Mosillo & Wolfe, 1976).

Procedures

For this study, during the 1981 fall semester, one first semester engineering graphics class, EDG 105, was randomly divided into a treatment group and a control group in order that a comparison could be made regarding the effectiveness of two methods of teaching engineering graphics. A pilot study had been used during the summer of 1981 to check for any unanticipated problems. Five topics representative of engineering graphics were selected: bar graph, breakeven graph, orthographic projection, isometrics, and obliques. These occurred approximately one per week during weeks three through seven of the fifteen week semester. For each of these separate topics a certain order of procedures was followed as shown in Figure 1. First, the entire class was given the lecture on the specific topic. Second, the entire class used traditional manual drawings for the first drawing assignment. Third, for the required second or more complex assignment on each of the topics, the class was divided into the treatment and control groups. The control group used the traditional manual method on the second exercise while the treatment group went to the computer lab and each student used interactive computer graphics (which required no computer programming) to draw a similiar exercise on the given topic. This sequence of lecture, initial assignment, and second assignment (groups separated) was followed for each of the five topics as they were spaced throughout the semester.

ORDER OF PROCEDURES

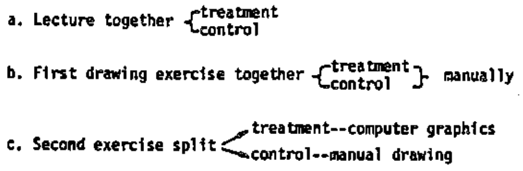
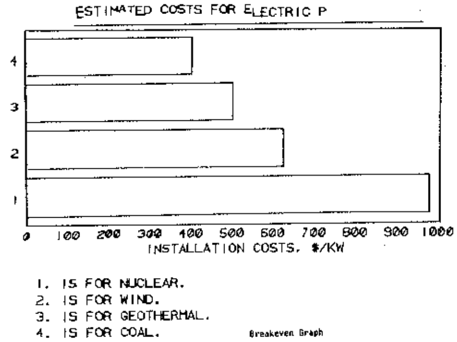


FIGURE 1

No programming experience was needed by the students using computer graphics. The emphasis was to teach engineering graphics by using the computer as a teaching tool. Just as chalk boards, overhead projectors, and triangles have become well accepted teaching aids, in this case user-oriented interactive computer graphics was used to teach graphics.

Modifications were made to in-house software programs available in the EDG Department so that the programs would be more user-friendly. The data file for the geometrical objects had already been entered by the faculty before the students were involved. Students responded to prompts on the CRT screen regarding positioning, size, scale, angles, number of bars, titles. The students then saw the drawing produced line-by-line on the CRT screen. Of the three terminals used, one was connected to a plotter to give the student a paper copy if the student so desired. A qualified assistant was in the computer lab to give assistance if needed. Figure 2, 3, 4, 5, and 6 are examples of students' exercises drawn with the computer. Lettering flaws are due to technical hardware problems. Figure 7 is an example of a related assignment plate for the control group.



Note: Lettering flaws are due to technical hardware problems.

FIGURE 2

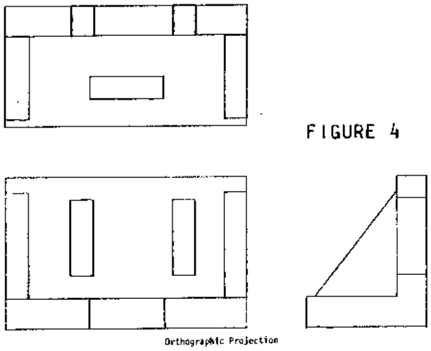


FIGURE 4

Orthographic Projection

The hardware consisted of three systems that each used a North Star Horizon microcomputer with floppy disk drives. The three terminals were Lear-Siegler alphanumerics with added graphics boards. One plotter by Houston Instruments was also used.

Measurements

Weekly quizzes and a comprehensive exam that are routinely used within the EDG Department were incorporated in this study. Faculty members within the department compile two versions of each weekly quiz for use by all sixty to seventy sections. Each teacher may select either version A or B. The first sixty to seventy percent of the fifteen minute quiz is composed of multiple choice questions which cover the theory presented during the week. On the remaining part of each quiz, the student must construct drawings representative of those for the week. A standard 100 multiple-choice question comprehensive exam is also used within the department. This is routinely administered as a pre-test at the beginning of each semester and as a comprehensive exam at the close of the semester. Throughout the study, efforts were made to ensure that the addition of computer graphics was no more disruptive than necessary to the normal routine of the EDG Department.

Both the weekly quizzes and the comprehensive exam were used as measurements to assess the effectiveness of the two teaching methods. The weekly quizzes measured the short-term retention of graphic principles while the comprehensive exam measured long-term retention of graphic principles. A computer graphics test composed of two parts was compiled especially for this study. The first part was designed to determine if the students had increased their knowledge of elementary computer graphics while they were being taught engineering graphics. The second part measured the students' attitude toward using computer graphics.

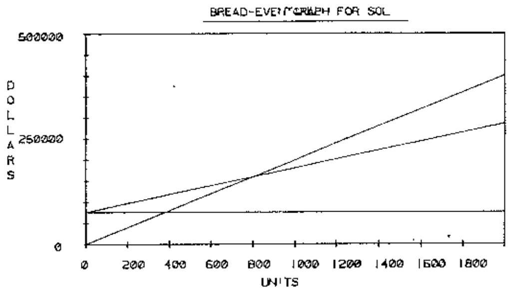


FIGURE 3

Note: Lettering flaws are due to technical hardware problems.

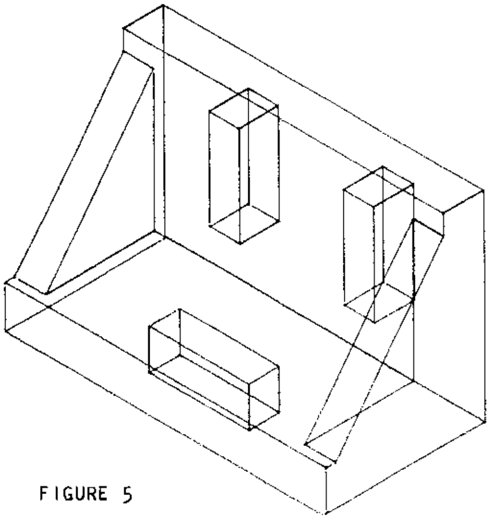


FIGURE 5

Isometric Drawing

Because both the weekly quizzes and the comprehensive exam covered more subject matter than was included in this study, some of the questions on both types of departmental tests were not considered pertinent to this study. Therefore, when the data was analyzed, the analysis was first performed using all questions; then the analysis was repeated after deleting inappropriate questions and using only the pertinent remaining questions.

continued on p. 6

Design of a Door Paint Dolly

by: Dr. Yuan H. Liu
Miami University - Hamilton

Introduction

This research project on the design of a door paint hanger transfer dolly was provided by Pease Industries, Inc., located in Fairfield and Cincinnati, Ohio. The dolly (see Fig. 1) is used to carry door paint hangers (see Figs. 2 and 3), weighing one pound, twelve ounces each, from a place adjacent to where doors are painted to where doors are to be hooked up on hangers. After the doors are hung (see Fig. 4), they are carried away by fork lift. Each of the doors is then hung on a power-operated paint line conveyor (see Fig. 5) for painting.

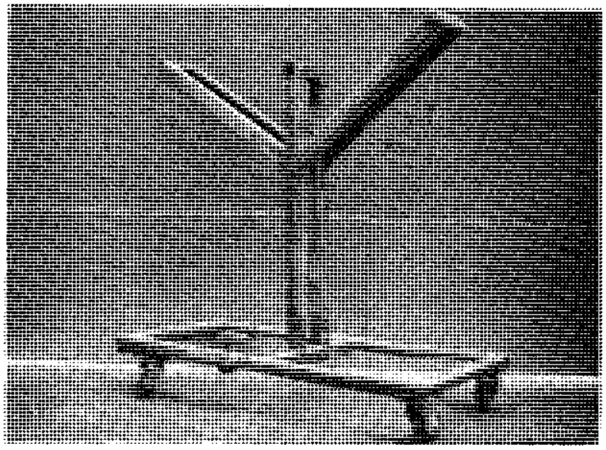


FIGURE 1
The presently used dolly which is employed to carry door paint hangers.

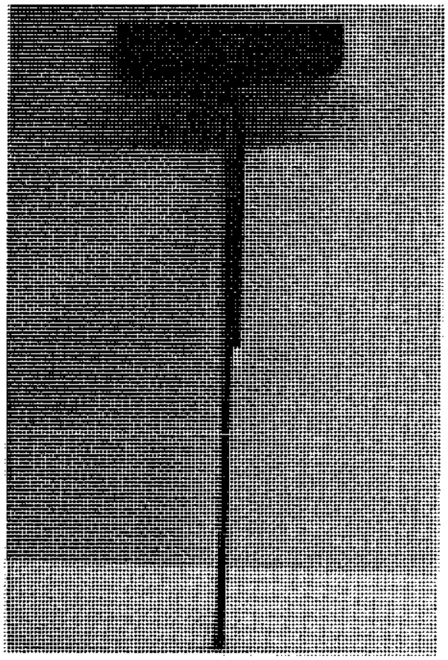


FIGURE 2

The front view of the door paint hanger.

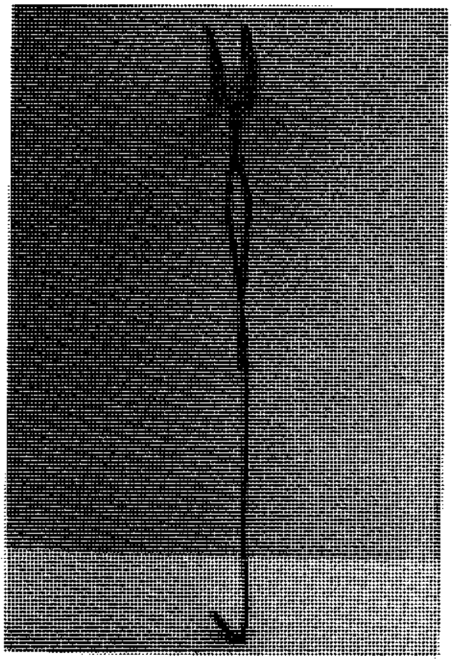


FIGURE 3

The right-side view of the door paint hanger.

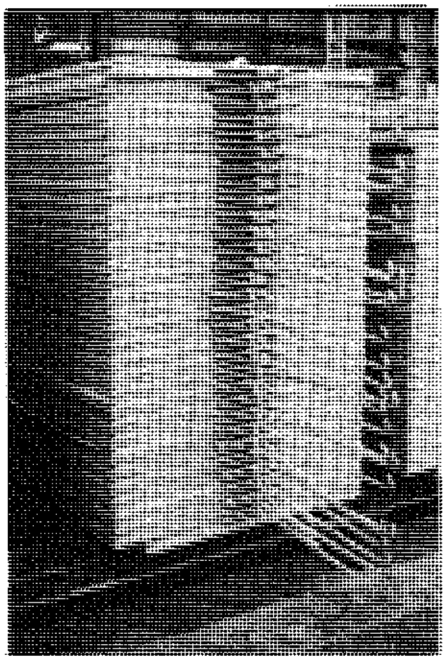


FIGURE 4

The doors are hooked up on hangers.

FIGURE 5

Each of the doors is hung on a power-operated paint line conveyor for painting.

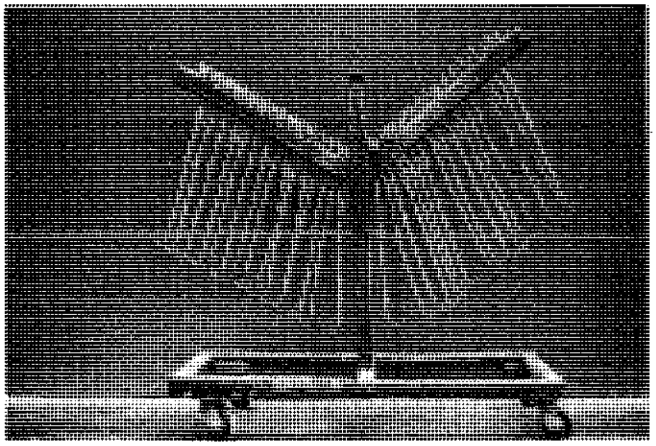


FIGURE 6
The dolly presently used can carry approximately 31 hangers at a time.

Statement of the Problem

The dolly presently used can carry approximately 31 hangers (see Fig. 6) at a time. According to Mr. William M. Bursk, Manager of Pease Technical Center in Cincinnati, this dolly does not carry enough hangers at a time. In order to save time and manpower, a dolly is needed that can carry at least one hundred hangers at a time. Mr. Bursk asked if my students and I could help design a dolly to replace those presently used, as Pease Industries lacked the manpower to do it.

Procedure and Results

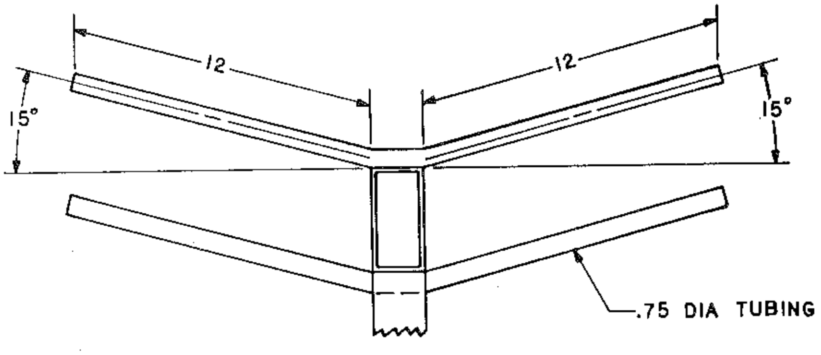
I talked to my students in our Equipment Design class, offered in the Second Semester of 1980-81, about the problem of the dolly and asked if anybody would be interested in resolving the problem as part of his class work. One student, Mr. William M. Truett, wished to get involved in the research project. Serving as the leader for the research project, I explained to him the type of dolly designed and suggested that he visit the actual work situation in the Pease Fairfield Plant.

We started to work on the research project in January, 1981, and discussed and exchanged ideas on dolly design for at least a half-hour each week for that entire Spring semester. Then in May we completed the project by making a combination of assembly and detail drawing and a sectional view. The dolly we designed can carry 108 door paint hangers at a time.

In May, Mr. Truett and I presented our design on the dolly to Mr. Bursk at the Pease Fairfield Plant. He was generally satisfied with the idea of our design and said that he would examine the two drawings we submitted to him. He planned to discuss them with one of the two industrial engineers working with him to see if everything in them was appropriate, accurate, and complete.

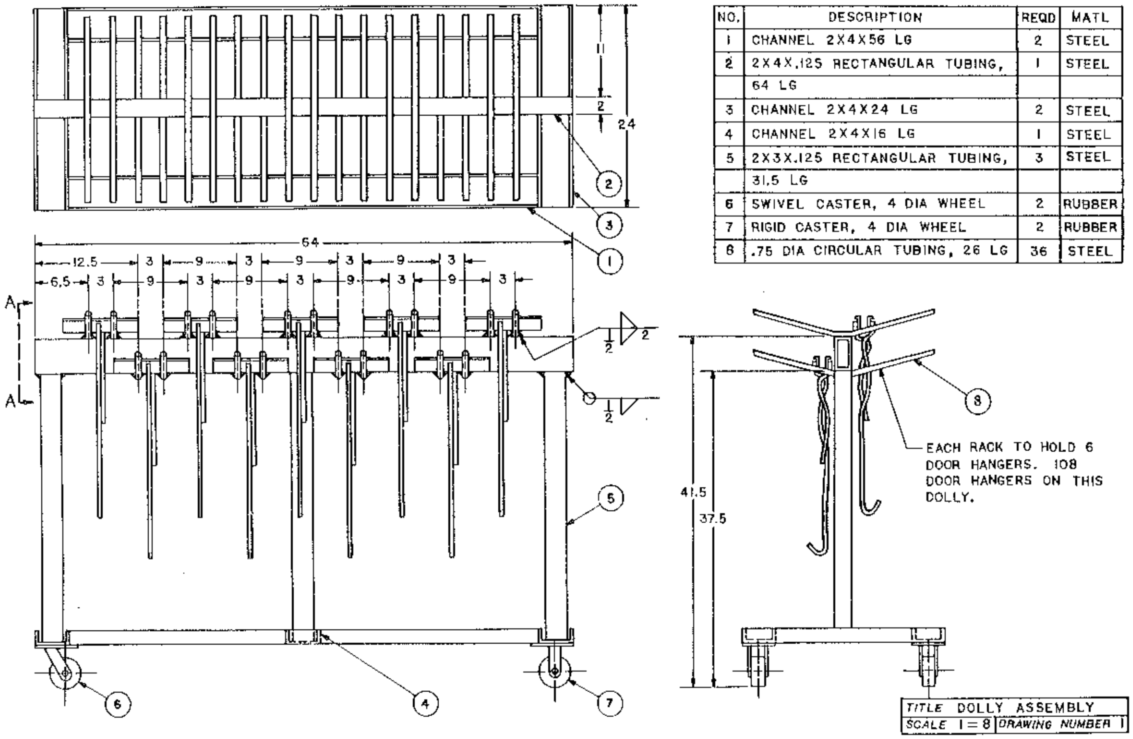
In August, Mr. Bursk suggested that some elements of the design needed to be changed: different materials had to be employed and dead weight and unnecessary components removed. In addition, changes were needed in structure, dimensions, and methods of joining components.

In early September, I talked to my students in our Die and Gage Design class about the necessity of revising our dolly design and asked if anybody would be interested in revising it as extra work for the class. Mr. William R. Graf indicated an interest and so I explained to him the special problems that needed to be overcome in changing the design. In September, he started to work on the revision of our design and by December he was finished. At that time Mr. Graf and I submitted the revision to Mr. Bursk.



VIEW A-A

TITLE REMOVED VIEW	
SCALE 1=4	DRAWING NUMBER 2



NO.	DESCRIPTION	REQD	MATL
1	CHANNEL 2X4X56 LG	2	STEEL
2	2X4X.125 RECTANGULAR TUBING,	1	STEEL
	64 LG		
3	CHANNEL 2X4X24 LG	2	STEEL
4	CHANNEL 2X4X16 LG	1	STEEL
5	2X3X.125 RECTANGULAR TUBING,	3	STEEL
	31.5 LG		
6	SWIVEL CASTER, 4 DIA WHEEL	2	RUBBER
7	RIGID CASTER, 4 DIA WHEEL	2	RUBBER
8	.75 DIA CIRCULAR TUBING, 26 LG	36	STEEL

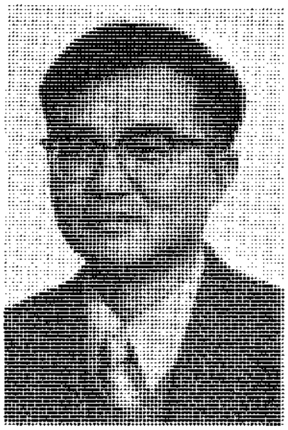
EACH RACK TO HOLD 6 DOOR HANGERS. 108 DOOR HANGERS ON THIS DOLLY.

TITLE DOLLY ASSEMBLY	
SCALE 1=8	DRAWING NUMBER 1

The revision consists of an assembly drawing for the dolly designed (see drawing 1) and a removed view (see drawing 2). This new design incorporates 36 pieces of steel circular tubing that comprise eighteen racks, two tubes per rack. Each of these eighteen racks is welded to a piece of steel rectangular tubing. Pairs of adjacent racks are welded one on top of the tubing and one underneath, with ten racks on top and eight below. Each of the eighteen racks can hold six door paint hangers; thus, the dolly can carry 108 hangers at a time, 77 more than the one presently used.

Conclusions

Mr. Bursk believed that the revised design on the dolly was workable, timesaving, and handy. I can attest that Mr. Truett, Mr. Graf, and I gained valuable practical experience in problem-solving while designing the dolly, and we were pleased to be of service to one of our important local industries.



