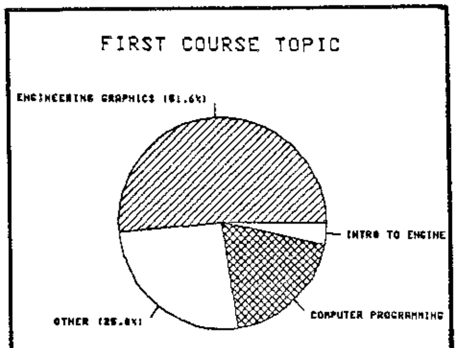

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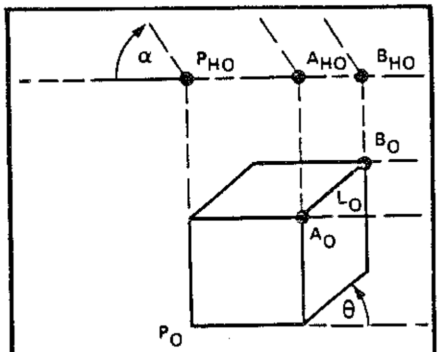

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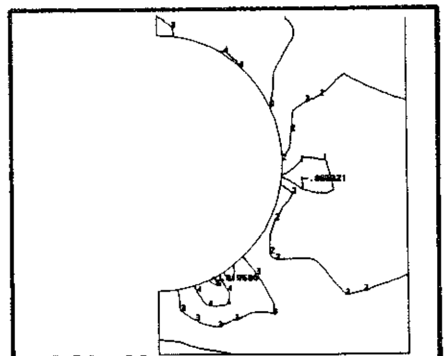

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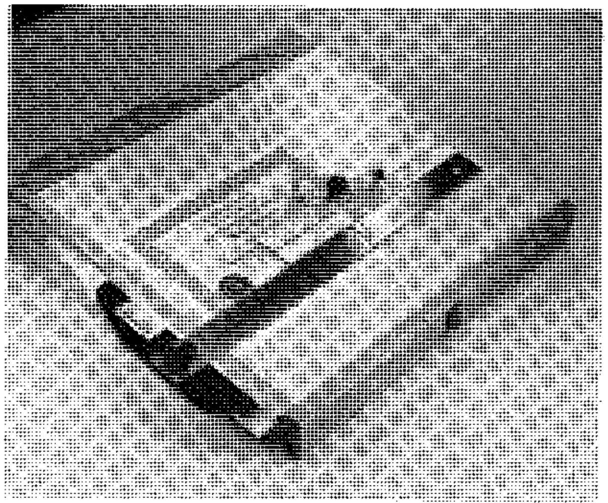
ENGINEERING DESIGN GRAPHICS JOURNAL

SPRING 1984 VOLUME 48 NUMBER 3

NOTICE

This issue is Volume 48, Number 2.
We apologize for this error. - Ed.



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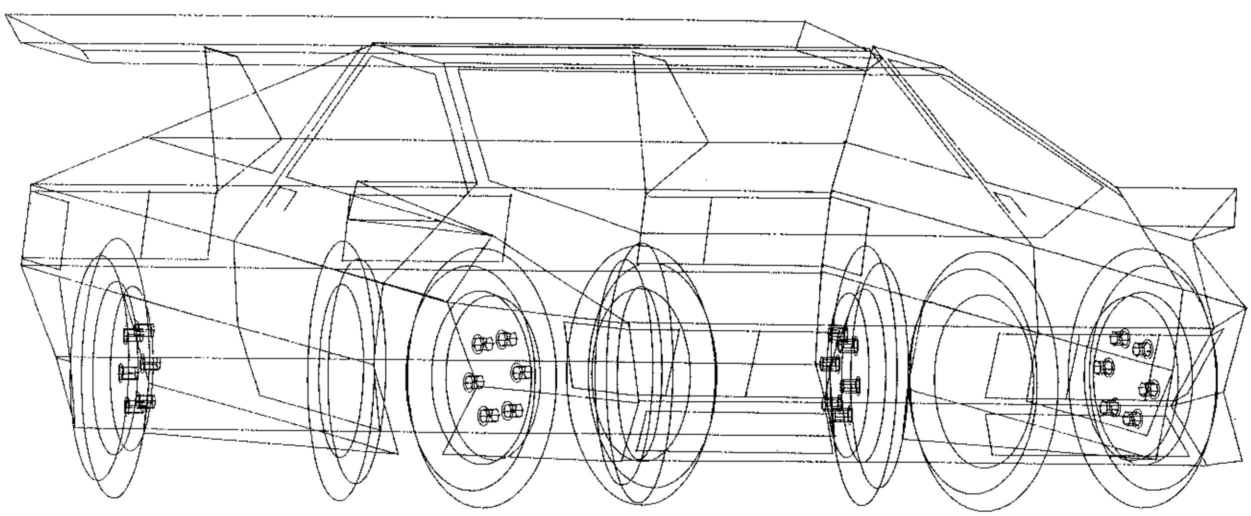