Yuan H. Liu

Conducting this research project in dolly design was significant and rewarding. Designing this dolly was of benefit not only to the industry, but to me and my students as well.

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continued from p.7

DIRECTOR-TECH & PROF COMMITTEES (84-87)

DR. MING H. LAND
Appalachian State University

Ming Land was a Professor of Industrial Education and Architecture at Miami University for twelve years, but recently moved to Appalachian State, where he is a Professor and Chair of Industrial Education and Technology. Ming received his B.S. in Taiwan, his M.S. from Northern Illinois, and his Ph.D. from Utah State. He is an active teacher and researcher in Engineering Design Graphics, Technical Drawing, and Industrial Teacher Education, and has authored over 40 articles and reports. Ming has been an active member of EDGD since 1976.

photo unavailable

DIRECTOR-ZONES (84-87)

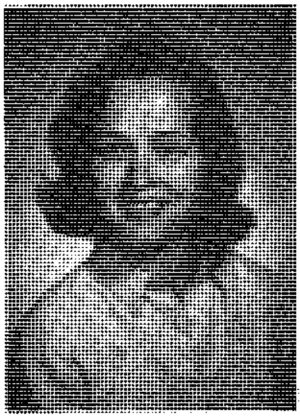
RETHA GROOM
Texas A & M University

Retha is an Assistant Professor of Engineering Design Graphics at A&M where she has been teaching five years. In 1981 she was Chair of the Division's Teaching Techniques Committee, and served as moderator of a session at the annual conference at USC. At the annual conference at Texas A&M in 1982, she served on the registration committee and as a judge for the Creative Engineering Design Display. Retha earned her B.S. from Central Arkansas, her M.S. from Memphis State, and Ph.D. from Texas A&M.

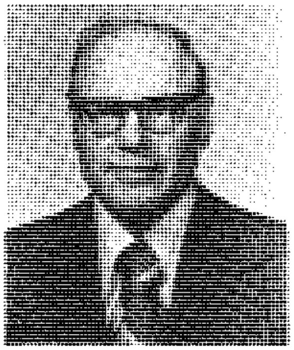
DIRECTOR-ZONES (84-87)

LOUIS G. SKUBIC
South Dakota State University

Louis Skubic has had a broad background in industry and teaching. He served in the US Navy as a gunnery officer (1942-46) and as Professor of Mechanical Engineering at Michigan College of Mining and Technology, Sault Branch (1947-54). Since then he has been with SDSU as Professor of Mechanical Engineering, Assistant Dean of Engineering, Acting Dean of Engineering, and is now Head of the General Engineering Department. Louis has been in ASEE and EDGD for many years and has served as a Campus Activity Representative, on the Education Committee, Human Factors Committee, and as Zone Chair.



Retha Groom



Louis Skubic

Freshman Graphics at Triton College

by: L.V. Brillhart & Eric A. Bell
Triton College

Introduction

Engineering education has traditionally been a structured continuum. Students are introduced to scientific and mathematical fundamentals. The knowledge acquired from these courses is immediately applied to core engineering courses. Only after students are well acquanited with the basics of their chosen field are they introduced to the design process. Triton College felt that the introduction of computers and specifically computer graphics should be introduced into the curriculum in an analogous manner. Students should be introduced to the fundamentals of computer usage and programming in the freshman year, continue their programming skills with further computer courses and then apply their skills in core courses. This sequence of exposure to the computer was felt to adequately prepare them for the decision making process of advanced courses, especially design courses.

Triton College is a public community college located in the western suburbs of Chicago. Although the school is big, 26,000 students, only four hundred students elect to major in engineering. Since the school subscribes to an "open-door policy", any student who wants to take freshmen engineering graphics may do so. The mean math ACT scores for the past eight years are shown in Fig. (1).

While during some years, students have an apparent achievement level equal to that of four-year colleges, many of the students are considerably below accepted standards for engineering students. The experimental group, hence, is average or below average as evidenced by Math ACT scores.

In accordance with community college philosophy, class sizes are kept small (less than 27) and while part-time instructors are used extensively, graduate teaching assistants are not used. The course is taught to approximately 200 students per year. The computer lab, shared with mechanics students, is open about 68 hours per week.

Since students can only take the first two years of engineering at Triton and then must transfer to four year institutions, an additional constraint is placed on the college. Material taught in the graphics course not only has to satisfy the requirements of teachers at the college, but must also be equivalent to courses taught at four year colleges to which students transfer.

Course Structure

The decision to add computer graphics to the existing graphics course necessitated restructuring of the physical plant as well as writing of handouts for the graphics course. The classroom was divided by a wall into a graphics lab and a classroom accommodating a maximum of 27 students. The computer lab is connected by a door, and a window is provided for simultaneous supervision of both components of the classroom.

Two Tektronix 4052 computers, a 4662 plotter and a 4956 digitizer were purchased. In addition, an Epson printer and DECwriter terminal with modem were acquired. A diagram of some of the equipment is shown in Fig. (2).

This limited equipment allowed for 1/2 hour per student on the computer. The schedule for the course is shown in Fig. (3).

The traditional course was a 3 semester hour course, meeting six hours per week, which combined descriptive geometry and drafting. Since the teacher had to devote considerable time to helping students with the computer, a manual, clearly demonstrating each step in a solution, was prepared. In addition, two problem workbooks were prepared so that comprehension of each topic could be tested with a rudimentary problem before applied problems were assigned. These materials augmented a standard text and three half-hour lectures by the instructor.

For most lectures, a canned computer program exists to compliment "on-the-board" tasks. In addition, projects

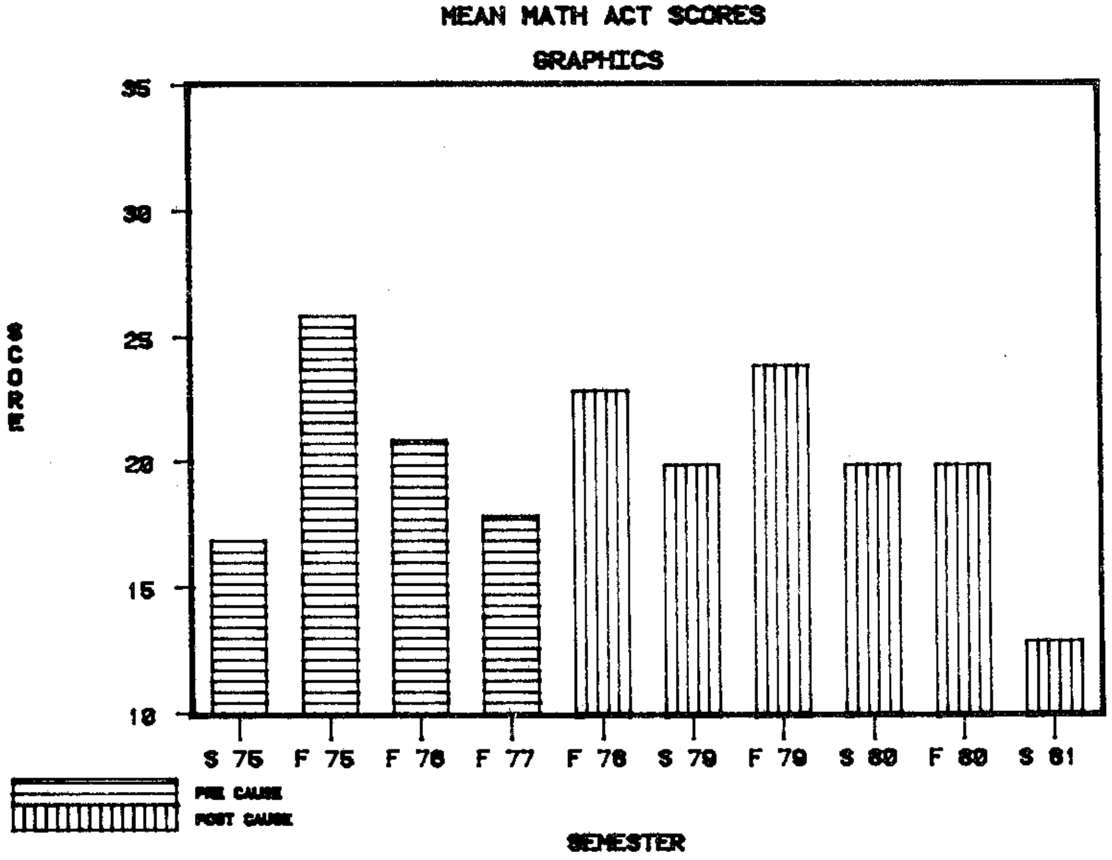


FIGURE 1

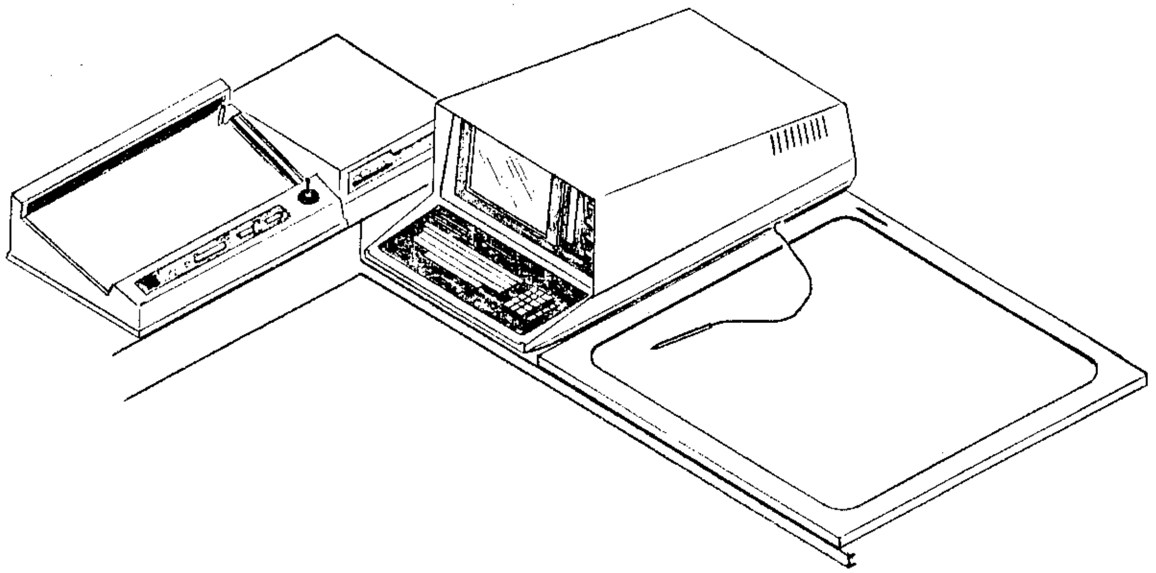


FIGURE 2

start the second week of the semester and programming instruction starts during the fourth week. A typical three hour meeting starts with a 45 minute lecture on the topics covered that week. "On-the-board" and computer assignments are then stated. The instructor then chooses two students, takes them to the computer lab and explains the computer graphics lesson(s) for the week. These students then explain the computer lesson to the next two students. This procedure continues until all students have shared the learning and teaching experience. To prevent this method from deteriorating into a game of telephone an extensive manual has been prepared for computer utilization. For the rest of the three hours, the instructor acts as a reference person for the students who are drawing and the students doing computer graphics.

The manual consists of the following sections:

1. System Description
2. Data Graphing
3. Descriptive Geometry
4. Drafting
5. BASIC Language
6. Peripherals
7. Error Messages
8. Rom Packs

The system description section introduces students to the basic hardware, including the Tektronix computer, plotter, and graphics tablet. Annotated keyboards are shown with all key and switch functions explained.

Data graphing consists of three programs: one which draws line and bar graphs (Fig. (1) in this paper has been drawn using this program), one which draws pie charts, and one which produces scripts and the shapes used in making flowcharts. These programs, while supporting the graph drafting activity, are used primarily as an introduction to the computer. The programs are user-friendly to the extreme and produce dramatic output rapidly, hence computer anxiety is attenuated. Since the programs require use of virtually all special function keys, the introduction is comprehensive. The flowchart program is used to demonstrate creativity using the computer. Students are asked to produce graphic designs (logos, illustrations, ads, schematics, etc.) using this program.

In the area of descriptive geometry, students use the six canned programs listed in Fig. (3). A four-fold purpose is accomplished:

1. Students receive further practice on the computer with fewer directions needed.
2. Students learn to use the digitizer.
3. Students reinforce learning on the board.
4. Students are introduced to the method of conics.

An example of the output of the "True Length, Bearing & Slope of a Line" program with data for initial location of the front and top views of a line is shown in Fig. (4). Steps in obtaining the final results are done slowly, one step at a time.

Three drafting programs are used in the second half of the course. "Iso-Rotation" allows students to enter coordinates of points defining a solid as triplets. The program then draws the isometric and three principal orthographic views. The isometric may be rotated about all three axes. New orthographics can then be drawn for the new isometric's orientation. An example is shown in Fig. (5).

The "Drafting" program is best described by listing the menu as shown in Fig. (6). The "shading" program menu is given in Fig. (6). Both programs are quite versatile since changes may be made without starting from scratch. In addition, everything may be viewed at any point. A quadruled grid is always provided for easy location of points.

The computer manual has three additional sections which are procedural. The interaction with a mainframe computer, plotter printer, and tape are described. Use of control characters is delineated. Finally, the use of two ROM packs, one which integrates and differentiates and one which is a program and text editor, are described and sample programs and output given.

Programming

The extended BASIC language is taught by means of individualized instruction which occurs simultaneously with traditional instruction and use of canned programs. Since students proceed on their own with only occasional instructor intervention, all directions are extensive. A sample page is shown in Fig. (8).

The lesson objective is given at the top, with a sample program on the upper left and line by line documentation on the right. The directions for entering and running the program are given below. After the program runs successfully, each pair of students is asked to write a similar program so that they may demonstrate comprehension of the module. A total of 21 modules is used to teach students enough BASIC to write rudimentary programs with use of graphics.

After the BASIC language modules are completed, each student (or pair of students) is asked to choose a project which demonstrates the students' understanding of computer graphics. Projects are generally chosen from descriptive geometry, math, science, or mechanics. Some students have also chosen to write games (tic-tac-toe, hang-man, craps, Russian roulette). All projects must be interactive and must include static or dynamic graphics.

WEEK	TRADITIONAL COURSE	CANNED PROGRAMS	PROGRAMMING/PROJECT
1	Graphics	Data Graphing Pie Chart Text Writer	
2	Points and Lines	Data Graphing Pie Chart Text Writer	Sketch Pad
3	Points and Lines	True Length, Slope & Bearing Keyboard Entry & Digitizer	
4	Points and Lines	Shortest Distance Between Two Lines	Input/Output
5	Points and Lines	Shortest Horizontal Distance Between Two Lines	Arithmetic Dperations
6	Lines and Planes	True Size, Dip & Strike of a Plane	Graphic Operation
7	Lines and Planes		Loops
8	Lines and Planes	Intersection of Line & Plane (Visibility)	Arrays
9	Lines and Planes		Data Statements
10	Lines and Planes		Character Strings
11	Orthographic/ Isometric	Isometric Rotation/ Orthographic	Interaction with Peripherals
12	Orthographic/ Isometric	Drafting	Projects
13	Orthographic/ Isometric	Drafting	Projects
14	Cabinet/Cavalier	Drafting	Projects
15	Sections	Drafting/Shading	Projects
16	Dimensions	Drafting	Projects
17	Tolerancing		Projects

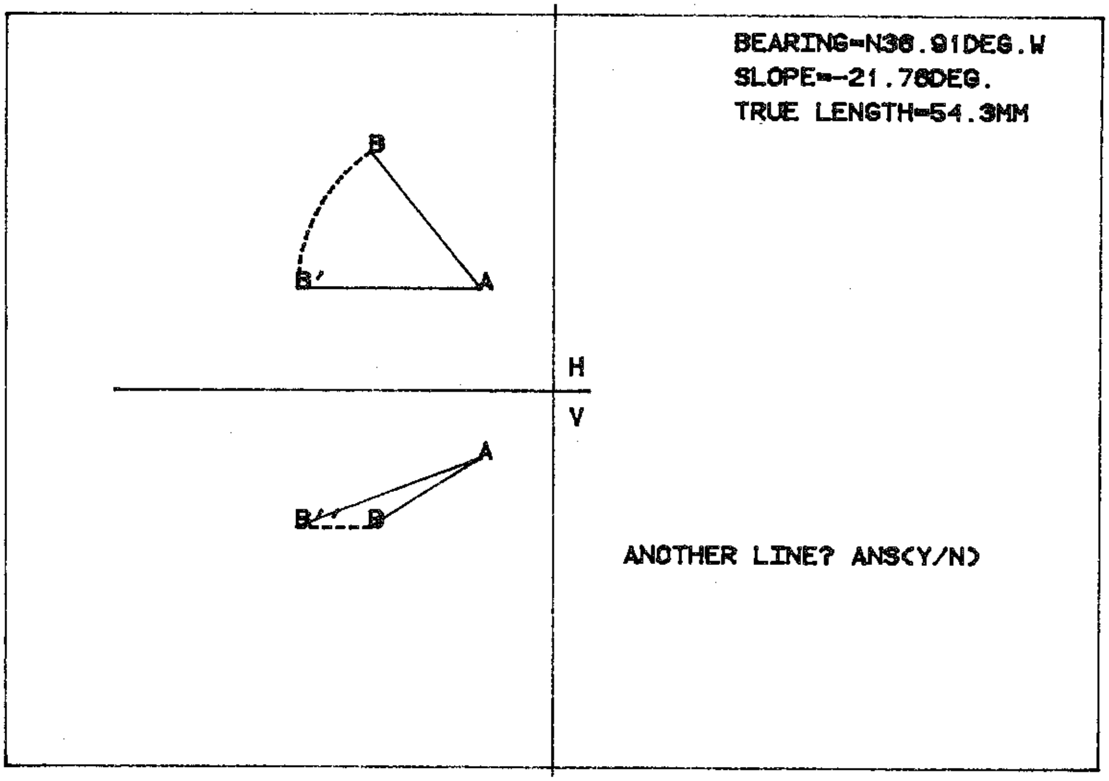
FIGURE 3

Conclusions

Since the status of computer graphics in freshman graphics courses at four year colleges is presently volatile at best, Triton has chosen a three-pronged approach as an interim solution for satisfying the requirement of receiving institutions of their students. Traditional graphics is taught. Canned programs are used and students learn to write graphics oriented programs. Creativity on the part of the student is emphasized to engage their enthusiasm and allow them to explore the capabilities and limitations of computer graphics in engineering.

The effect of computer graphics on student performance was studied using a standardized final exam as the instrument. The final exam performance normalized with respect to Math ACT scores is shown in Fig. (9).

A significant improvement in final exam performance can be seen after incorporation of computer graphics in the course since computer aided instruction is minimum. The authors attribute this primarily to an increased enthusiasm for the course.



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BEARING=N38.91DEG.W
SLOPE=-21.78DEG.
TRUE LENGTH=54.3MM

ANOTHER LINE? ANS(Y/N)
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FIGURE 4

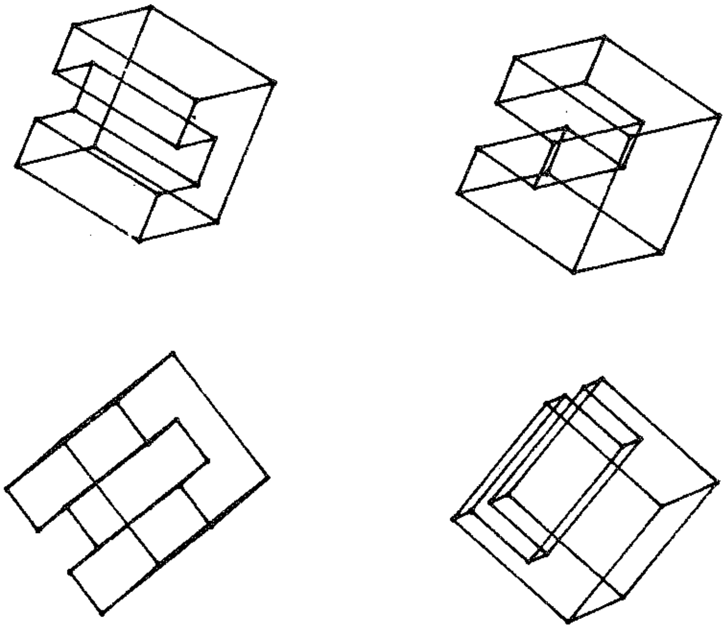


FIGURE 5

DRAFTING PROGRAM

Description of menu

USER DEFINABLE KEY	TITLE	DESCRIPTION
1	Menu	List Menu
2	See All	Erases screen and draws everything entered so far on screen
3	Draw All	Draws everything on Plotter (Make sure Plotter is ready)
4	Dimensions	Dimensions Drawings
5	Stop	Stops everything. You can press another USER KEY to resume.
6	Solid Circle	Draws solid circles
7	Solid Arc Deg. Deg.	Draws solid arc given radius, center point & beginning and end degree.
8	Solid Arc Point to Point	Draws solid arc, given radius and two points.
9	Solid Line	Draws solid line from starting point to end point.
10	Enclosure Draw	Draws continuous series of solid lines.
11	Init	Erases all input.
16	Dotted Circle	Same as 6, only dotted
17	Dotted Arc Deg. Deg.	Same as 7, only dotted
18	Dotted Arc Point to Point	Same as 8, only dotted
19	Dotted Line	Same as 9, only dotted

FIGURE 6

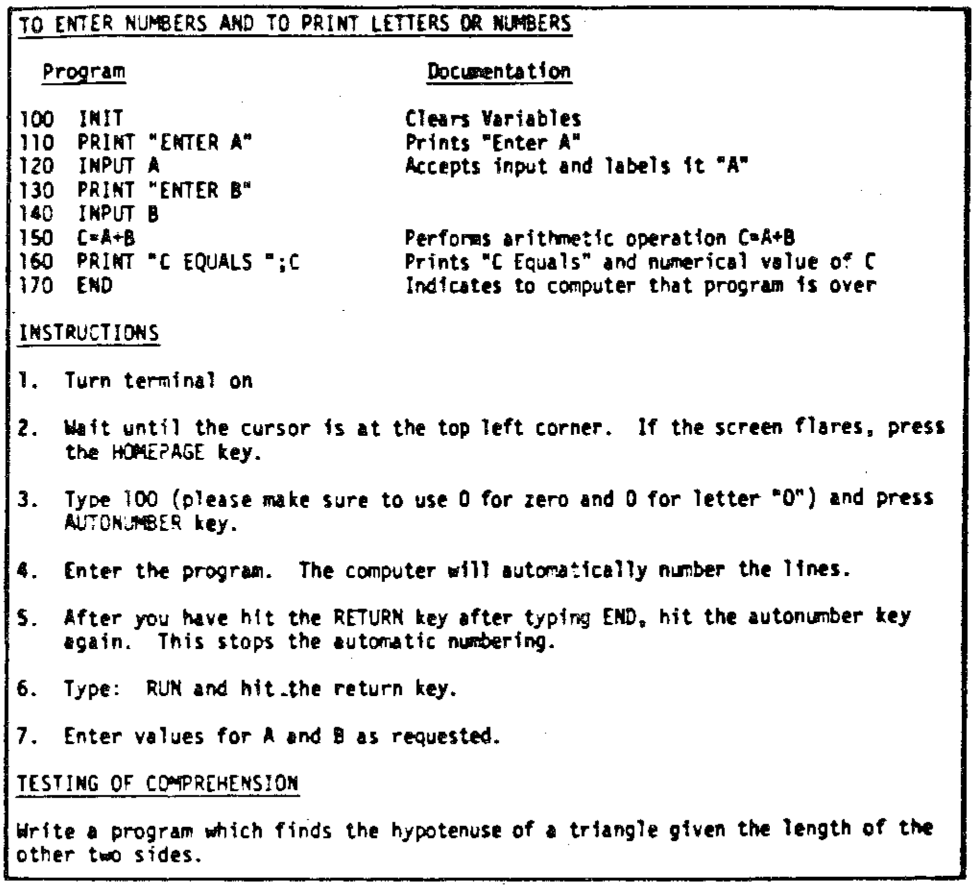
SHADING PROGRAM

USER DEFINABLE KEY	TITLE	DESCRIPTION
1	Directions	Gives directions for the program.
2	Enc. Shade	Will shade enclosure you are about to enter.
3	Shades Circles	Will shade circle you will define.
4	Unshade Enclose	Void an area you have already shaded.
5	Unshade Circle	Unshades Circle
11	Init	Erase all variables
13	Clear Enc. & Circles	Erases borders but leaves shading

FIGURE 7

14	Clear Shade	Keeps borders, deletes all shading
15	End	Ends your operation but keeps variables
17	Draw on Plotter	Draws on Plotter
18	Shade only on Plotter	Shades only on Plotter
19	Draw Enc. Only	Draws enclosures only
20	Self-Destruct	Deletes all

FIGURE 7



TO ENTER NUMBERS AND TO PRINT LETTERS OR NUMBERS

Program	Documentation
100 INIT	Clears Variables
110 PRINT "ENTER A"	Prints "Enter A"
120 INPUT A	Accepts input and labels it "A"
130 PRINT "ENTER B"	
140 INPUT B	
150 C=A+B	Performs arithmetic operation C=A+B
160 PRINT "C EQUALS ";C	Prints "C Equals" and numerical value of C
170 END	Indicates to computer that program is over

INSTRUCTIONS

1. Turn terminal on
2. Wait until the cursor is at the top left corner. If the screen flares, press the HOMEPAGE key.
3. Type 100 (please make sure to use 0 for zero and O for letter "O") and press AUTONUMBER key.
4. Enter the program. The computer will automatically number the lines.
5. After you have hit the RETURN key after typing END, hit the autonumber key again. This stops the automatic numbering.
6. Type: RUN and hit the return key.
7. Enter values for A and B as requested.

TESTING OF COMPREHENSION

Write a program which finds the hypotenuse of a triangle given the length of the other two sides.

FIGURE 8

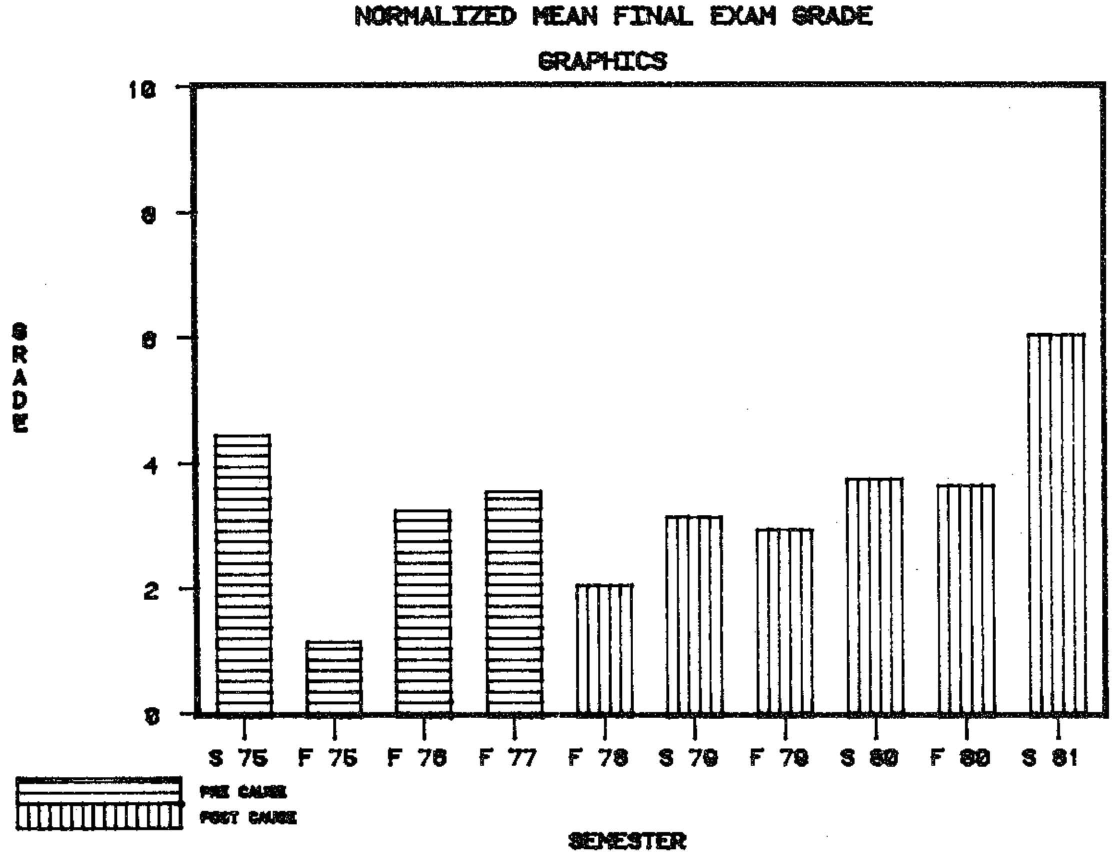


FIGURE 9

continued from p.6

while also learning much more about computer graphics. At the same time, the treatment group required significantly less time to learn the principles being taught. It may be concluded, therefore, that the method of teaching engineeering graphics through a combination of traditional manual exercises followed by user-oriented computer graphics (without any programming) is an effective and efficient way to teach engineering graphics and simultaneously introduce computer graphics to the freshman engineering student (Groom, 1982).

accept the computer as another tool

Summary

In terms of students' learning and students' time, this method of combining manual and computer graphics has obvious advantages. Clearly this method could be extended to other related topics in engineering graphics. It is a matter of time before computers will be as common in the classroom as they are in industry. This method would then release more classroom time to be spent elsewhere -- either on new topics or on more thorough coverage of existing topics. Assistance to crowded curricula is at hand!

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Prosthetic Design:Reflecting the Importance of Careful Goal Identification

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In engineering design, the problem which is to be solved must first be identified and then defined in terms of the specific goals to be achieved by any viable solution. In this paper, upper-limb, myoelectrically-controlled prosthetics are reviewed as examples of engineering designs which seek to achieve specific engineering and physiological goals, thereby demonstrating both the extent and the variety of goals which can be associated with an engineering project.

Prosthetic Program & Goals

The program for the design and fitting of a prosthetic device for an individual patient may be similar to that used at the University of Alberta Hospital in Edmonton, Canada, which is as follows:

- a medical and prosthetic history is taken
- a myotester is used to locate any potential surface electromyographic (EMG) sites ('myo' refers to muscle)
- a prosthetic development plan is discussed with the patient, case physicians, etc.
- a prosthetist prepares the artificial limb using commercially available components
- The patient is fitted with the device
- postprosthetic training is conducted by an occupational therapist; this training includes
  - a) a checkout drill to insure that the degrees-of-freedom offered by the device are achieved by the patient,
  - b) the simulation of daily tasks (dressing, grasping, eating) and
  - c) the incorporation of the device into daily life.
- An evaluation is conducted after several months to determine the success of the prosthetic in meeting the needs of the patient.

There are numerous engineering and physiological goals which should be achieved by upper-limb prostheses; Table I lists some of these goals. A brief review of the history of myoelectrically-controlled, upper-limb prostheses will lead us to specific case histories which reflect the difficulties and the challenge awaiting the rehabilitation engineer as he seeks to achieve these goals.

Historical Review

Prosthetic devices for the hand, wrist, and elbow have undergone a great deal of development since World War II.

Body-powered, cable-connected designs have proliferated; however, these devices are awkward, slow, and quite limited in their ability to emulate normal limb movements (Mann, 1981). Above-elbow amputees, in particular, must

(1) retrain their muscles to use such mechanisms,
(2) devote substantial attention to the operation of the device, and
(3) endure occasional coupling and interference between the elbow and terminal-device (hand or hook) components which result from their operation by a single common cable.

Cybernetic prostheses seek to replace physiological control functions with electromechanical systems which include a synergy or combined action between the central nervous system and the prosthesis. Biopotentials (usually myoelectric signals) are detected and used to control the response of the prosthetic device. Such devices, if properly designed,

(a) do not require retraining of the amputee or complete concentraion during use,
(b) provide feedback to the user of his limb's position and its interaction with the environment, and
(c) allow graded or proportional control of the device (i.e., the prehension force and closing rate of the terminal device is proportional to the degree of activity at the control site (Childress & Billock, 1970)).

The development of myoelectrically-controlled prosthetics can be divided into three historical phases (Childress & Billock, 1970):

Laboratory phase .... 1945 - 1959
Experimental fitting phase 1959 - 1967
Commercial phase ...... 1967 - Present

Reiter's work (1948) included opening and closing an artificial hand via myoelectric signals; the amplifier used vacuum tubes and, as a result, was only a bench model. (Solid-state technology has allowed the later development of self-contained compact designs.)

Russian (Kobrinsky, 1960) and British (Bottomley & Cowell, 1964) investigators developed myoelectrically-controlled hands during the 1940's and 1960's, all of which utilized surface electrodes to detect muscular activity. (The Russian below-elbow device was susceptible to electrical interference.)

None of these designs provided true cybernetic synergy (Mann, 1981) since the myoelectric signals were employed in a binary mode, i.e., signals which were above a certain threshold level activated a particular motion (opening or closing of the hand). As a result, the mechanical responses of the devices were not proportionally controlled and the control channels operated independently (as opposed to the agonist/anatagonist pair synergy found in neuromuscular physiology). In addition, the myoelectric signals used for the control were probably not originating from the natural muscles for such control (i.e., wrist muscles are more superficial - nearer the surface - in the arm than those whoch control the fingers and thumb; hence wrist muscles were probably used to control the electric hand (Mann, 1981) .

The experimental fittings stage continued with the development of the Boston Arm (Mann, 1981), (Rothchild & Mann, 1966) which used signals from the relevant, natural but dysfunctional biceps (agonist)/triceps (antagonist) muscle pair to proportionately control an elbow mechanism. In addition, some force feedback was provided to the amputee in this design.

There are seven (7) primary degrees-of-freedom of the human arm, excluding the motions of the wrist, fingers, and thumb: clavicular extension and abduction; humeral abduction, rotation, and flexion; forearm supination and elbow flexion (Mann, 1981). A properly designed prosthetic device should offer such multiple degrees-of-freedom to the user. Myoelectrically-controlled devices were developed which sought to achieve several degrees-of-freedom corresponding to normal physiological abilities; these devices include:

Temple Arm (Taylor & Finley, 1974) which applied pattern recognition to correlate levels or groups of myoelectric signals at multiple electrode sites; some elbow and wrist coordination was achieved, but hand prehension was limited.

Swedish Arm (Clynes & Milsum, 1970) which used a computerbased analysis to determine the proper placement of electrodes on the forearm stump in order to detect distinct patterns of muscular activity and then coordinate this activity with mechanical responses. Pronation-supination of the wrist, finger prehension, thumb rotation, and wrist flexion were all controlled through muscle synergies. However, the high cost for production of this artificial limb has limited its marketing.

Utah Arm (Jacobsen & Mann, 1973) is under development; it is quiet, smooth in operation, and said to "... most closely (approximate) the natural limb of any ... hardware to date".

An evaluation and comparision of some devices with a cable-operated elbow has been conducted (Jerard & Jacobsen, 1980); the results indicate that amputees prefer the Utah Arm (with a biceps/triceps control) to the cable-operated or Boston Arm designs.

Case Studies and Creative Design

Surface electrodes provide safe, convenient measurements of muscular activity (although such electrodes are less efficient, due to skin impedance, than percutaneous (through skin) and subcutaneous (implanted) electrodes (Clynes & Milsum) ; however, some patients cannot use such surface measurement for controlling purposes. In these cases, prosthetic designers have demonstrated new levels of creativity in order to provide amputees with useful devices. (Two case studies will illustrate such creative design efforts shortly.)

Commercially available electric hands and wrists are available (Stein et al, 1980). These hands are intended for below-elbow amputees and are controlled myoelectrically by muscles (e.g., long wrist extensors, flexors) which frequently remain after amputation. The wrists are intended for use by mid-forearm level amputees with residual pronation-supination which allows them to operate a rotary microswitch in the prosthesis.

Higher-level amputees (short below-elbow and above-elbow) do not have suitable control methods for several degrees-of-freedom wrist rotation. As a result, new prosthetic designs were needed for the following individuals.

Case Study 1: Implantation (Stein et al, 1980)

A 63-year-old male with a left below-elbow amputation (dating to World War II) had minimal pronation and supination of the residual limb. He wanted to wear an electronic wrist rotator which would allow him greater freedom to pursue his hobbies of carpentry and furniture finishing; however, a needle EMG examination indicated that there were no surface EMG sites available for tapping the pronator teres and supinator muscle portions which remained intact.

A device was implanted which included four EMG probes to provide independent sites for myoelectric control of four functions: hand opening (wrist extensors), hand closing (wrist flexors) and wrist rotation in two directions (propinator and supinator). The signals (40 V - 100 V) which were obtained were greater than that required for myoelectric control; furthermore, the implantation achieved stable operation near electrical equipment (e.g., power tools) and did not suffer from other environmental sensitivities (e.g., temperature, moisture content of the skin) which sometimes limit the operation of surface control sites. (A final unit consisting of an electric hand, electric wrist, four myoelectric amplifiers and a power control and logic (PCL) module - designed for myoelectric control of wrist rotators - was constructed.)

Case Study 2: Tristate Control (Stein et al, 1980)

A 34-year-old male with a right above-elbow amputation at the mid-humeral level and a partial forequarter amputation on the left side (due to a farming accident) was initially fitted with a cable-controlled elbow and hook on the right side. (Conventional devices did not allow a functional fitting of the left side, due to the high level and bilateral nature of the amputations.)

An EMG examination of the right-side indicated that (although the bicep muscles were not present) there were suitable signals from the triceps and from a small portion of the coracobrachialis muscles. The problem to be solved, therefore, was to myoelectrically control three joints (elbow, wrist, and hand) with only two muscle sites.

A cable-driven elbow was used, including a circuit in which a small EMG signal controls a particular movement and a larger signal activates a relay for controlling another movement. Such grading of the signal amplitudes from a single site to control two different functions is known as tristate control. No surgery is required, interchangeability can be easily accomplished and a choice of functions is available with this type of control.

The two right-side muscles could then control four movements:

closing and opening of the hand (via low and high levels of contraction in coracobrachialis) and

pronation and supination of the wrist (via low and high levels of contraction in the triceps).

The patient was eventually fitted on the left-side with an electric elbow, wrist, and hand which used a combination of tristate and touch control. (His left shoulder touched metal contacts - thereby using the skin as a high-impedance conductor - to complete a circuit which produced a switching action to control the elbow and wrist movements; a tristate module was used to open and close the hand via the medial portion of the deltoid muscle.

Conclusion

These two case studies indicate the need to fit the individual patient with the prosthetic system which best achieves his specific needs. The myriad goals which are associated with various prosthetic situations indicate that continued research and creativity are required in prosthetic design. Furthermore, prosthetic designs demonstrate the importance of careful goal selection, definition, and achievement in successful engineering design efforts.

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Speed[5]

Grasping Accuracy[1,5]

Compression Accuracy[5]

Self-contained, self-suspended[3,5] (eliminate harness, etc.)