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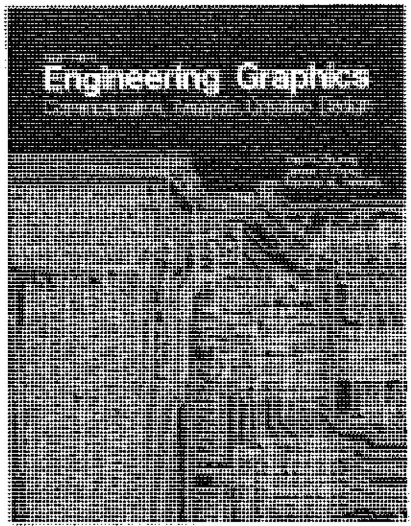

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ENGINEERING DESIGN GRAPHICS JOURNAL is published - one volume per year, three numbers per volume, in Winter, Spring, and Fall - by the Engineering Design Graphics Division of the American Society for Engineering Education, for teachers and industrial practitioners of Engineering Graphics, Computer Graphics, Design Graphics, and Creative Design.

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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 application of engineering graphics for understanding and practices.

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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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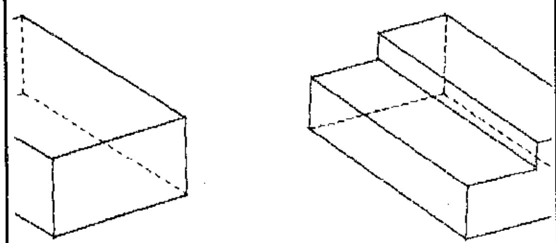
ENGINEERING DESIGN GRAPHICS JOURNAL

SPRING 1984 VOLUME 47 NUMBER 2

DEPARTMENTS

FEATURES



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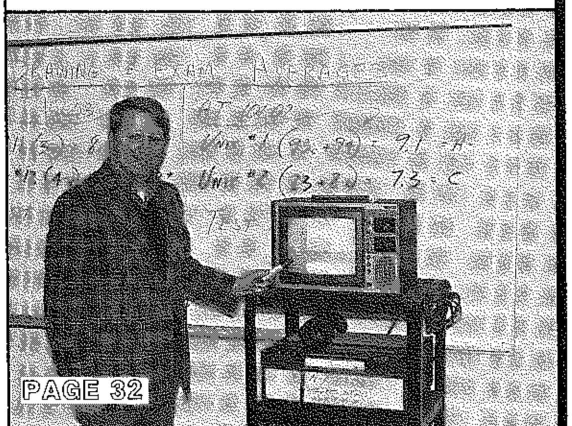

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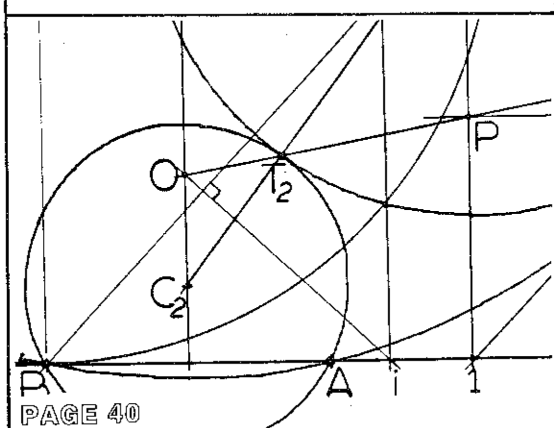

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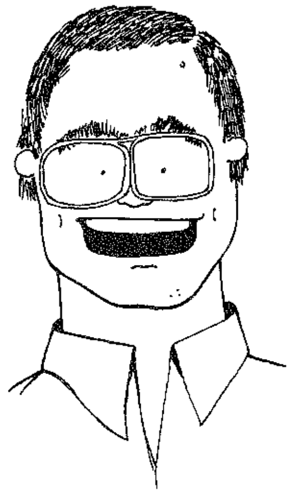


EDITOR'S PAGE

The past year in graphics has been a busy one for most of us. There has been much change both in curriculum and in the students we see in our courses. Some of the changes have caused some to question the very purposes of graphics.