Fine (physiological) Control[5]

Training - short time period[1,5]
    not difficult, not complex[1,2,5]
    begins on day of surgery[3]

Use of Commercially Available Components[1]

Use of Biocompatible Materials[1]

Public (user, observer) Acceptance[1] (includes appearance and function)

Use of Specifically Relevant Muscles[1,2]

Ease of Signal Acquisition[1,4]

Tristate Control if needed[1,3]

Increased Use of Residual Muscles[1,3]

Minimum Cost[1,2]

Safety[2,4]

Convenience[2]

Reliability[1]

Minimum Maintenance and Servicing[1]

Multiple Degrees-of-Freedom[1,2]

Minimum Effort, Minimum Concentration[4]

Sensory Feedback[1,2,3,4]

Agonist-Antagonist Synergy[2]

Separation of Signals[1]

Efficient[4]

Proportional Control[2,3] (response should be proportional to the degree of signal activity)

References

[1] Stein et al (1980)
[2] Mann (1981)
[3] Childress and Billock (1970)
[4] Clynes and Milsum (1970)
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TABLE 1
Goals Which May Be Associated
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define engineering problem through goal identification

Descriptive Geometry-Based CAD

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Introduction

With the advent of high-speed, low-cost technology, scientists and engineers have devised numerous applications for their own specific work on large processors. One area, that of Computer-Aided-Design (CAD), has received a great deal of attention in recent years. A variety of software packages has been developed addressing CAD. Yet while some of them focus on specialized functional areas (three-dimensional drawing, for example), others do not. Clearly, an ideal, all-encompassing dominant system that fulfills the needs of a large cross-section of users has yet to emerge. It is apparent that many years of challenging research and developmental work remains to be done in this area.

The purpose of this paper is to present another approach to CAD, one aimed at taking a new step towards developing the "ideal" system. Using the facilities (and assistance) of Princeton's Interactive Computer Graphics Laboratory (ICGL), we have designed and developed the elements of an interactive, three-dimensional CAD system that we hope will ultimately satisfy the needs of the engineering designer, as well as illustrate, in an educational mode, the principles of descriptive geometry and engineering drawing (since our CAD system is based on these principles). All of the work to date has been performed on the IBM 3033 and 3081, Princeton University's time-sharing facilities. In addition, all of our programs have been written in APL, a powerful manipulator of matrix algebra that lends itself very well to dealing with 3-D geometric concepts.

Background Philosophy

From the beginning, we attempted to conceptualize and implement a 3-D interactive system that would take advantage of the computer's computational power and marry it to the theory of descriptive geometry as well as provide a powerful tool to a designer with little or no programming experience. Furthermore, we sought methods of illustrating fundamental principles of descriptive geometry and engineering drawing, thereby creating an educational tool (and foundation for an instructional course) in the process. Central to this desire was our firm belief that the user of any CAD system must first fully understand the basic concepts employed in any 3-D drawing. Despite the impressive graphical outputs it can produce, a computer often has the tendency to "control" the designer by providing a fixed mechanism of viewing objects without conveying their basic composition or orientation in space, thus requiring the designer to respond to the demands of the computer rather than vice-versa.

Initially, we assembled, as a feasibility demonstration, a limited inputing mechanism with front, side, and top viewing windows (conventional by most standards) as well as perspective and axonometric capabilities (Fig. 1). The two-cursor input method to register 3-D points was very burdensome and made us wonder whether the designer was better off using the traditional pencil and paper approach instead. It should be noted here that we operated on an IBM 3277 display terminal with a Tektronix 618 graphic attechment and a joystick throughout - the present state-of-the-art computer technology at ICGL (in the Spring of 1983, an IBM 3250 Graphic Display System with light pen will be on-line). In addition, although we could rotate an object about the coordinate axes to obtain any view we desired, this provision of flexibility could easily confuse students who did not comprehend the transformations involved (the intermediate orientations in space) enroute to an observed view. In short, we wanted to take advantage of a three-dimensional data structure, but not at the expense of the user.

This initial demonstration clearly indicated the need to devise a new facility both to input and view three-dimensional figures on a two-dimensional screen in order to fulfill our objectives. The special quality of our system lies in just such a mechanism (described below).

A New Viewing Approach

The implemented viewing structure directly applies methods used by design-draftsmen in setting up successive orthogonal pictures using standard paper and pencil procedures. A point's location in a desired view depends on its distance to projection planes in two previous views (Slaby (1956) presents a clear explanation of this and other concepts). However, it would be inefficient to perform calculations in the

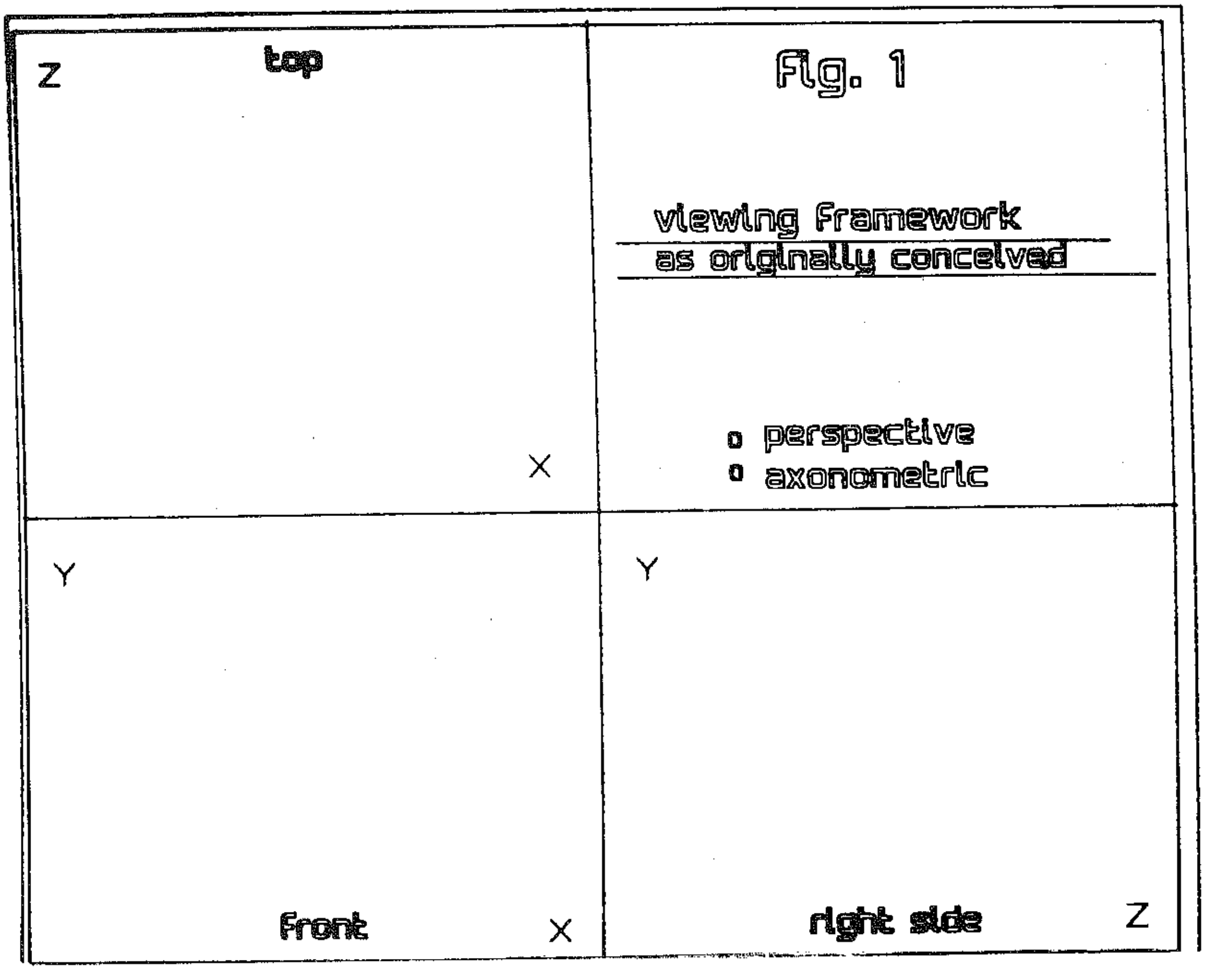
Fig. 1

viewing framework as originally conceived

same manner - that is, in two dimensions - even though it could be done if, for no other reason, to take the burden off of the designer. This approach would involve measuring distances between points and projection planes as well as determining positions perpendicular to these planes for successive projections.

Instead, by observing that a new view consists of rotating three-dimensional points in the immediately adjacent view by 90 degrees about the line representation of the common projection plane (see Fig. 2), it was evident that matrix algebra, in principle, could solve any viewing problems. In fact, Adams and Rogers (1976) provide a compact 4x4 matrix using homogeneous coordinates to rotate any set of 3-D points about an arbitrary axis in space:

$$\begin{bmatrix} N_1{}^2 + (1-N_1{}^2)\cos & N_1N_2(1-\cos\ ) + N_3\sin & N_1N_3(1-\cos\ ) - N_2\sin & 0 \\ N_1N_2(1-\cos\ ) - N_3\sin & N_2{}^2 + (1-N_2{}^2)\cos & N_2N_3(1-\cos\ ) + N_1\sin & 0 \\ N_1N_3(1-\cos\ ) + N_2\sin & N_2N_3(1-\cos\ ) - N_1\sin & N_3{}^2 + (1-N_3)^2\cos & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Given that theta, the angle of rotation, is always 90 degrees for our purposes, any term with a cosine factor goes to zero while those with a sine factor reduce to one. Furthermore, by placing the line representation of the projection plane in the Z=0 plane, N3, the normalized Z-component of the axis vector, goes to zero. We can make this assumption since the viewing screen exists in only two dimensions. The axis can therefore lie on the screen (Z=0 plane) even though the Z-coordinates of an object may place it well "behind" the screen. After simplifications, the matrix becomes :

$$\begin{bmatrix} N_1{}^2 & N_1N_2 & -N_2 & 0 \\ N_1N_2 & N_2{}^2 & N_1 & 0 \\ N_2 & -N_1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

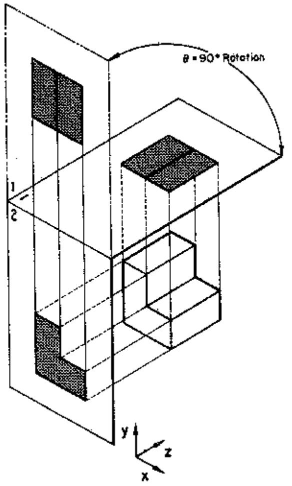

Fig. 2

To actually create a new view in the programming end, several sub-routines must be employed. The first one prompts the user to input end points for the new projection plane (to be used interchangeably with "line") by first entering one point and then "rubber-banding" a line connected to it until he is satisfied with the positioning of the second end point. These two points, in effect, determine a vector and also angle theta relative to the horizontal. Yet a problem emerges. Given that a positive angle constitutes a counterclockwise rotation, then which point should serve as the head of the axis? Clearly, the answer depends on where the object(s) to be projected lies. Since we have assumed the Z-axis to protrude into the screen, then conceivably a 90 degree rotation of data behind the screen brings it "forward," with its subsequent two-dimensional projection superimposing itself nearly on top of the adjacent view (Fig. 3). However, a rotation in the "other" direction, i.e. with the axis vector pointing in the opposite direction, would bring about a proper projection. Thus, the user must tell the computer which view number the new view is adjacent to so that the computer can determine on which side of the line the object data resided (by associating a center-of-gravity point for the objects with each view). A three-element vector of information, containing the x and y coordinates of the axis tail as well as angle theta, can be stored for further reference.

The rotation angle theta then serves as an input to a program which calculates the simplified rotation matrix MAT. The program SYSTEM3 functions primarily to establish new views and object data (Fig. 4). Line 8 applies this matrix, MAT, to a properly indexed set of three-dimensional data points to calculate those constituting the new view. APL permits the programmer to establish three-dimensional data tables so that each plane of points within a table may be associated with a different view. The indexed plane can be derived from the view number information inputed previously by the user. Line 7 updates a 3-D array of transformation matrices (which we will call TOTMAT) relative to the first or base view. To illustrate, for each newly-created view, a matrix containing the inner product of MAT and the matrix in TOTMAT associated with the adjacent view is determined and concatenated onto TOTMAT, thereby assuming the identity of the new view's transformation matrix (Fig. 5). Ultimately, every matrix in TOTMAT builds up the views from the base view (which can have the identity matrix associated with it). If one wishes to see quickly the seventh view of some object, he need only apply the seventh matrix in TOTMAT to the points in the base view instead of re-multiplying as many as seven arrays! Furthermore, should one wish to relate points between two nonadjacent views (for editing purposes, let us say), he has only to apply the inverse matrix of one view (to bring the data points back to the base view) and then multiply by the other view's matrix. This seemingly indirect method is preferable to retaining a much larger array of matrices relating views directly. Besides, once one projection plane is re-oriented, all of the matrices in TOTMAT become invalid.

Thus, the process of creating new views involves calculation of new angles, matrices, and the updating of data tables. At this point, a brief explanation of the remaining data tables is warranted. We have implemented a hierarchical structure involving four main tables, a node table (NT), an object table (OT), and two viewing tables, TOTPTS and VIEWDATA. Deferring discussing of OT until later, the node table (NT) simply contains the original 3-D points in the base view in the order in which they were inputed. TOTPTS, unlike NT, is a three-dimensional array (MxNx6) with each plane (M) of coordinates representing object data in a different view. It contains the linked points in their proper order as calculated earlier by MAT (each of N rows contains two 3-D points). VIEWDATA then substitutes drawing flags for the third-dimensional coordinates of each link in TOTPTS, thereby providing the data for a drawing routine (since only two dimensions of data can be drawn initially). These permanent tables may be updated each time an editing program changes the information stored in NT and OT. We feel that these tables save computer time by not having to reformulate

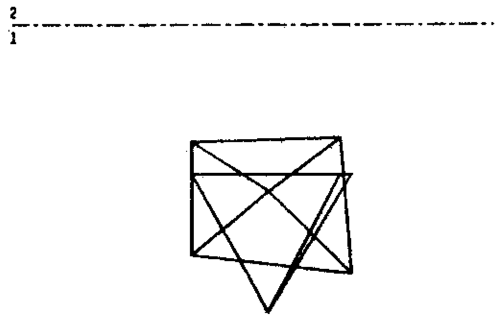

Fig. 3

superimposing one view of a pyramidal structure on top of another

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     ∇ PT1 SYSTEM3 PT2;PTS;MAT;NEWPTS;CPDATA;X
[1]   ⍝INCORPORATES SEVERAL PROGRAMS, ALLOWING USER TO ENTER NEW CUTTING
[2]   ⍝PLANE AND SEE RESULTANT VIEW. THIS PROGRAM UPDATES TOTMAT,TOTPTS,
[3]   ⍝COG, AND ESTABLISHES CURRENT SET OF 'PTS' 8/11/81 EFP (REVISED11/5).
[4]    →OUT×⍳(0=1↑1↓⍴TOTPTS,[2] SUBTOTP)∧1≤1↑⍴LINES
[5]    PT1 CP3 PT2
[6]    NEWVIEW3 CPDATA
[7]    TOTMAT←TOTMAT,[1] TOTMAT[(⍳0)⍴VIEWNUM;;]+.×MAT
[8]    NEWPTS←(((2×1↑⍴PTS),3)⍴,PTS←TOTPTS[(⍳0)⍴VIEWNUM;;]) SPIN3 MAT
[9]    TOTPTS←TOTPTS,[1]((0.5×1↑⍴NEWPTS),6)⍴NEWPTS
[10]  ⍝VIEWNUM←1↑⍴TOTPTS
[11]   UDTTAB3
[12]   UDCOG3
[13]   UDDL3
[14]   DRAW X←BUILDVIEW3
[15]  ⍝REVISED 8/19/81 EFP TO DRAW DLINE
[16]   →0
[17]  OUT:READYSYS3B
     ∇
```

Fig. 4

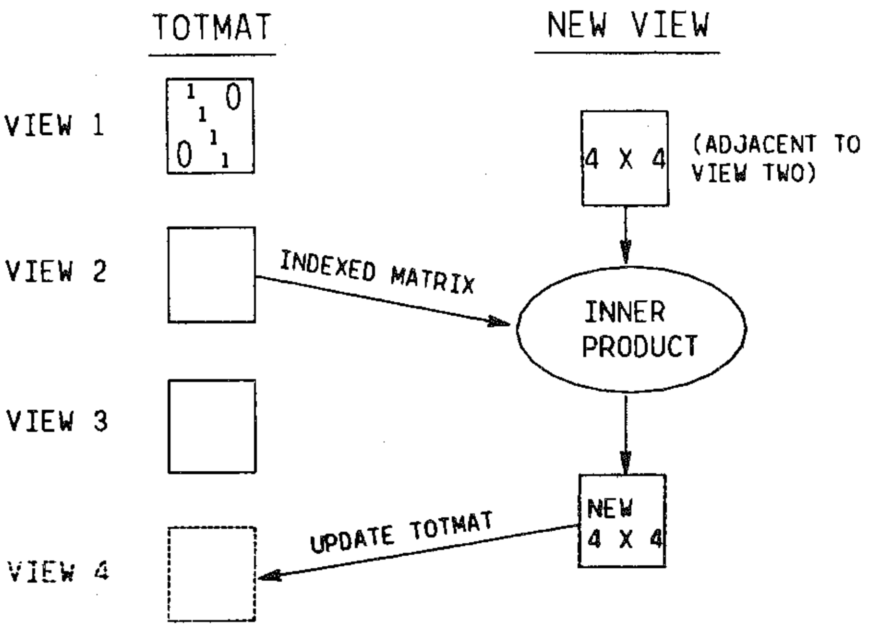


Fig. 5

updating transformation matrices

connected links of objects from NT and OT each time a redraw routine is called for. This is especially the case when several views of complicated objects must be inspected.

If the designer desires a different set of auxiliary views of an object(s), another program can erase all but the base view. Of course, TOTPTS and VIEWDATA are each then reduced to a single plane of points. Since the computer has stored the object data in NT, any new set of views can then be established. More importantly, only the principles of descriptive geometry limit the types of views available to the designer.

Inputing Object Data

The greatest challenge which faced us throughout the developmental stages of a convenient interactive 3-D design system has been that of finding an efficient, acceptable algorithm for inputing three-dimensional data on a two-dimensional screen, especially within the framework of depicting other than principle orthographic views (i.e. those besides top, side, and front ones). Though seeking to exploit the computer's extraordinary "number-crunching" potential, we did not wish to compromise the need for "user-friendliness," the smooth interface between a designer and his/her machine. An individual designer with little computer experience could be easily confused and discouraged by the thought of pressing innumerable keys to display single points, a process which is not conducive to creative design. In addition, we were already working with the handicap of a slow moving joystick, another natural hindrance to the designer who is comfortable with a freeflowing pencil.

Our adopted method involves the use of a "default plane" (seen as a line or an edge view) to pick up the third dimension of a two-dimensional point input. As originally conceived, this default "line" would be placed in a view adjacent to the one where a point was to be created. By calculating perpendicular distances to the common projection plane, the point's position in the view containing the default line (DL) could be determined and hence its third dimension since two views provide this information. But this was a classical illustration of two-dimensional thinking. After further consideration, a better utilization of the default line concept was deemed possible.

By considering an inputed point in a given view not as a node but as a point view of a line, then whenever the DL appears as a plane (and not as an edge) in the same view, a 3-D point of intersection must result from the notion of a piercing point between a line and a plane. Its location in other existing views can then be easily calculated with the aid of the transformation matrices in TOTMAT (Fig. 6). The key routine, then, involves the establishment of a DL. We have written a program enabling the user to select any line parallel to a projection line and then moving it around in a certain view in the "nostore" mode (a feature permitting constant refresh capabilities on the graphics screen) until the user decides to "place" it down. The program then arbitrarily assigns third coordinates to the mid and end points of the line (since three noncollinear points determine a plane), transforming all three back to their position in the base view.

At this time, a subroutine determines the points' collinearity in all subsequent views (setting up flags). In any view where they do determine a plane, another program calculates the equation of such a plane, determining the A,B,C and D coefficients of the equation Ax + By + Cz = D. All of this information is then stored in a table (PLDEF).

three dimensional point inputing

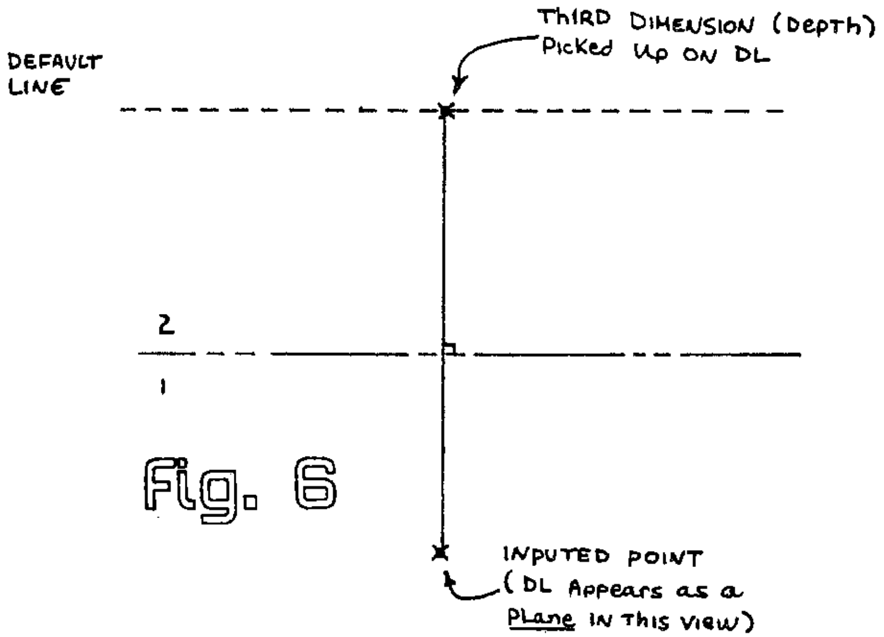


Fig. 6

The data inputing process, then, first involves ensuring that the user does not input a point in a view where the DL exists as an edge. In such a case, a single point of intersection will not result, either, because the line associated with the point and the plane associated with the edge are parallel, or because the line lies on the plane (in which case an infinite number of intersection points would result). Another program helps the user visually by drawing the edges in such views, thus alerting him to these possibilities.

Assuming that the user has inputed a point in a view without an edge of the plane, a program will calculate the 3-D point of intersection in the given view before transforming it to all other views. First, it creates the equation of the line represented by the point by first intersecting planes parallel to the X-Z and Y-Z planes. Then, given the equation of the default plane, it solves a system of three linear equations. Finally, it updates the main node and object tables as well as TOTPTS and VIEWDATA.

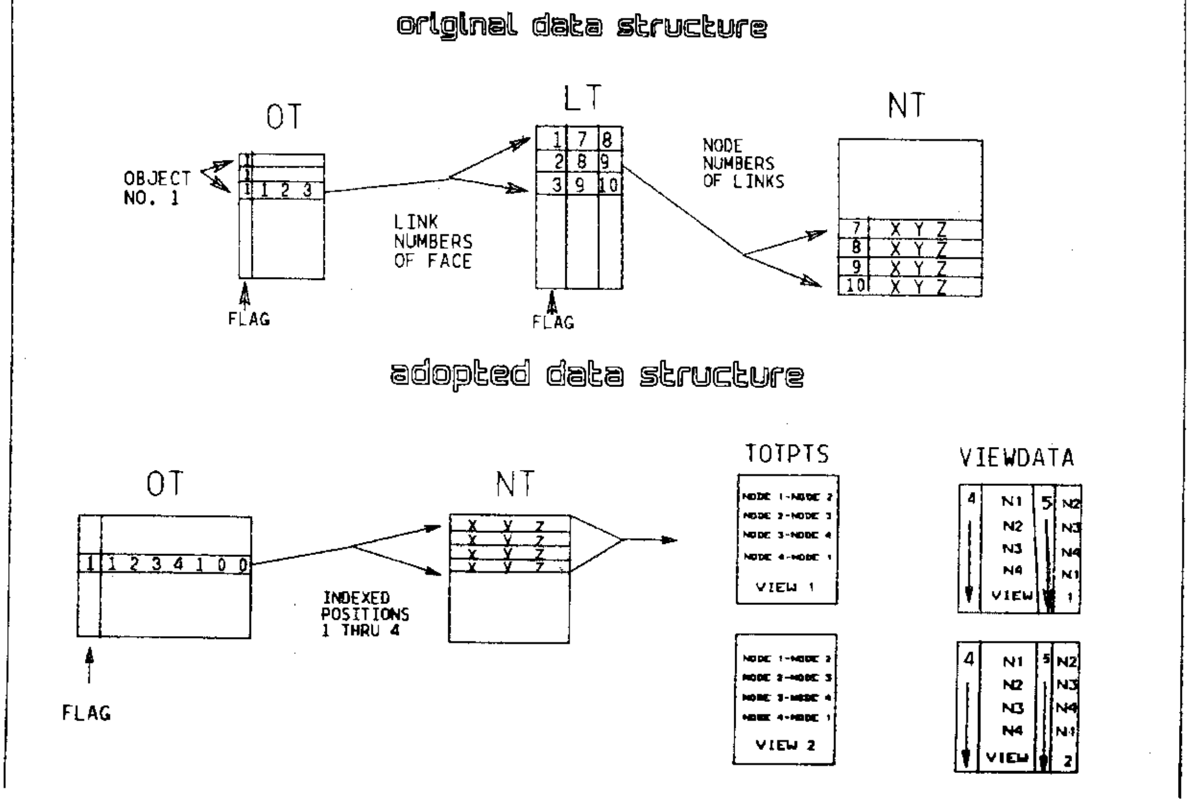
Regarding this entire process, we decided to depict objects as sets of planar faces. Each face, in turn, was made up of consecutively-linked nodes.

Consequently, each row in the two-dimensional table DT would first contain a flag indicating which object number the face would belong to and then list, in order, the node numbers linked together. The first node in the chain would be duplicated in the end to guarantee the closing of a face. Any zeros appearing afterward would serve only as filler to maintain data integrity (Fig. 7). Thus, point editing would simply involve inserting a node number into the chain or removing one from it. This approach permits a designer to create nonanalytical objects such as rectangular pyramids since he can assign nodes to several attached faces. In addition, we have implemented an object and face identification scheme in which, by proper link identification, the user can ask to see all faces and or objects containing the link. This identification can take the form of numerical (Fig. 8) and/or visual information (highlighting).

A Discussion of the Approach

Aside from displaying views in a framework familiar to students of descriptive geometry, our system obviously gives the designer unlimited freedom in selecting and inputing data in auxiliary views via properly chosen projection planes. In many other CAD systems, the designer may only see his/her objects in the more common horizontal, vertical, and profile planes. They may also do so in our system, but there are no restrictions. Regarding the inputing mechanism, the system provides for switching between and among views when creating default lines and object faces, a built-in flexibility. And despite having to use a default line, the user can input rapidly, especially when creating faces that appear as edges in certain views (in this case, the default line does not have to be moved since the depth will not change).

Fig. 7



Our approach also bypasses the cumbersome numbering method used by several CAD systems to identify ambiguous points, especially those in which different nodes are superimposed on top of one another in distinct views. In addition, the relatively few number of global data tables needed to drive this system facilitates a smoother assimilation of additional features.

We recognize several limitations to what we have done so far. Computer-aided drawing can only feel comfortable to designers if their drawing instruments are familiar to them. Ideally, a light pen and the "sketch pad" system used at M.I.T. (Coons & Mann, 1965) in the early 1960's would provide designers with that familiarity. A joystick equipped with a limited number of degrees-of-freedom for movement does not lend itself well to the creation of complicated objects since it is awkward to manipulate. Furthermore, the fact that the DL must be constantly moved <u>and</u> that every node in a face must <u>be</u> properly identified (to the data tables) regardless of its obvious appearance on the viewing screen slow down the inputing process. It is unclear at this point just how complicated a nonanalytical object can be accommodated in our system. Finally, although we have considered the CPU time taken up by our various algorithms, no thorough study of computer efficiency of our system has been undertaken by us. Our main concern to date has been in the feasibility end of satisfying our stated objectives.

<u>Additional Work</u>

Although the primary discussion in this paper has centered on the viewing and inputing processes, several other features have been incorporated. The main editing features involve node addition, node deletion, and link movement. In the latter, the user can "pick up" a point in any view and move it, still attached to any links it belongs to, to another position. In the area of user-friendliness, a two-screen format provides a menu of functions to the user (Fig. 9) in which he can invoke a program by simply pressing a single button. On-line tutorial panels provide information on each of these functions. Also, we have implemented an elaborate set-up of built-in error checks in the message display field (Fig. 10), thereby providing some form of "intelligence" to the system. For example, if the designer wishes to delete a node and its associated links from a three-sided face, the system will prevent him from doing so, informing that a "face" cannot have only two nodes and a single link.

We have also demonstrated the system's ability to display and manipulate analytical objects such as right cones and cylinders. By inputing three pieces of information (radius, height, and center), a user can create and view such objects almost immediately. The object data can be represented in a format compatible with the existing data structure (using 25 faces per object). Once inputed, these objects can then utilize the editing functions available to their nonanalytical counterparts. Another group of programs creates new viewing capabilities for the system. Four viewing windows that rotate existing images successively about the coordinate axes can be juxtaposed next

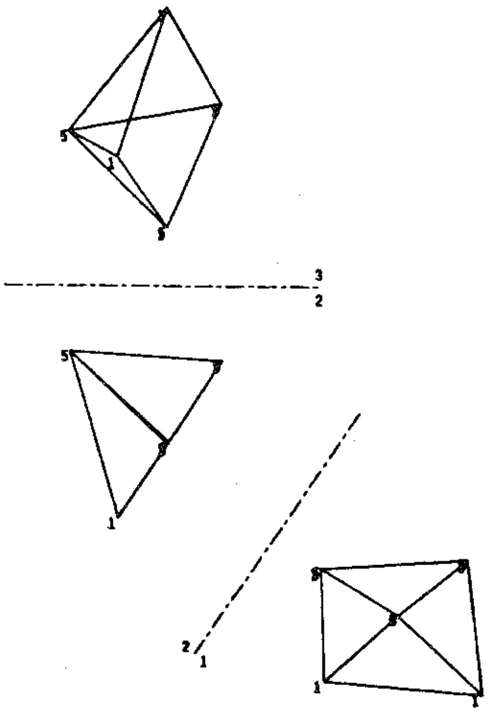


Fig. 8

Illustration of numerical face identification to the current viewing framework (Fig. 11). A menu of options allows for window enlargement as well as editing within this new viewing arrangement. As explained earlier, several CAD systems get around a limited viewing arrangement by providing for this rotation scheme. We have simply made this feature another option in our system.

In unfinished areas, a routine now works that permits the designer to input fixed angles between links as he creates his objects. This is the first step towards some sort of dimensioning analysis. Also, we have coded an entire group of programs that directly illustrate basic descriptive geometry principles. These include the true length of a line, the true shape of a plane, the piercing point of a line and a plane, and the angle between a line and a plane. It is our intention to use them as a teaching device to students. Finally, we have also successfully tested an algorithm to find lines of intersection between 3-D objects. This determination is not difficult for analytical shapes. But objects that cannot be described by equations present a more challenging problem.

Summary

This paper has described the elements of a special three-dimensional computer-aided design system developed at Princeton University. Limited by technological and financial constraints, we have addressed twin objectives: namely to provide an efficient and effective 3-D tool to the designer and a teaching device to students of descriptive geometry and engineering drawing. In the process, a new viewing and inputing mechanism has been introduced. Although much more work remains to be performed, we feel several limitations associated with other CAD systems have been overcome.

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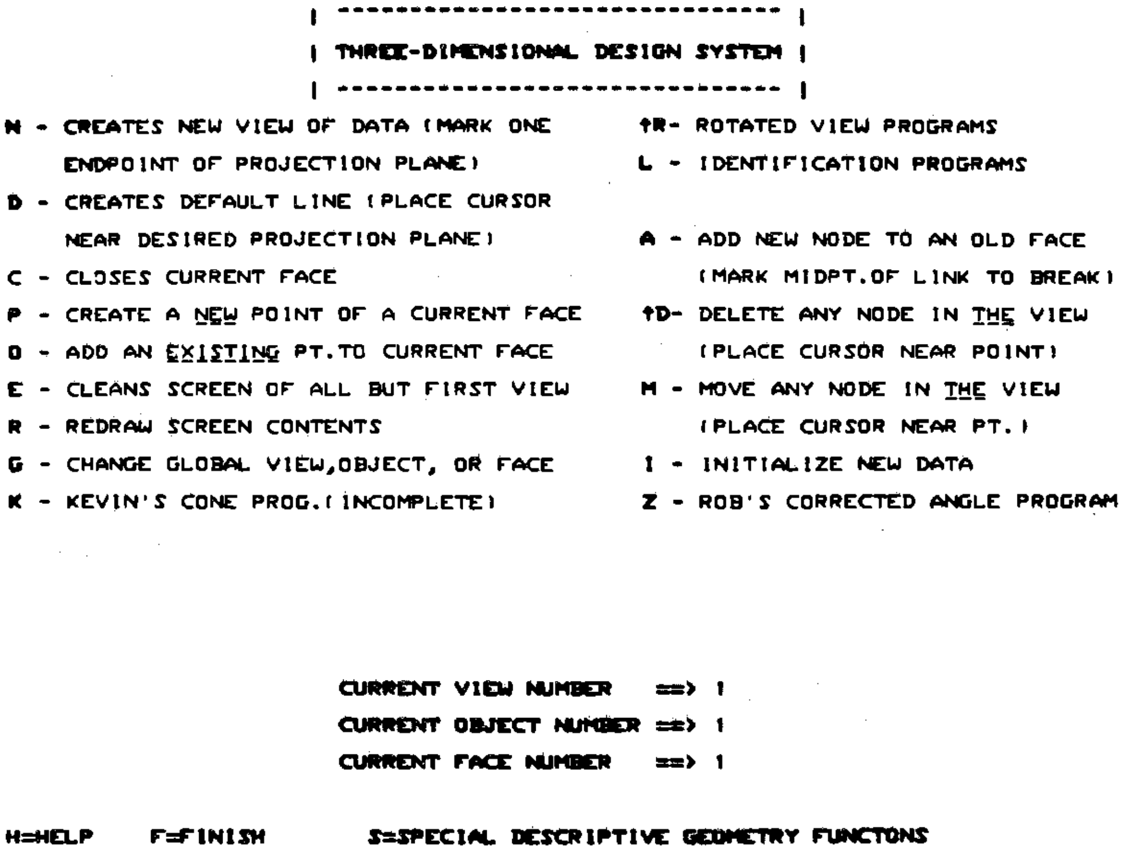
Slaby, Steve M., Engineering Descriptive Geometry (New York, N.Y.: Barnes and Noble Books, 1956), p. 12

Fig. 9



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                 | ------------------------------ |
                 | THREE-DIMENSIONAL DESIGN SYSTEM |
                 | ------------------------------ |
N - CREATES NEW VIEW OF DATA (MARK ONE       ↑R- ROTATED VIEW PROGRAMS
    ENDPOINT OF PROJECTION PLANE)            L - IDENTIFICATION PROGRAMS
D - CREATES DEFAULT LINE (PLACE CURSOR
    NEAR DESIRED PROJECTION PLANE)           A - ADD NEW NODE TO AN OLD FACE
C - CLOSES CURRENT FACE                          (MARK MIDPT.OF LINK TO BREAK)
P - CREATE A NEW POINT OF A CURRENT FACE     ↑D- DELETE ANY NODE IN THE VIEW
O - ADD AN EXISTING PT.TO CURRENT FACE           (PLACE CURSOR NEAR POINT)
E - CLEANS SCREEN OF ALL BUT FIRST VIEW      M - MOVE ANY NODE IN THE VIEW
R - REDRAW SCREEN CONTENTS                       (PLACE CURSOR NEAR PT.)
G - CHANGE GLOBAL VIEW,OBJECT, OR FACE       I - INITIALIZE NEW DATA
K - KEVIN'S CONE PROG.(INCOMPLETE)           Z - ROB'S CORRECTED ANGLE PROGRAM



                    CURRENT VIEW NUMBER   ==> 1
                    CURRENT OBJECT NUMBER ==> 1
                    CURRENT FACE NUMBER   ==> 1

H=HELP    F=FINISH       S=SPECIAL DESCRIPTIVE GEOMETRY FUNCTONS
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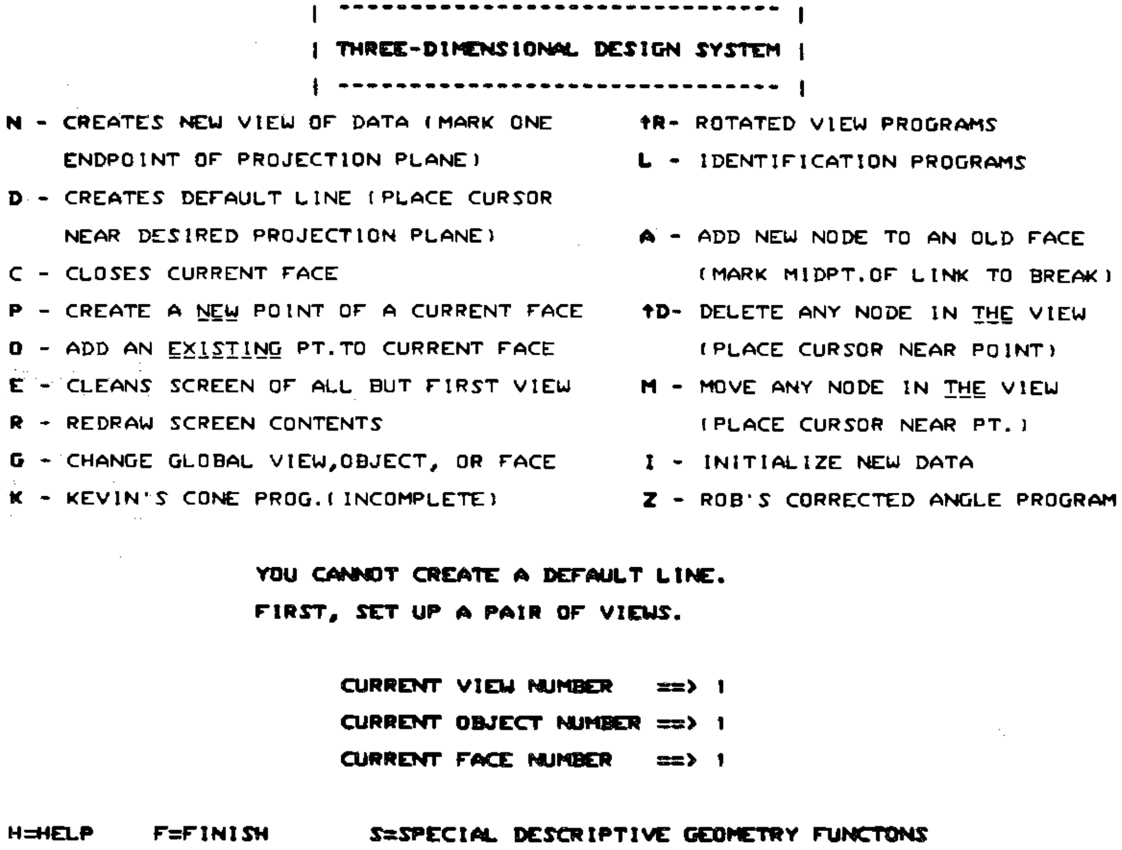
Fig. 10



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                   | ------------------------------- |
                   | THREE-DIMENSIONAL DESIGN SYSTEM |
                   | ------------------------------- |
N - CREATES NEW VIEW OF DATA (MARK ONE        ↑R- ROTATED VIEW PROGRAMS
    ENDPOINT OF PROJECTION PLANE)             L - IDENTIFICATION PROGRAMS
D - CREATES DEFAULT LINE (PLACE CURSOR
    NEAR DESIRED PROJECTION PLANE)            A - ADD NEW NODE TO AN OLD FACE
C - CLOSES CURRENT FACE                           (MARK MIDPT.OF LINK TO BREAK)
P - CREATE A NEW POINT OF A CURRENT FACE      ↑D- DELETE ANY NODE IN THE VIEW
O - ADD AN EXISTING PT.TO CURRENT FACE            (PLACE CURSOR NEAR POINT)
E - CLEANS SCREEN OF ALL BUT FIRST VIEW       M - MOVE ANY NODE IN THE VIEW
R - REDRAW SCREEN CONTENTS                        (PLACE CURSOR NEAR PT.)
G - CHANGE GLOBAL VIEW,OBJECT, OR FACE        I - INITIALIZE NEW DATA
K - KEVIN'S CONE PROG.(INCOMPLETE)            Z - ROB'S CORRECTED ANGLE PROGRAM

              YOU CANNOT CREATE A DEFAULT LINE.
              FIRST, SET UP A PAIR OF VIEWS.

                   CURRENT VIEW NUMBER   ==> 1
                   CURRENT OBJECT NUMBER ==> 1
                   CURRENT FACE NUMBER   ==> 1

H=HELP    F=FINISH        S=SPECIAL DESCRIPTIVE GEOMETRY FUNCTONS
```
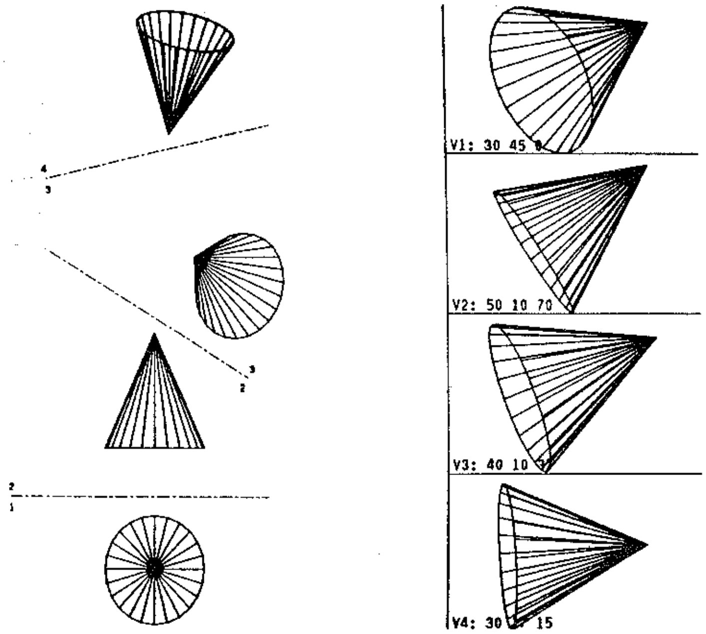