First, a comment on the attraction of computer graphics. More people have shown an interest in graphics than ever before. You see some strange students these days, each hungry to pick up some understanding of visual imagery: dance, theater, music, climatology, geology, chemistry... they all see graphics, and by this I mean computer graphics, as their salvation.

But the bottom line is that these people still know nothing about graphics, or computer graphics technology. They expect everything to be automatic (after all, it's a computer, isn't it?). They expect it to be magic. Typically their response is "but can't it do this?" Well, yes, if it were set up to do that. "Well, can't I just push a button and it will rotate, section, dimension, figure mass properties, and do a color rendering?" Well no, because it isn't set up to do that.

The danger in all of this is that a large section of the technical population is now accessing very powerful graphics without the knowledge of how, why, or why not.

Our responsibility as graphics educators then has changed. We are still the guardians of the true gospel, and to a select group of engineers, technologists, and designers we will continue to expound its virtues. But to an entirely different group of people ... the chemists, dancers, filmmakers, agronomists, etc. ... we have a different charge. That charge is to dispel the heretics, flush the interlopers, and spread the message that:

1. Graphics has always been important, not just since the advent of the computer.

2. To use graphics intelligently is to understand graphics. To not understand graphics is to be used by graphics.

3. There is no substitute for a soild graphical preparation.

4. There is no substitute for a solid computer preparation.

Many graphics areas will be in the position to offer a campus-wide introductory graphics course ... sort of an English 100 ... to a wide audience. Have any of us thought of what "Graphic Composition 100" might look like? What is the part of graphics that is so basic, so universal that the course would be appropriate for both a dance and an anthropology major?

What is happening now is the worst possible case: these students show up on your doorstep, hungry to be anointed with the graphical oils, yet unwilling to go back and learn the basics. They want to do some very sophisticated things RIGHT NOW! We should start discussing this right now so that our voice might come across as one.

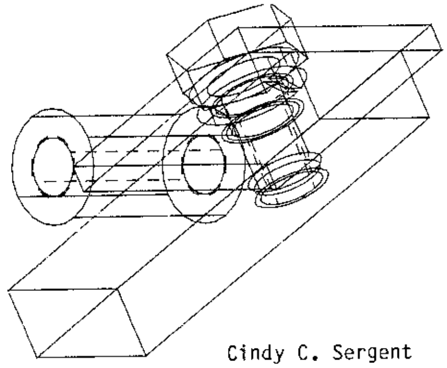
A second observation, this time on the unattractiveness of computer graphics. Up until a few years ago, graphics people did graphics. Now, not only as I just discussed with the case of a heterogeneous student population but also with the graphics innovators, ALL SORTS OF PEOPLE MAKE GRAPHICS. Go to SIGGRAPH and I venture you will see mathematicians, philosophers, lots of electrical engineers and computer scientists, their shirttails hanging out, peering from behind thick black-framed glasses, their hair uncombed for weeks or months, each involved in perfecting a more parsimonious algorithm for displaying some trivial image that graphics people have been making for years by hand. The more that these people take over the making of graphics the more non-graphical it will become.

An older professor, lucky enough to retire before having to personally deal with some of this madness, said it best:

> " It's not really amazing that machines can't produce graphics of as high a quality as that which can be done by hand, what is really amazing is that they can be made to draw at all."

These last two negative points come to bear when dealing with non-graphical technical students who crave computer graphics. It is up to us to look these would-be graphics converts square in their beady little eyes and say "Why don't you take Graphics 200, 210, and 220 and then come back. Maybe then you'll understand what you want out of this technology." We owe it to the student, to ourselves, and to graphics.

This is my last editorial as a faculty member of the Department of Engineering Graphics at Ohio State. After 10 years, I return to Purdue to teach in their Technical Graphics department in the School of Technology. If I have the opportunity to continue as editor this change should increase the horizons of the EDGJ. In these 10 years I learned a lot about what is true and untrue in graphics. I only wish all of you could have had the same exposure to the old and the new technologies as I was lucky enough to experience. It was a time that will be difficult to recapture. I guess I shouldn't try.