Fig. 11



Comparison of EG Instruction in the U.S. & China

Associate Professor Zeng Damin
South China Institute of Technology
People's Republic of China

Presented at the ASEE Annual Conference,
June 20-23, 1983
in Rochester, New York USA

It will be difficult for me to make a complete comparison of engineering graphics instruction between the United States and China, since I have worked at only one university -- Princeton University in the United States for an academic year. But from my observations to date, there exist many great differences and each have their own advantages and disadvantages. I will try to make a brief comparison from the following five aspects:

1. The Instruction Program

In China, a unified instruction program of engineering graphics was instituted by the Ministry of Education. This program was developed by a small group of engineering graphics experts, who were selected by the Ministry of Education from all of the institutes of technology in China. Basically, every teacher must follow this program on which his/her lectures are based. The program contains: (a) the purpose and task of the course, (b) the basic requirement of the course, (c) content of the course, and (d) explanation of the program (including the sequence, key points, depth and range of the course, suggestions for exercises and drawings, suggestions for the distribution of teaching period, instruction link and method, the relationship with other related courses). In the United States there seems to be no unified instruction program, teachers can develop, for the most part independently, their own program, according to the need and level of students, to get excellent results from their instructions. For instance, Professor Slaby created a mini course in Engineering Graphics last year which only lasted two weeks. He worked out a successful program and achieved the desired result. When the course finished, a student wrote him his opinion and said that it was fitted focus, if it lasted longer it would be a waste of time, if it was shorter, it would confuse us. In China, there are thousands and thousands of teachers who have very great differences in teaching experience. For instance, in my institute there are a total of fifty-five teachers who are teaching engineering graphics. How is it possible to guarantee to achieve good instructional results with this large number? The unified instruction program we find here is indeed needed.

2. The Teaching Period

The teaching period of Engineering Graphics in the United States seems to be universally much shorter than in China. For instance, the teaching period of the course, Surveying and Engineering Drawing instructed by Professor Slaby, involves a total of 48 periods in which 16 are devoted to surveying and 32 for engineering drawing. I was much surprised when I learned this. I wondered how one can teach this course within such a short time. But the facts showed me that Professor Slaby and his students achieved excellent results from his course of study, and I personally have drawn a salutary enlightenment from it. One can achieve a very good result in a short time when an efficient method was used. In China, the teaching period is much longer. It is generally classified into four types: 150 periods for machine building and ship building, 120 periods for civil engineering, 80-100 periods for chemical engineering and electrical engineering and 60 for electronics, mathematics and mechanics, in which about half periods are used for lecture, the other for laboratories. The distribution of teaching periods for descriptive geometry and engineering drawing is approximately one third for the former and two thirds for the latter. Each type of course has its own instruction program. The types of 150 and 120 periods are completed in two semesters, others in one semester. Although it seems comparatively much longer than the teaching period in the United States, there are still a number of teachers in China who say that it is too short. Since engineering graphics is widely used nowadays students need to solve many graphical solutions and geometrical translations, etc. But it may not be possible to do this. On the contrary, the teaching period presently is being cut down little by little, because the specialized engineering courses need more and more time. I think that this also happened in the United States. So we have to learn from this experience of yours.

unified graphics program in China

3. The Lecture

In China all lectures are given in a well-organized systematic way, step by step, a concept is developed to a new concept. All steps and concepts are given with a minute description under the aid of different kinds of models and wall maps, and sometimes movies, slides and video tapes. Most of the students can understand the material very well. But there is a side effect that this approach will be of little help for developing the ability to analyze and think on one's own. The only remedy is to assign more analytical exercises to the students and this will take a lot of teaching periods. I admired Professor Slaby's lectures very much, he only gave a brief description of the key points and some important examples and also gave numerous assignments to the students to read and solve after class by themselves. I observed that all students studied very well.

4. The Laboratory

As mentioned above, in China about half of teaching periods were arranged for laboratory time. All students did their exercises under the instruction of teachers in laboratory room. Students can ask questions immediately when they have problems in their exercises and teachers can find out which concepts students still do not fully understand. Students do many exercises throughout the whole course, in which are included 100 or more problems in descriptive geometry and 3 1/4x5 full size (500x750 cm^2) sheets of drawing paper with drawing instruments and 2x3 3/4 full size sheets of freehand sketches. Is this too much or not enough? It is the problem still debated in China, but all of the instructors maintained that after this training, students should handle drawings in the designs that follow with ease. At Princeton all exercises were assigned to be finished at home. Although the quantity is much less than in China, the course of study contains a simple design training. Assigned topics, design and drawing all were done by students themselves. It is a very good attempt, some Chinese teachers have proposed to try the approach, but there may exist many difficulties, because descriptive geometry and engineering drawing is the freshman course in China and begins in the first semester.

5. The Textbook

It is well known that in the United States, there are a lot of textbooks about descriptive geometry, engineering drawing, architectural drawing and computer graphics. Each one of them has its own characteristics and is very rich in content. Some of them were translated into Chinese and published, such as "Three Dimensional Descriptive Geometry" by Steve M. Slaby, "Four Dimensional Descriptive Geometry" by Steve M. Slaby, "The Fundamental Mathematics for Computer Graphics" by David F. Rogers and J. Alan Adams. The purpose is to introduce these books to Chinese colleagues and students as reference books. In China many textbooks have been written and used by a number of institutes themselves. Only a few of them were published by the Educational Publishing House (Government Publishing House), as a universal textbook. There are three "Engineering Drawing" for 150 periods, two "Engineering Drawing" for 80-100 periods, and "Architectural Engineering Drawing" for 120 periods and one "Electronic Engineering Drawing" for 60-80 periods. These were written to meet the demand of the Instruction Program, and selected by the group mentioned above. As time goes on, more textbooks in different systems and styles should be published for user's choice.

55 graphics teachers at one institute

Difference is a good thing. Only the existence of differences can make progress. But progress depends on mutual exchange and cooperation. We warmly welcome you to participate in the International Conference on Engineering and Computer Graphics which will take place in 1984 in Beijing, People's Republic of China. I can foresee great progress taking place after this conference in our great field of Descriptive Geometry and Engineering Graphics.

Thank you.

Visibility of Spatial Bodies:a quick method

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Israel Institute of Technology

Introduction

When a certain body is observed from a specific point of view E (eye) not all its parts are visible; the invisible ones are, generally, omitted in drawing the body's picture.

The selection of the hidden parts is, generally, performed in this way: each point A of the body's surface is connected to E by means of a ray EA which intersects all the body's faces at distinct points A1, A2 ... Every piercing point is checked in order to know if it lies within the boundaries of the corresponding face and, when this condition is satisfied, its distance, from E, along the ray EA is calculated.

The piercing point of EA whose distance from E is minimal is seen by the eye, all the remaining points are hidden.

The coordinates of E, A and the piercing points used for all the calculations are related to three different systems of coordinates: the "Eye Coor. System;" the "Screen Coor. system" and the "Spatial Coor. System." (1)

This kind of selection requires a lot of work and time. The selection, according to the proposed method, is based on a completely different principle - the "Visibility Principle" - which takes into account only the intersections between the various segments of the body's picture.

In addition, it combines the three above said systems in a single rectangular system XYZ the -"Unified System"- in which the ZX-plane is the -"Picture Plane"-; the XY-plane is the -"Ground Plane"- and the eye E always belongs to the ZY-plane.

In regard to this system any spatial point A has only one orthogonal projection A* on the ground plane and, because A* does not belong to the ray EA, the two rays EA, EA* pierce the picture plane at distinct point A_p, A^*_p.

Let us suppose that another point B of the ray EA does not coincide with A. It follows that B* does not coincide with A* and, while the two points A, B are projected, from E, on the picture plane at a single point Ap=Bp, the points A*, B* are projected at distinct points A*p, B*p. As a consequence the pictorial ordinates of A*p, B*p are not equal and:

1. when the ordinate of A*p is greater than that of B*p the point B is nearer to E than A, and conversely.
2. when the ordinate of B*p is greater than that of A*p the point A is nearer to E than B.

This statement, essential in determining the visibility of a point, constitutes the -"Visibility Criterion"-.

Now, consider the point of intersection between two segments of the body's picture. This point can be the projection, from E, of a real intersection between the corresponding spatial segments or it can be the piercing point of the picture plane with a ray, starting from E, intersecting the spatial skew segments at the points A, B.

In the first case A coincides with B and the same is valid for A*, B*; A*p, B*p; in the second one A is distinct from B and likewise are A*, B*; A*p, B*p. Then, by using the visibility criterion we can select the segment which is nearer to E.

In the same way we examine each point of intersection between the various segments of the body's picture and at the end the visibility of the body is determined.

The proposed method is very simple and it is suitable for: any polygonal, curved, twisted surface; two or more adjacent surfaces, two or more intersecting surfaces, parametric patch surfaces. Details of the proposed method are reported in the following paragraphs.

1. The Simplified System is composed of a rectangular system R (Fig. 1), whose axes X,Y,Z, are linked to the mutually perpendicular axes U,W, of a plane system P.

The origin M of R coincides with the

"visibility principle" intersection of segments of the body's picture

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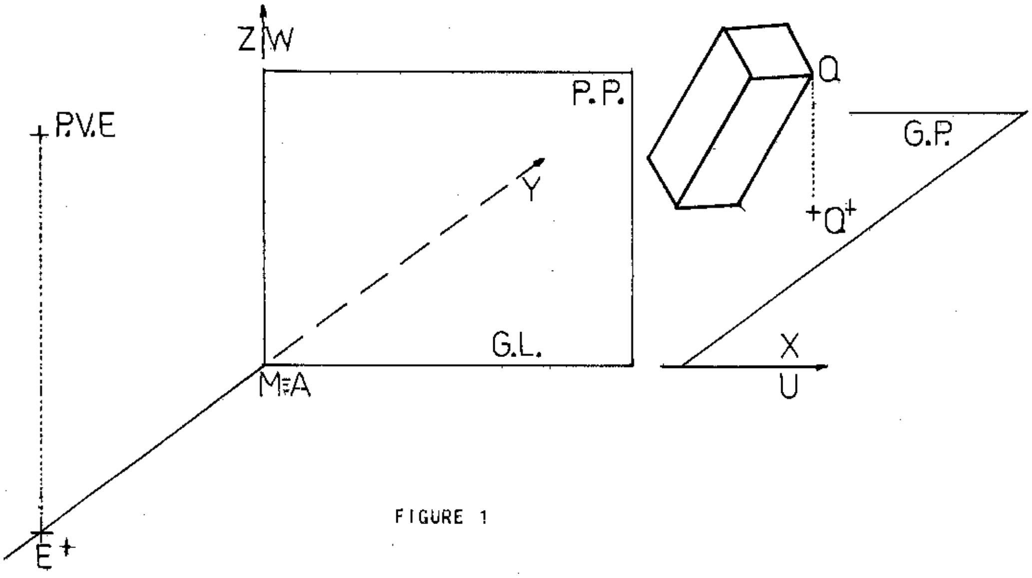

FIGURE 1

one A of P; the abscissa's axis X of R coincides with the one U of P and the altitude's axis Z of R- with the ordinate's axis W of P. The Y-axis of R is perpendicular to both X, Z and it is oriented as shown in figure 1. In addition the XY-plane is used as the "Ground Plane" (G.P.) of the pictorial system and the UW-plane as its "Picture Plane" (P.P.) on which the points of the given body are projected from a certain point E - named "Station Point" (S.P.) or "Point of View" (P.V.) - or from a point at infinity in which case the rays of projection are parallel. The U-axis is named "Ground Line" (G.L.).

The orthogonal projection E* of the P.V.E., on the XY-plane, is always located on the negative side of the Y-axis at a distance D from A. The Altitude of E, above G.P., is denoted by H.

The given body can be rotated and tilted in regard to the axes X,Y,Z and can be located anywhere in space. So, the P.V.E. can project it at any desired visual angle.

Any spatial point Q(P.V.E. included) has only one orthogonal projection Q* on the G.P. and the projections Q_p, Q^*_p of Q and Q* from E (Fig. 1 and Fig. 2) on the P.P. are the piercing points between P.P. and the two rays EQ, EQ*. Because EE* and QQ* are vertical lines the two points Q_p, Q^*_p lie on a line v, perpendicular to the G.L., which passes through the point of intersection Q_o between G.L. and the line E*Q*.

It follows that the U-abscissa "UQ" of Q equals the U-abscissa "UQ*" of Q* because both of them are equal to the segment AQ_Q. But the W-ordinate "WQ" of Q and "WQ*" of Q* differ because the

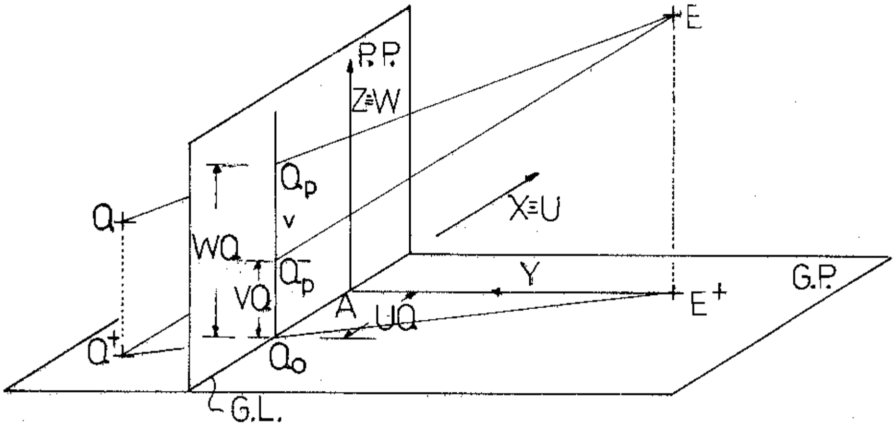

FIGURE 2

height "ZQ" of Q and "ZQ*" of Q* (ZQ*=0) are not equal.

Henceforth, in order to simplify the notations, the ordinate "WQ*"of Q* will be denoted "VQ". Then the symbol Q(UQ, VQ,WQ) indicates that the pictorial coordinates (in short pi.co.) of Q are UQ, WQ, and the pi.co. of its orthogonal projection Q* on G.P., are UQ,VQ.

2. The Visibility Criterion. Let us suppose that two spatial points A,B lie on a ray passing through E (Fig. 3) and their orthogonal projections A*,B* - on a straight line passing through E*.

According to this situation the pictures A_p,B_p,$A*_p$,$B*_p$ must lie on a line v, perpendicular to G.L., which passes through A_o=B_o. In addition A_p must coincide with Bp (see Fig. 2) and WA=WB.

It follows that two distinct skew segments: "a" through A, and "b" through B, are seen from E as two segments a_p, b_p cutting each other at the single point Ap=Bp. For this reason the point Ap=Bp is considered as a double-point.

But A*p,B*p are distinct points whose ordinates VA, VB are different; therefore the picture $a*_p$ - through $A*_p$ and $b*_p$ - through B*p do not intersect at a point of v.

The length of A*E* is linked to the value of the ordinate VA in the sense that when A*E* enlarges or diminishes, the same applies to VA. This is valid for B*E* and VB and for any other point of the line A*E* too.

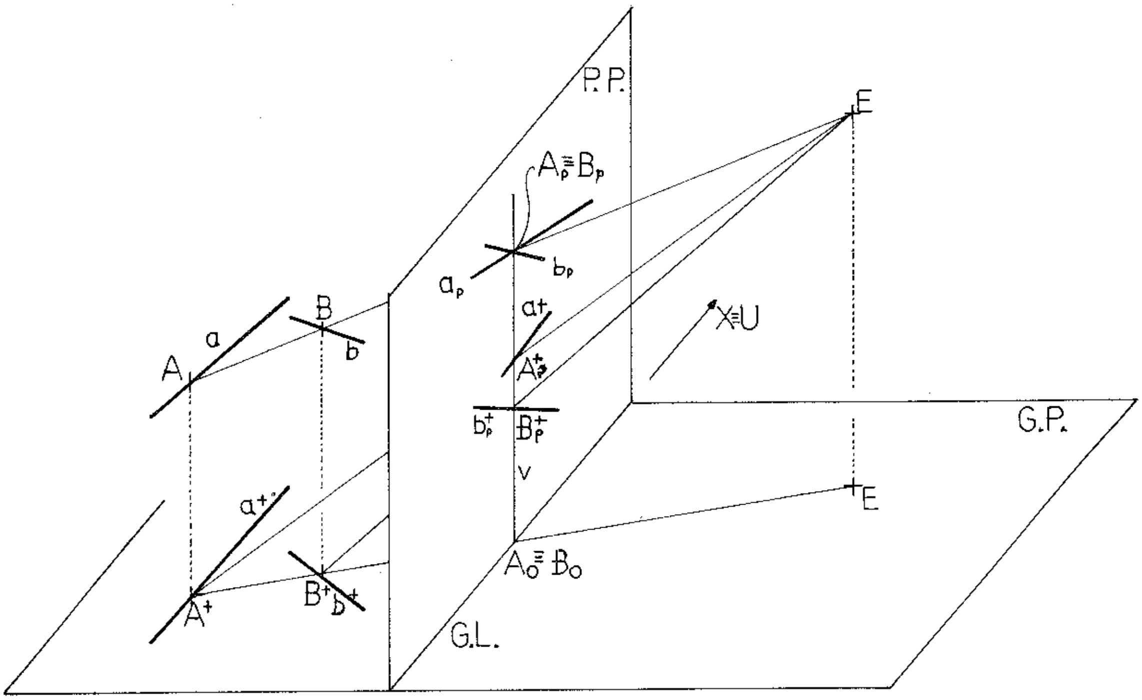

FIGURE 3

In our case (see Fig. 3) VA>VB and consequently A is farther from E than B. This conclusion, essential in determining the visibility of a segment, is used as "Visibility Criterion" (in short VI. CR.).(2)

3. The Mapping of The Surface. Cut the surface (in short SF) of the given body with two sets of auxiliary surfaces which originate two sets of lines belonging to SF. (see Fig. 4 and Fig. 5).