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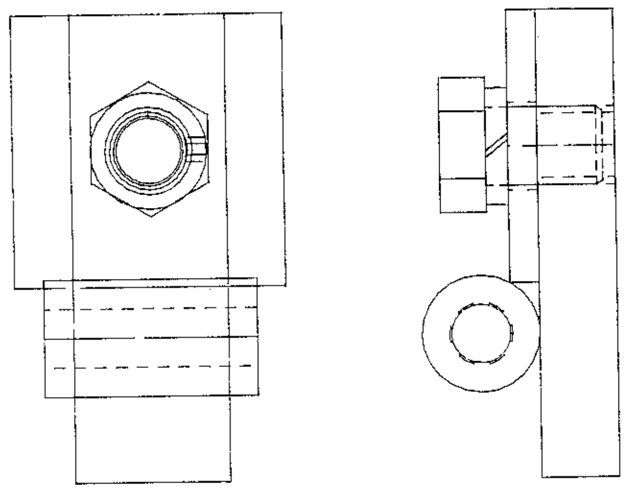

SOFTWARE EXCHANGE

This is the start of what will be a continuing part of the EDGJ - a software exchange. Since none of you have contacted me saying that you have all of this great stuff you want to share, I will start by identifying those I know who are actively developing graphics software. I advise you to contact these individuals directly to find out what they are doing.

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DEAF STUDENTS

Deaf Students in The Engineering Design Graphics Classroom: An Increased Happening

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Department of Engineering Graphics
The Ohio State University
Columbus, Ohio

Susan Rose, Ph.D.
Department of Educational Psychology
University of Minnesota
Minneapolis, Minnesota

Introduction

Public Law 94-142 and 5.8.504 mandate opportunities for handicapped students to be educated within the mainstream of nonhandicapped students. The major challenge and benefits of these laws are to change the attitude of the normal population and to increase the level of educational expectations, in particular among young handicapped people embarking on post secondary education. One such group is the hearing handicapped individual. Recently, innovations in education for the hearing impaired including the availability of good educational programs, use of sign language and improved hearing aid technology as well as the early identification of deafness has enabled increased numbers of deaf stuents to reach post secondary level equivalency in regular educational programs. Until recently, technical education was available to the hearing impaired only at the National Technical Institute for the Deaf. With the assistance of litigation and ligislation increased programming for the deaf student at post secondary institutions is expanding. In 1981 50 such programs were available of which over 30 included technical vocational programs. More than half of the students enrolled in these institutions were in graphics, communication, engineering and health technology related areas.[1] Since then both the number of students and programs have increased. The probability of finding a deaf person in some design graphics course is extremely high.

Why Deaf Students Choose Fields Using Graphics?

The importance of graphics as perceived by engineering educators is embedded in the role it plays as part of conceptual design and analysis.[2] The tools necessary for this process include visual thinking and visualization of geometric and physical objects as active mental skills. Rote learning such as memorization or 'see and do' tasks do not assist in this type of thinking ability. This is particularly true if the deaf student acquired a severe to profound hearing loss at a very early age prior to the normal language development period. These deaf students live in a viaual world and for most part the sound (if available) is distorted and not easy to comprehend.

Fifteen deaf students were tested in the Science and Engineering Orientation Program at the University of Houston. All showed great facility in mechanical and graphical reasoning, while having almost no English language skills. One student performed at the twelfth grade level in mechanical reasoning, math computation and abstraction but only read English at the second grade level! Those deaf students who enrolled in the Engineering program did very well in Engineering Graphics but could not handle other language related subjects.[3] Waldron and Rose[4] conducted a series of graphical problem solving tasks on the computer and found that the deaf students could do equally well in these tasks as hearing. The dependency on the visual sense as a primary source allows deaf persons to do well in space related subjects such as graphics.

deaf students have a natural understanding of graphics

How Do I Teach A Deaf Student?

Deaf students, when they "see" they attend, perceive, discover, and think like any other person. However, the code which the deaf student uses to do this is different. Hearing persons rely largely on audio-symbolic association for the higher cognitive areas particularly the association with aural-verbal language. However, deaf students utilize the visual-symbolic association relying primarily on visual spatial coding for cognitive processing. To convey the problem solving tasks the instructor can conveniently use the graphic medium to demonstrate step-by-step procedures with little or no words. Many graphics teachers are very adept at this. Reduced verbal information supported by visual graphic demonstration can be most effective with hearing impaired students as well as non-handicapped students e.g., Step 1. Draw a line AB

A B

2. Find the Midpoint C

Line AC = Line CB

A C B

Some helpful hints for including the hearing impaired student in the instructional process follows:

- Avoid long complicated verbal discussions explaining the procedures.
- When using the blackboard, demonstrate or model each step and, preferably, write directions in a basic format.
- If using an overhead projector it is important to have the room lighted with transparencies that can be clearly read.
- In introducing new vocabulary, graphical demonstrations with simple sentences help. A basic rule is that the more visual-graphic information one can use the easier it is to explain.
- In examinations, use basic vocabulary. If necessary, use a separate exam with adapted syntax so that you are measuring their graphics knowledge and not their mastery of the English language. One can presumably leave this to the English teachers.
- Assignments, announcements, changes in scheduling should be posted in writing.

Who is an interpreter?

Interpreters for the deaf function in a similar manner as foreign language interpreters. An interpreter for the deaf is a person who can translate the spoken English expressions into a graphical language, such as American Sign Language or Sign English. In educational settings, frequently it is beneficial to the student if the interpreter supplements sign language communication with some illustrations and notes regarding the classroom lecture.

Interpreter services are often provided by the institution or rehabilitation agencies at the request of the students. At first, an interpreter in the classroom may seem a bit strange. But most instructors report that soon the interpreter becomes part of the scenery and even forgets that he or she is present. Note takers are sometimes employed, also, since the deaf student is unable to follow the instructor, the interpreter and be able to write simultaneously. However, the benefits of note taking are extremely limited. The most helpful information is provided by the regular instructor through writing, drawing and demonstrating. Non-handicapped students also benefit from this extra effort. The interpreter can be used to communicate with the deaf student in a one-to-one situation, however, reading and writing (the direct approach) can also be used as long as the communication is interspersed with graphic illustrations. It must be recognized that this latter approach is slower for the instructor and the student but more effective since it is direct. If this communication is frustrating then an interpreter is the best solution.

Conclusions

Deaf students are able to succeed in the regular educational setting. Graphics, visual aids, computers and computer graphics allow the instruction to be made highly visual and accessible. Deaf students have a natural understanding of graphical procedures. A little extra thought in delivery can make the difference between no comprehension to complete comprehension. Visual imagery is used to some extent by all as an aid to problem solving. This is particularly true of the deaf student. The clearer the picture of the steps taken to solve the problem the easier it is for them to solve that problem. For the deaf learner, certainly a picture is worth a thousand words.

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CAD SURVEY

Summary of Survey Results
on
"Implementation of Computer Graphics and CAD Early in Undergraduate Engineering Education"

Compiled by
Computer Graphics Committee
Engineering Design Graphics
Division of ASEE

Ronald E. Barr, 1982-83 Chairman
University of Texas at Austin

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Queen's University, Canada

Robert Wilke
Texas A&M University

Billy Wood
University of Texas at Austin

Introduction

During the 1982 ASEE Annual Conference, a computer graphics survey was addressed to the general membership of the EDG Division of ASEE. The major intent of the survey was to ascertain the status of computer graphics and CAD instruction in the early years of engineering undergraduate education. The results of this survey were compiled and studied by the Computer Graphics Committee of the EDG Division during the 1982-83 academic year. The survey results were based on 31 response from graphics educators in leading engineering colleges in the United States and Canada. The responding schools' profile can be construed from the home institutions of the participating members of this report. The quantitative results of the survey, consisting of answers to 14 specific questions, have been graphically illustrated in this paper. The primary purpose of this summary paper is to interpret these results, in a qualitative sense, and to present a committee-based opinion of the future direction of computer graphics and CAD in undergraduate engineering education, as perceived in the 1982-83 school year.

First Instruction in Computer Graphics and CAD

The initial questions in the survey were geared to determine the curricular level at which computer graphics is first introduced to engineering students. An overwhelming response (84%) stated that computer graphics was taught at the freshman level at their own institution. In some cases, this freshman exposure involved a substantial number of students. For instance, six schools reported over 500 students involved in computer graphics in the freshman program. In about 50% of these cases, computer graphics is first introduced in traditional engineering graphics courses. This would seem to be a natural starting point since most engineering programs offer a freshman graphics course, and since computer graphics and CAD have had a substantial impact on traditional engineering drawing. In a smaller number of cases (20%) computer graphics is first introduced in a computer programming course. This offers an excellent opportunity to teach programming techniques related to graphics images, and conversely, graphics can help the development of programming skills. However, such a curricular approach to computer graphics should be preceded by instruction that insures engineering graphics literacy.

Hardware Methods for Computer Graphics Introduction

Most schools that responded have graphics terminals that are used for computer graphics instruction. In the typical case, a terminal is connected to a mainframe computer. However, a large number of respondents indicated the use of small stand alone systems for early computer graphics instruction. The low cost and flexibility of these new microcomputers might signal a direction that all freshman graphics programs could pursue if mainframe hardware is not available.