Sometimes the number of the lines of one, of the two sets, may reduce to 2. (see Fig. 5). Denote with "i" the number which differentiates the lines of the first set and with "j" - that of the second set; i=1...N; J=1...M.

The lines of the two sets determine, on SF, skew quadrilaterals that are numbered as a continuous sequence whose index is "k". The relationship between k and i, j - for a single surface - is: k=M(i-1)+j. When i=1, j=1, k=1, too.

4. Simplification. Each quadrilateral is considered twice: once as a fixed part of SF which is examined, in order to establish its visibility (in

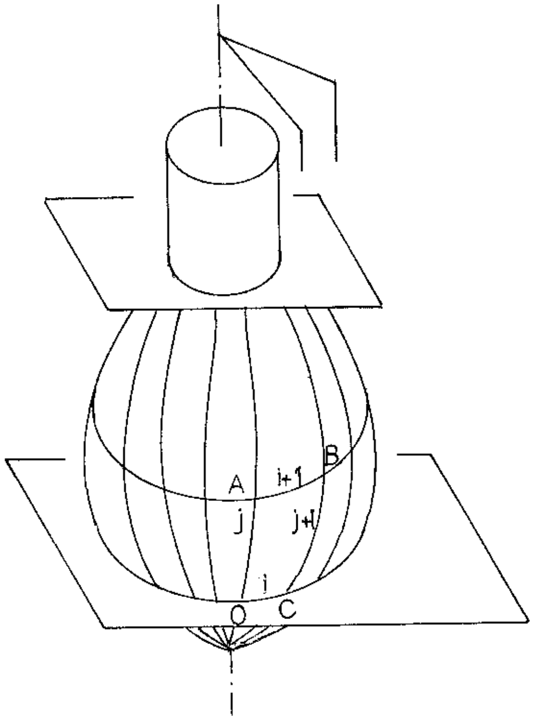

FIGURE 4

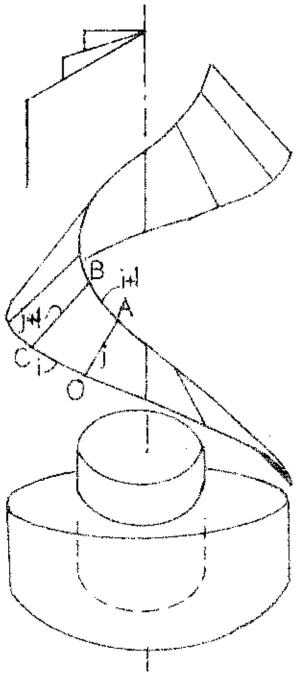

FIGURE 5

short SF.FI.), and then as a portion of SF that is liable to hide other portions (in short SF.VA.).

Logically all the sides of SF.FI. must be examined but practically only two - always AB, BC - are taken into account because the segments AB, BC of all the SF.FI. cover the net of the lines i,j, in its totality besides, perhaps, a single line i or/and a single line j. This simplification cuts the work's time by half.

Secondly, inscribe the examined SF. FI. into a rectangle (Fig. 6) whose sides are parallel to G.L. or perpendicular to it. It is evident that all the SF.VA. external to this rectangle cannot possibly hide SF. FI. and therefore they are discarded.

5. The Testing of A Segment. Henceforth the remaining SF.VA., denoted now as SFL, are put within an ordered sequence whose index L varies from 1 to a maximum value LMA varying according to the value of the SF.FI's index.

Let "a" be the indefinite straight line of the segment AB belonging to a certain SF.FI. (Fig. 7) and intersect it with the four sides of each one of the successive SFL (L=1...LMA).

Because SFL is a quadrilateral there are two possibilities:

1) All the four points of intersection lie on the extensions of the sides of SFL (see SFL2 of Fig. 7) - in this case SFL1 cannot hide any portion of "a".

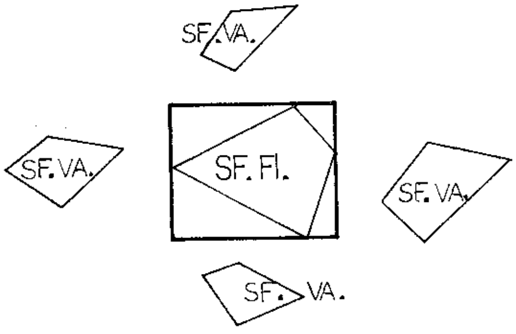

FIGURE 6

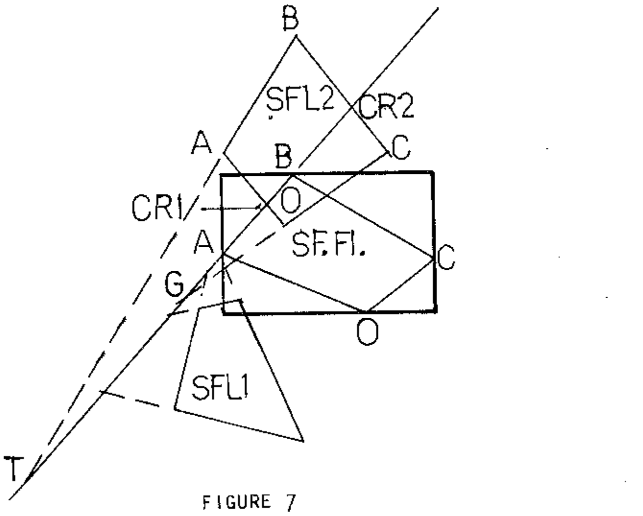

FIGURE 7

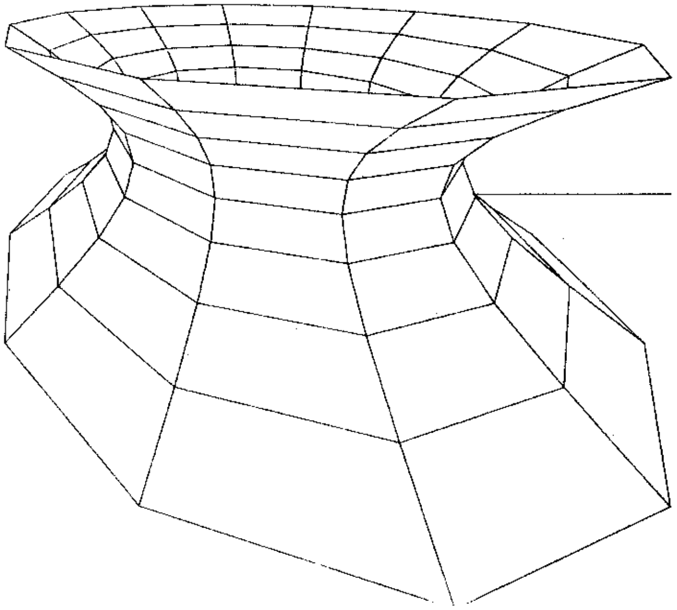

FIGURE 8

2) Two points of intersection lie on the extensions of two sides of SFL (see SFL2 of Fig. 7) and the other two points lie between the ends of the two remaining sides; these two last points are double-points and therefore in this case SFL2 is liable to hide a limited segment of "a".

The discrimination between simple-point and double-point is based on the comparison of the abscissa UCR of the point of intersection CR with those of the ends 1, 2 of the corresponding side 1-2 of SFL. When U1 UCR U2, the point is simple and when U1 UCR U2 - is double. In this second case the visibility is determined according to the V1. CR.

suitable for single or double curved, intersecting, or parametric patch surfaces

Finally only the visible segments of "a" that lie <u>within</u> its points A, B are drawn.

Then the whole procedure is applied to the indefinite line "b" defined by the segment BC of the same SF. FI..

6. <u>Conclusion.</u> The computer's program follows the instructions of the precedent paragraphs and applies them to <u>all</u> the SI.FI. of the given body.

This program is very simple because the method solves the visibility problem in a straightforward manner and avoids lengthy and complicated calculations.

This new method is suitable to one single surface (Fig. 8, Fig. 9); two (or more) intersecting surfaces (Fig.11); parametric patch surfaces.

The pictures can be drawn in perspective (or axonometric) projection (see Fig. 8, 9, 10); or in orthogonal projection (see Fig. 11, 12).

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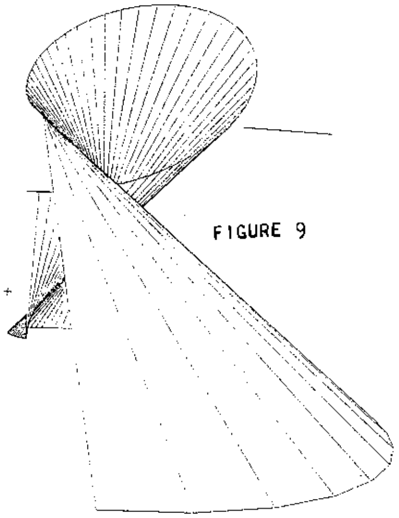


FIGURE 9

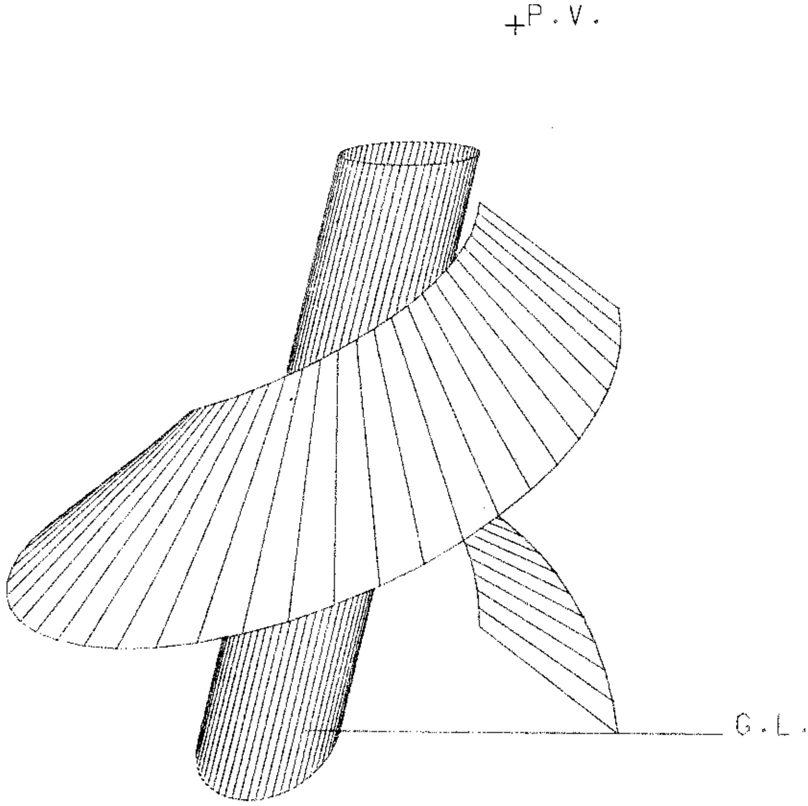


FIGURE 10

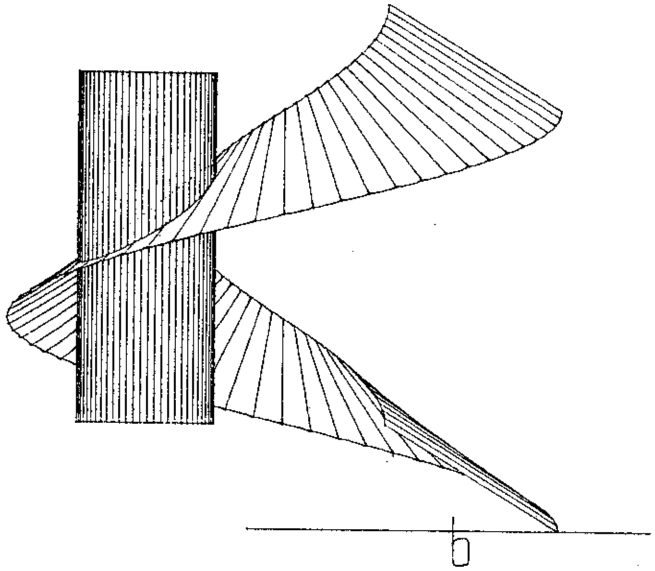


FIGURE 11

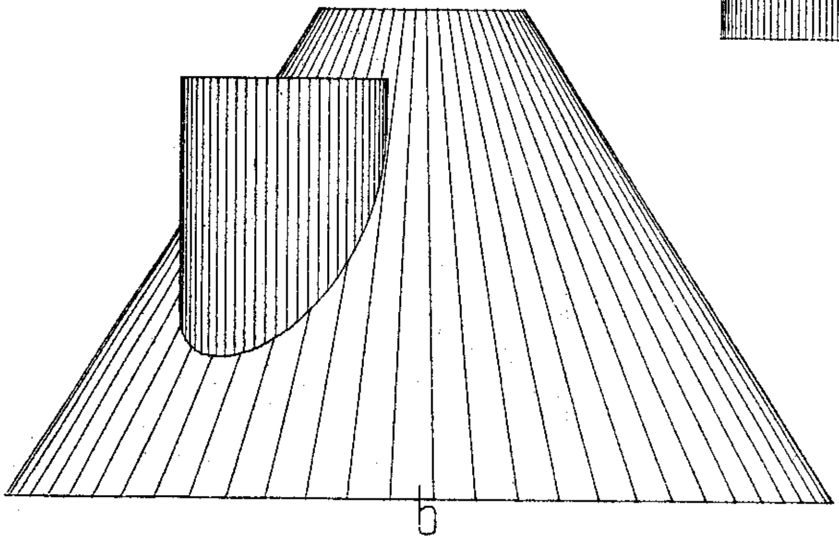
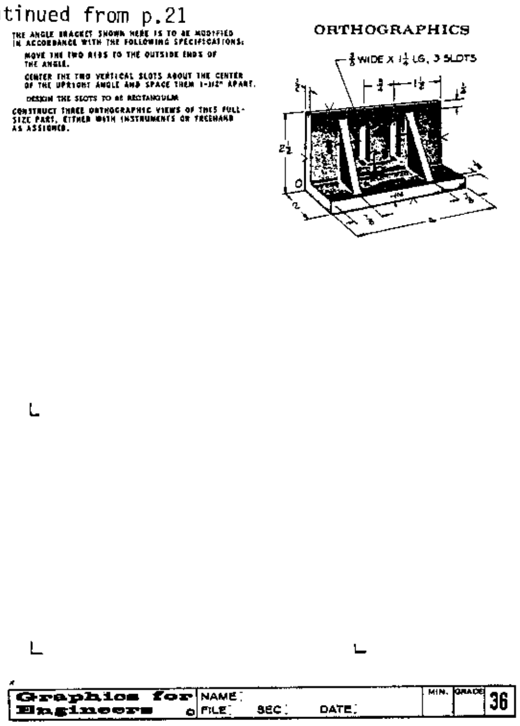


FIGURE 12

continued from p.21



ORTHOGRAPHICS

THE ANGLE BRACKET SHOWN HERE IS TO BE MODIFIED IN ACCORDANCE WITH THE FOLLOWING SPECIFICATIONS:

MOVE THE TWO RIBS TO THE OUTSIDE ENDS OF THE ANGLE.

CENTER THE TWO VERTICAL SLOTS ABOUT THE CENTER OF THE UPRIGHT ANGLE AND SPACE THEM 1-1/2" APART.

DESIGN THE SLOTS TO BE RECTANGULAR

CONSTRUCT THREE ORTHOGRAPHIC VIEWS OF THIS FULL-SIZE PART, EITHER WITH INSTRUMENTS OR FREEHAND AS ASSIGNED.

Graphics for Engineers	NAME: FILE: SEC: DATE:	MIN.	GRADE 36

FIGURE 7

SUMMARY OF ANALYSES

Measurements.	Results
1. weekly quizzes a. all questions b. pertinent questions	1. no significant differences
2. comprehensive exam (pre-test, post-test)	2.
a. all questions	interaction significant at .01 level
b. pertinent questions	interaction significant at .05 level
3. computer graphics test (pre-test, post-test I, post-test II)	3.
a. subject matter	interaction significant at .001 level
b. attitude survey	interaction significant at .01 level
4. time	4. significant difference at .001 level treatment: 5.2 minutes mean control: 42.0 minutes mean

FIGURE 8

WEEKLY QUIZZES

	All Questions		Pertinent Questions	
Quiz	Treatment	Control	Treatment	Control
3	74.74	81.67	30.53	34.72
4	92.11	89.47	54.33	53.68
5	72.22	59.84	54.41	46.11
6	78.33	71.58	30.29	29.47
7	80.56	75.11	46.33	42.67
mean	79.59	75.53	43.18	41.33

FIGURE 9

COMPREHENSIVE EXAM

	All Questions		Pertinent Questions	
	Treatment	Control	Treatment	Control
Pre	34.58	39.00	5.16	5.84
Post	74.89	68.33	12.33	10.89
Change	40.31	29.33	7.22	4.94

FIGURE 10

COMPUTER GRAPHICS TEST

Subject Matter

	Treatment	Control
Pre	30.00	34.71
Post I	77.65	34.12
Post II	71.18	39.41

Attitude Survey

	Treatment	Control
Pre	23.22	22.17
Post I	17.72	20.44
Post II	16.89	20.39

FIGURE 11

TIME

	Treatment	Control
means	5.2 min.	42.9 min.

FIGURE 12

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Plot-a-Function

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INTRODUCTION

Graphing mathematical functions by hand is an activity that most graphics people disdain and avoid. However, with a microcomputer this task can actually be enjoyable. A versatile program will be presented for plotting two dimensional functions. This software is extremely general and can optimize the graph to fit any specified portion of the display area. Moreover, it can be used as a utility to graphically explore mathematical functions. Put away your calculators and irregular curves and grab the nearest Apple(TM) microcomputer. Plot-A-Function is more exciting than Veg-O-Matic.

PROGRAM FEATURES AND VARIABLE NAMES

The following features have been built into this program:

1) User definable viewport. The function can be plotted within any part, or all, of the display screen.

2) Variable interval size or sampling rate. Increasing the sampling rate allows the drawings of functions to appear smoother. On the other hand, the execution speed of the plotting program is reduced due to the greater number of calculations required.

3) User definable interval. Minimum and maximum X values can be specified by the user to allow inspection of the function over any desired range of X values.

4) Self-adjusting Y range. The vertical plot area will be optimized with a special provision that will insure that at least part of the X-axis remains visible for reference.

5) Special axes drawing subroutines which graphically locate the origin and both axes, when possible.

The significant program variable names are:

F(X)	any user defined function
XR,XL,YB,YT	plot area (viewport) parameters
NS	number of points to be plotted (sampling rate)
LOX	minimum or low X range parameter
HIX	maximum or high X range parameter

Examples

The '*' is the multiplication operator in the formulae below.

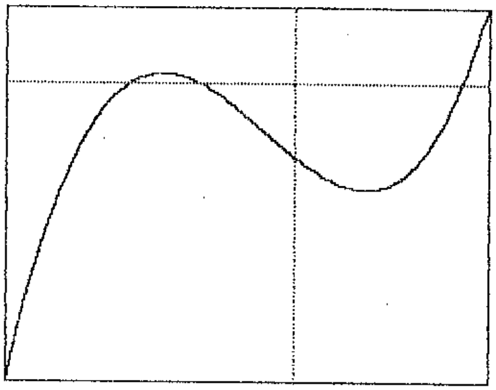


Figure 1: $F(X) = X^3 + X^2 - 3X - 3$, where $-3.0 <= x <= 2.0$. The sampling rate was 140.