The most advanced use of turnkey CAD systems in undergraduate training did not appear prevalent in the survey. Although eight respondents indicated that CAD systems (of some nature) were used in their freshman computer graphics program, only one institution reported actually having an industrial turnkey CAD system. this pattern may change in the future, though, as more schools find fiscal resources for CAD and as more industrial donation programs emerge. One observation is clear: the use of a graphics terminal, with its inherent interactiveness, is the current

ENGINEERING DESIGN GRAPHICS DIVISION - ASEE

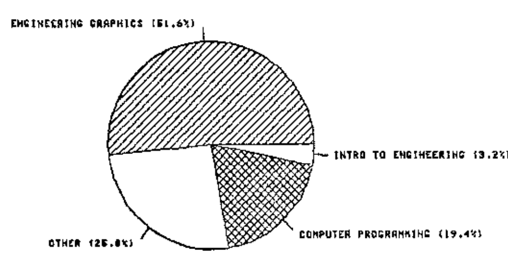
COMPUTER GRAPHICS
SURVEY

1. At what level of instruction do you first introduce computer graphics to your students?

Level of Instruction	% Response
Freshman	84.0
Sophomore	6.4
Junior	3.2
Senior	3.2
Other	3.2

2. In which course or topic is computer graphics first introduced?

FIRST COURSE TOPIC



3. What methods are used to introduce computer graphics in your freshman program?

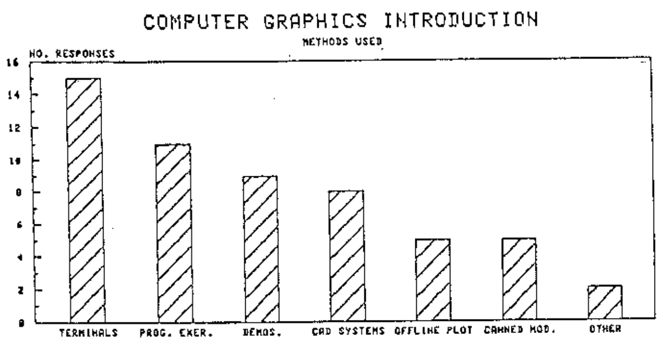


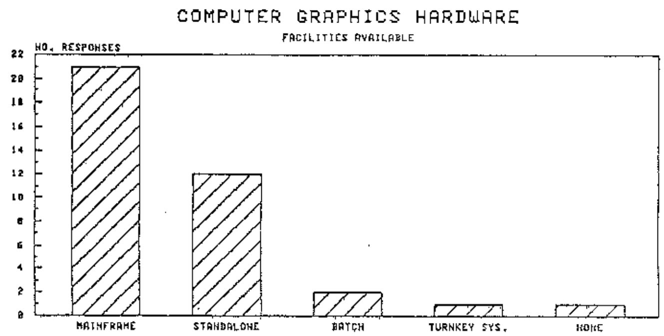
FIGURE 1

norm for computer graphics instruction, while the use of batchmode off-line plotting is outdated for graphics instruction.

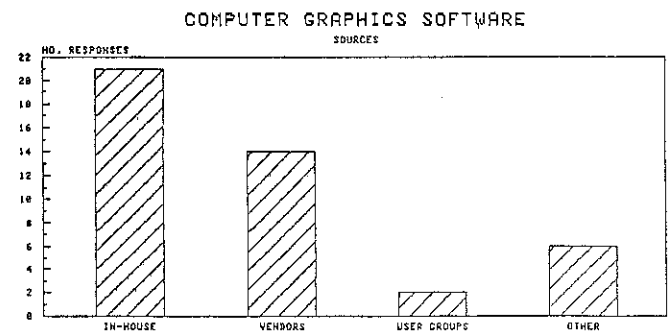
Software Methods for Computer Graphics Introduction

Although there appears to be many consistent trends in the way different institutions are introducing computer graphics, one area remains very unclear. In a question related to whether computer programming was taught before, during, or after computer graphics introduction, the response was very mixed. Approximately forty percent of the respondents indicated that computer graphics is introduced before programming. Apparently this is accomplished using demonstration, interactive software, and other means that do not require programming skills on the part of the student. An approximately equal percent of responses indicated that computer programming is part of the first introduc-

7. **What type of hardware facility exists at your school for teaching computer graphics to large undergraduate classes?**



8. **How has your school acquired software for teaching computer graphics?**



9. **Does your school offer an upper-level engineering course on computer graphics?**

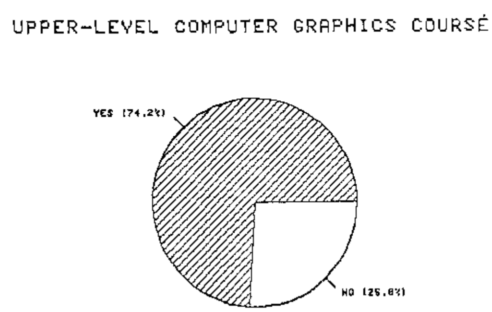
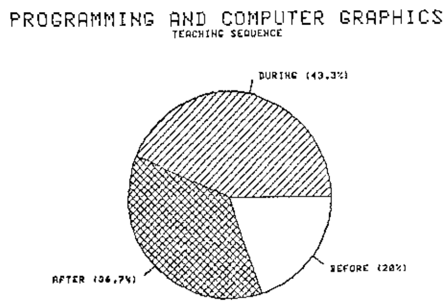


FIGURE 2

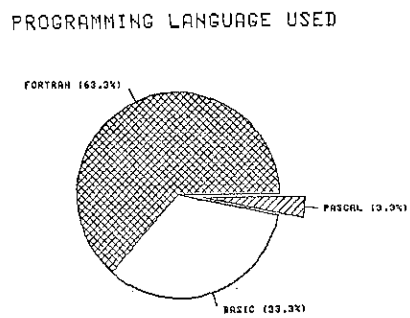
tion to computer graphics. This would facilitate a better understanding of the software mechanisms involved in the generation of graphic images. Determining which of these two approaches is better may not be easily ascertained, and the decision may rest on local curricular constraints and traditions at each home institution. Nonetheless, a natural progression would consist of simple computer graphics demonstrations followed by increasingly complex programming exercises. Whether this should occur in one packed course or in a sequence of courses that have additional objectives is still unresolved.

In the area of computer graphics software development, it is evident that instructional computer graphics software is currently being developed by teaching faculty. Over two-thirds of the respondents indicated that they used software that was developed in-house. This may not be a totally undesirable situation, since it offers an opportunity for staff development in computer graphics. Approximately one-half of the responding schools also used software supplied by the vendor. This software most likely falls into specialized areas such as graphs and charts. Unfortunately, no network exists for the systematic exchange of instruc-

4. With respect to your first student exposure to computer graphics, do you teach computer programming before, during, or after this exposure?



5. Which computer programming language is used to teach computer graphics?



6. Which textbook do you use for computer graphics instruction?

Textbook	% Response
Rogers & Adams	6.4
Scott	3.2
Foley & VanDam	3.2
Misc. Notes	16.2
No text used	71.0

FIGURE 3

tional computer graphics software amongst universities. It should be noted that FORTRAN and BASIC are the predominant programming languages used in engineering computer graphics. PASCAL is used much less frequently.

Advanced Instruction In Engineering Computer Graphics and CAD

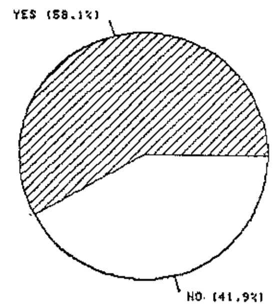
It is encouraging to note that almost 75% of the respondents indicated that their school offered an upper-level course on computer graphics. This course normally would take the form of an elective course, perhaps in a CAD/CAM block option. The contents of this course are relatively broad, but a "body of knowledge" for engineering computer graphics seems to be congealing. The most common topics in engineering computer graphics are two-dimensional and three-dimensional transformations which rely on matrix algebra. The use of interactive techniques is also recognized as important in an advanced computer graphics course. The more sophisticated topics, such as data structures and raster color graphics principles, were mentioned less frequently in the survey. In addition, it should be recognized that topics related to computer graphics hardware design are also a component of this advanced instructional effort.

10. What are some of the topics covered in your upper-level computer graphics course?

Topic	No. Responses
2-D Transformations	18
3-D Transformations	17
Interactive Techniques	16
Projections	13
Geometric Modeling	10
Data Structures	7
Color Graphics	6
Other	6

11. Are computer graphics and CAD techniques used as problem solving tools in other engineering courses at your school?

COMPUTER GRAPHICS AND CAD



12. If computer graphics and CAD techniques are used in other courses at your school, please list some of these courses:

Courses Listed

Statics
Dynamics
Machine Design
Network Theory
Mapping
Finite Elements
General Design