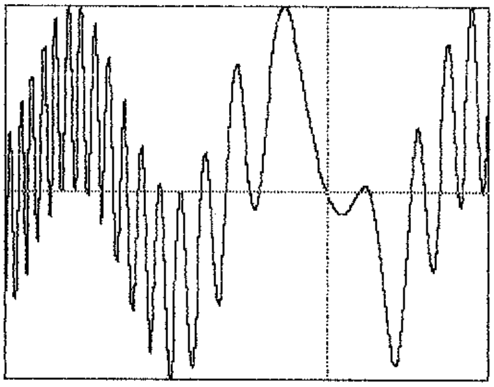


Figure 2: $F(X) = \sin X^2 - \sin X$, where $-10.0 <= X <= 5.0$. The sampling rate was 200.

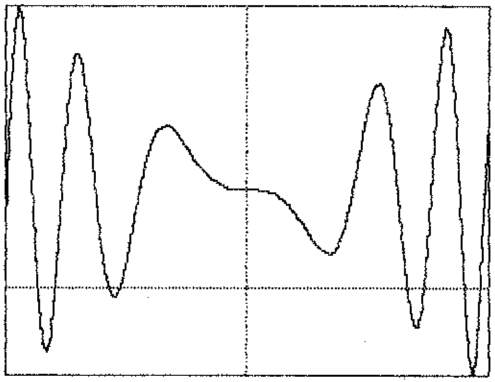
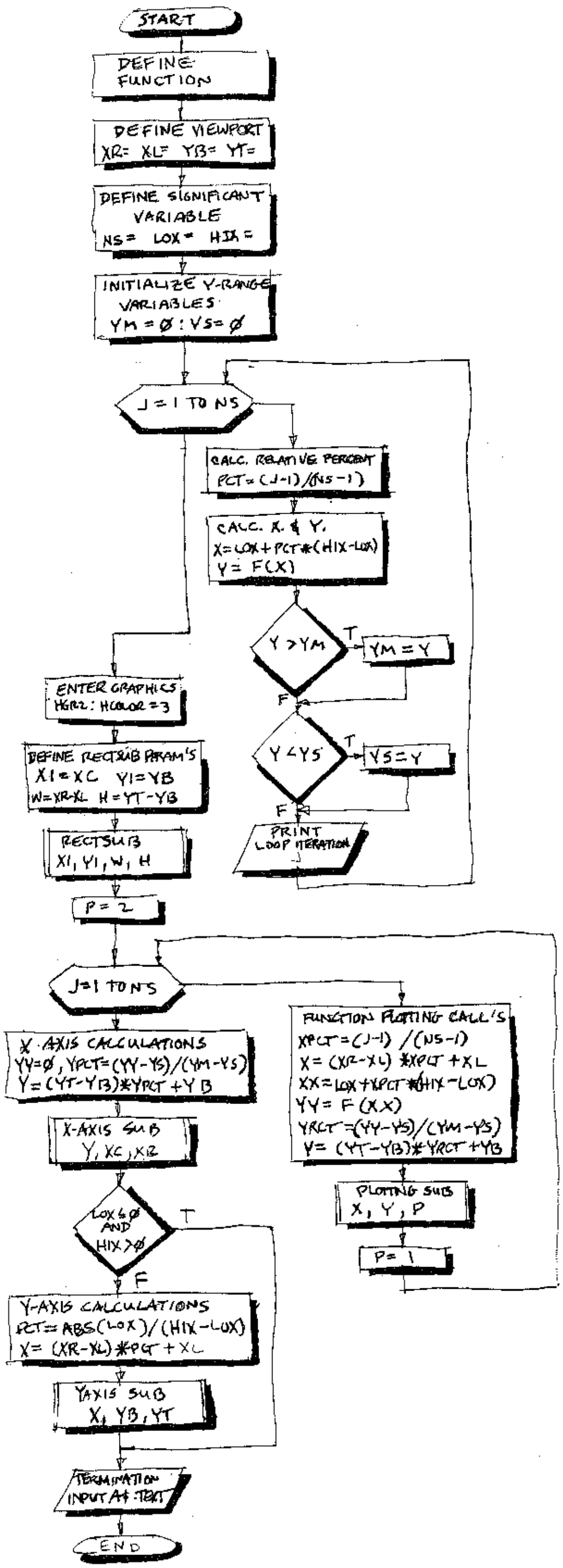
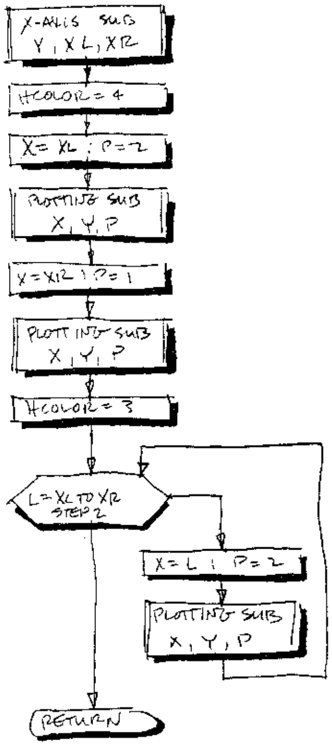


Figure 3: $F(x) = 1 -(\frac{\sin X^2}{2}) * X$

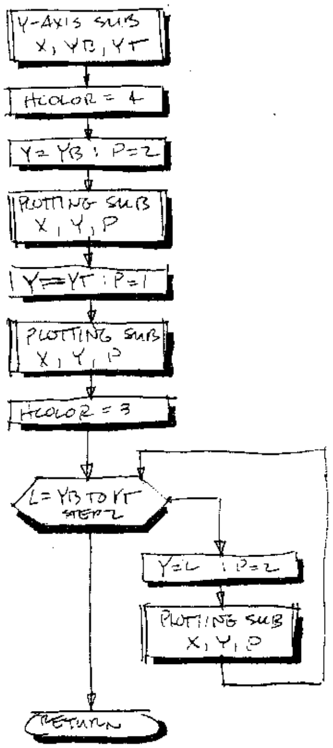
Plot-A-Function Flowchart



Flowchart 1: Main program



Flowchart 2: X-axis subroutine



Flowchart 3: Y-axis subroutine

The flowcharts for the main problem and the axes routines are given above and illustrate the logic contained within the program. First, the main program, flowchart 1, will be discussed. The function to be examined is stated at the beginning of the program code as a statement function. (In BASIC, DEF FN F(X) ...) The plot area can be maximized by setting the viewport parameters to the adjusted dimensions for HGR2, Apple(TM) page 2 graphics. (Corrected for aspect ratio giving an effective plotting area of 279 x 217). The sampling rate must be defined next. NS can be greater than 280 but it doesn't make sense to sample at a rate greater than the screen resolution. A reasonable sampling rate would be about 140, a sampling rate of 70 is usually sufficient. A rule of thumb concerning sampling is to seek the best minimum sampling rate.

A function is continuous by definition (for every X there is a corresponding Y). Therefore, the range to be considered must be given. This algorithm is parametric in the sense that the limits of the interval of observation must be stated. The variables LOX (low x), and HIX (high x) set the limits of the x range to be graphed.

Turning back to the logic diagram, the next aspect of the program deals with the Y range. Just prior to the first loop the Y range parameters, YS and YM, are initialized to zero. This will guarantee the presence of the X axis in the final image. The rationale is purely subjective. If the Y range, relative to the specified X range, consists entirely of positive or negative values then the presence of the X axis allows the magnitude of these values to be perceived. The loop crunches through the X range NS number of times. Using sizing, the calculated Y value is compared to YS and YM, saving by replacement smaller or larger Y values if found. At the end of this loop, based on the given X range, minimum and maximum Y range values are determined. Just so the user has something to do while these values are being found, the screen is cleared and the loop iteration is displayed.

With the X and Y range known the next part of the main program directs the computer to enter graphics. The viewport is outlined with a GOSUB to the rectangle subroutine. The plotting of the function can begin after the "pen" parameter is set to the up position for a move to the first point. The draw loop is opened with NS once again as the final or test value. Inside the loop a series of calculations are performed. First the relative percent X, XPCT is computed. Using XPCT the particular X-coordinate to plot is found based upon the plot area parameters. Again, using XPCT the X value which will be used in the function is calculated based upon the given X range. F(x) is obtained which represents the ordinate value at that point on the curve. With this relative value, using the minimum and maximum Y range quantities, YPCT is obtained. Once the relative percent Y is known all that remains is the calculation of the Y-coordinate to plot which is determined relative to the Y plot area parameters. With X,Y, a coordinate pair to plot on the curve relative to both the range parameters and the plot area parameters, and P, the plotting subroutine is GOSUB'd. After the first point, P will always be 1 or set to the draw position.

After the function is plotted the axes can be located and drawn. The X axis is drawn first since its presence was assured. See Flowchart 2. Its relative position on the display is determined using Y = 0. Once the Y screen coordinate is determined the X axis subroutine is GOSUB'd. Next, the location of the Y axis, if present, is calculated. The procedure for drawing both axes is similar. First blank out a line by undrawing (drawing a blank line) between the corresponding viewport edges. This in effect erases the line. Then using a loop with a step size of two, plot every second pixel on that line. Note: in the Y direction correction of the aspect ratio and roundoff plays havoc with this dotted line.

Before the Y axis can be plotted a check is performed to insure if in fact it lies between LOX and HIX. Since the Y axis is located where x = 0, an IF statement determines LOX < 0 < HIX. If this condition is true then find it and GOSUB the Y axis subroutine. See Flowchart 3. If this condition is false the axis lies outside the display area then do nothing. Finally, in either event begin the termination sequence.

CONCLUSION

This program provides an excellent tool for inspecting and visually evaluating two dimensional functions. It can be used in a fairly interactive manner. Critical values can be redefined quickly and the program re-executed. The listing of the complete program is given below. Experiment with a variety of functions, sampling rates and X ranges. Many custom features may be added to this code like; axes graduation and calibration, annotation and true interactive prompting. I'll leave these for you. Try using Plot-A-Function and experience the ease of graphing functions. You'll never want to use Veg-O-Matic again.

plot-a-function is more exciting than Veg-o-Matic

PROGRAM LISTING

```
100  REM  <<<<< PROGRAM PLOT-A-FUNCTION >>>
>>
110  REM
120  REM  COPYRIGHT 1983 W.J.KOLOMYJEC
130  REM
140  REM  <<<<< DEFINE FUNCTION HERE >>>>>
150  DEF  FN F(X) = X * X * X + X * X - 3 *
 X - 3
160  REM
170  REM  DEFINE PLOT AREA
180 XR = 279:XL = 0:YT = 217:YB = 0
190  REM  DEFINE NUMBER OF SAMPLES
200 NS = 140
210  REM  DEFINE X RANGE (LIMITS)
220 LOX =  - 3
230 HIX = 2
240  REM  INITIALIZE Y MIN. & Y MAX.
250 YM = 0:YS = 0
260  REM  FIND Y MIN. & Y MAX VALUES
270  REM  IF BOTH ARE + OR - THEN EITHER ON
E OR THE OTHER WILL STAY ZERO
280  HOME : VTAB 6: PRINT "REQUIRED NUMBER
OF SAMPLES = ";NS
290  VTAB 8: PRINT "THINKING..."
300  FOR J = 1 TO NS
310 PCT = (J - 1) / (NS - 1)
320 X = LOX + PCT * (HIX - LOX)
330 Y =  FN F(X)
340  IF Y > YM THEN YM = Y
350  IF Y < YS THEN YS = Y
360  VTAB 10: PRINT J
370  NEXT J
380  HGR2 : HCOLOR= 3: REM  INITIALIZE GRAP
HICS
390  REM  DRAW RECTANGLE AROUND PLOT AREA
400 X1 = XL:Y1 = YB:W = XR - XL:H = YT - YB
: GOSUB 1500
410  REM  PLOT FUNCTION
420 P = 2
430  FOR J = 1 TO NS
440  REM  XPCT IS BASED ON SAMPLING RATE
450 XPCT = (J - 1) / (NS - 1)
460  REM  FIND X-COORD TO PLOT
470 X = (XR - XL) * XPCT + XL
480  REM  FIND X-COORD TO CALC. Y
490 XX = LOX + XPCT * (HIX - LOX)
500  REM  FIND Y-COORD AS F(X)
510 YY =  FN F(XX)
520 YPCT = (YY - YS) / (YM - YS)
530  REM  FIND Y-COORD TO PLOT
540 Y = (YT - YB) * YPCT + YB
550  GOSUB 1000
560 P = 1
570  NEXT J
580  REM  LOCATE X-AXIS, WHERE Y=0
590 YY = 0:YPCT = (YY - YS) / (YM - YS)
600 Y = (YT - YB) * YPCT + YB
610  GOSUB 2500: REM  PLOT X-AXIS
620  REM  LOCATE Y-AXIS, WHERE X=0
630  IF LOX <  = 0 AND HIX > 0 THEN 650
640  GOTO 680
650 PCT =  ABS (LOX) / (HIX - LOX)
660 X = (XR - XL) * PCT + XL
670  GOSUB 2600: REM  PLOT Y-AXIS
680  INPUT A$: TEXT : REM  TERMINATE
999  END
1000  REM  <<<<< PLOTTING SUBROUTINE >>>>>
1010  REM  PARAMETERS: X,Y AND P
1020  REM  P VALUE IS BEAM CONTROL: 1=DRAW,
 2=MOVE
1030  REM  FLIP Y COORD. AND CORRECT ASPECT
 RATIO (0.881)
1040  REM  PLOT AREA: 0<=X<=279,0<=Y<=217
1050 Y9 = 192 - (Y * 0.881 + 0.5)
1060  IF P = 1 THEN  GOTO 1100
1070  IF P <   > 2 THEN  PRINT "PEN ERROR":
STOP
1080  HPLOT X,Y9
1090  RETURN
1100  HPLOT  TO X,Y9
1110  RETURN
1500  REM  <<<<< RECTANGLE SUBROUTINE >>>>>

1510  REM
1520  REM  PARAMETERS:
1530  REM  X1,Y1 THE COORDINATES OF THE LOW
ER LEFT CORNER
1540  REM   W THE WIDTH IN PIXELS
1550  REM   H THE HEIGHT IN PIXELS
1560  REM  NOTE:
1570  REM  THIS SUBROUTINE REQUIRES PLOTSUB

1580  REM
1590 X = X1:Y = Y1:P = 2
1600  GOSUB 1000
1610 X = X1 + W:Y = Y1:P = 1
1620  GOSUB 1000
1630 X = X1 + W:Y = Y1 + H:P = 1
1640  GOSUB 1000
1650 X = X1:Y = Y1 + H:P = 1
1660  GOSUB 1000
1670 X = X1:Y = Y1:P = 1
1680  GOSUB 1000
1690  RETURN
2500  REM  <<<<< X-AXIS SUBROUTINE >>>>>
2510  REM  PLOT OVER LINE IN BLACK
2520  HCOLOR= 4
2530 X = XL:P = 2: GOSUB 1000:X = XR:P = 1:
 GOSUB 1000
2540  REM  PLOT EVERY OTHER PIXEL
2550  HCOLOR= 3
2560  FOR L = XL TO XR STEP 2
2570 X = L:P = 2: GOSUB 1000
2580  NEXT L
2590  RETURN
2600  REM  <<<<< Y-AXIS SUBROUTINE >>>>>

2610  REM  PLOT OVER LINE IN BLACK
2620  HCOLOR= 4
2630 Y = YB:P = 2: GOSUB 1000:Y = YT:P = 1:
 GOSUB 1000
2640  HCOLOR= 3
2650  REM  PLOT EVERY OTHER PIXEL
2660  FOR L = YB TO YT STEP 2
2670 Y = L:P = 2: GOSUB 1000
2680  NEXT L
2690  RETURN
```

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And so, my fellow Americans~ ask not what your country can do for you~ ask what you can do for your country. My fellow citizens of the world ask not what America will do for you, but what together we can do for the freedom of man.

John Kennedy

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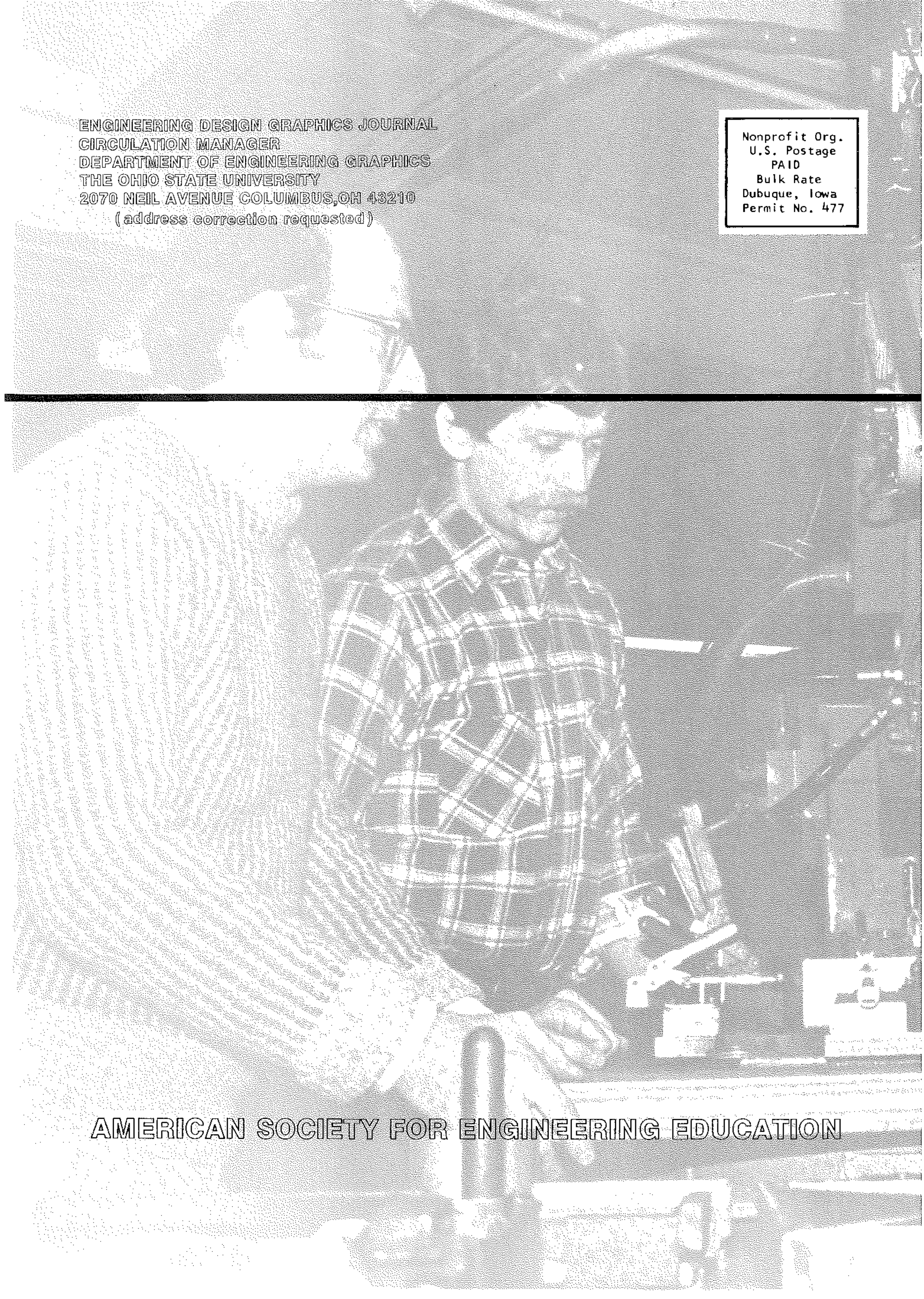

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