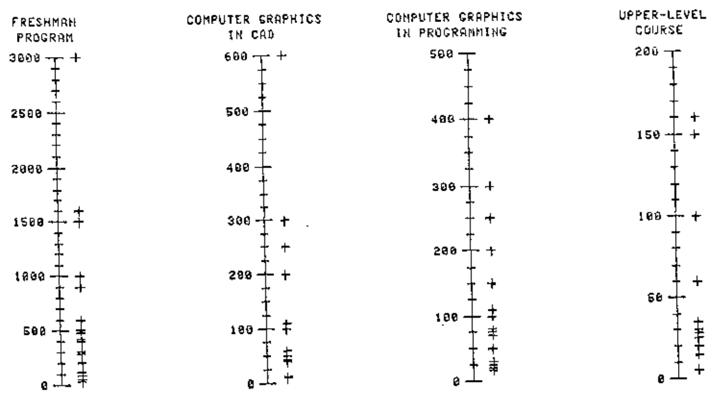
FIGURE 4

The integration of computer graphics and CAD in other core engineering courses is less obvious. Respondents mentioned that CAD was used in such courses as statics, machine design, electrical network theory, and mapping. However, the systematic use of computer graphics and CAD, which ultimately will be common tools in engineering practice, is not yet evident in engineering education. Almost 42% of the respondents indicated that computer graphics and CAD were not used as problem solving tools in other engineering courses at their schools as of yet.

Conclusions and Recommendations

The survey was concluded with a series of general questions in order to solicit global opinions on computer graphics in engineering education. Special note should be made of the first three global responses, since they represent a rather strong similar agreement over all the entries. From these responses, and based on general extrapolations from the survey results, several conclusions can be drawn:

13. Please estimate the number of students involved at each of the following levels of computer graphics at your school:



14. Which of the following statements agree with your overall opinion of computer graphics in the engineering curriculum (check all that apply):

Statement	% Agree
Computer graphics should be introduced in the freshman year.	93.5
Computer graphics should be used in other engineering courses where applicable after a suitable introduction.	87.1
Computer graphics should be taught with engineering graphics (drawing) courses.	83.8
Computer graphics should be taught with computer programming.	45.2
A separate upper-division course on engineering computer graphics should be introduced as a required course.	25.8
Computer graphics should be used in other engineering courses, but no effort should be made to introduce it as a separate topic.	12.9
Engineering educators should not be concerned with computer graphics.	3.2

FIGURE 5

1. It is clear that computer graphics should be introduced in the freshman engineering program. The most logical place for this first introduction is the traditional engineering graphics course.

2. This first introduction could involve some programming exercises, but that is not necessary since interactive programs and demonstrations are useful. Nonetheless, the core computer programming course in the undergraduate engineering program should include some element of computer graphics, at least at the level of computer generated 2-d drawings.

3. A second-level engineering computer graphics course should become part of the curriculum, currently as an elective course. This course should include 2-d and 3-d matrix transformations and projections, as well as interactive graphics principles and hardware design considerations.

Chairman's Note

Professor Robert Wilke of Texas A&M University has recently reported to the committee results of a similar computer graphics survey which his group undertook in the summer 1983. The results of his survey corroborate the general observations of this committee report, and offer extended details in some areas. Interested persons may wish to contact Professor Wilke for additional information.

OBLIQUE METHODS

A COMPUTER GRAPHICS METHOD
FOR
CREATING OBLIQUE PROJECTIONS

Donald S. Bunk
Graphics Systems Programs
IBM Corporation
Kingston, New York

Introduction

Oblique projection can be produced from two principal orthographic views of an object. It is usually practical to use the plan and profile views for projectors and the frontal viewing plane as the "picture" or "oblique" viewing plane. This paper defines the analytical relationships for the foreshortening and receding angle of an oblique line as a function of the lines of sight to the object as represented in the plan and profile views. It also illustrates a procedure for creating oblique projections of objects from principal orthographic views of the object using computer graphics. The CADAM Computer graphics program was used to develop the procedure described in this paper.

Background

The procedure for creating principal, auxiliary, or isometric views of an object using CAD programs such as CADAM are well known and used as a matter of course. However, the procedures for creating oblique or perspective projections with 2D CAD programs are not as well documented for the end user.

In the process of investigating the possibilities for applying the CADAM program to Pictorial drawing it was determined that the well known procedure for creating an oblique projection from two principal views of an object could be applied to a computer graphics generated model. It was also shown that foreshortening along the receding axis and the receding angle are a function of the oblique line of sight. Equations were formulated which allow the user to either predict the characteristics of an oblique projection which are related to a given line of sight or to determine the line of sight required to produce a desired set of characteristics for the projection.

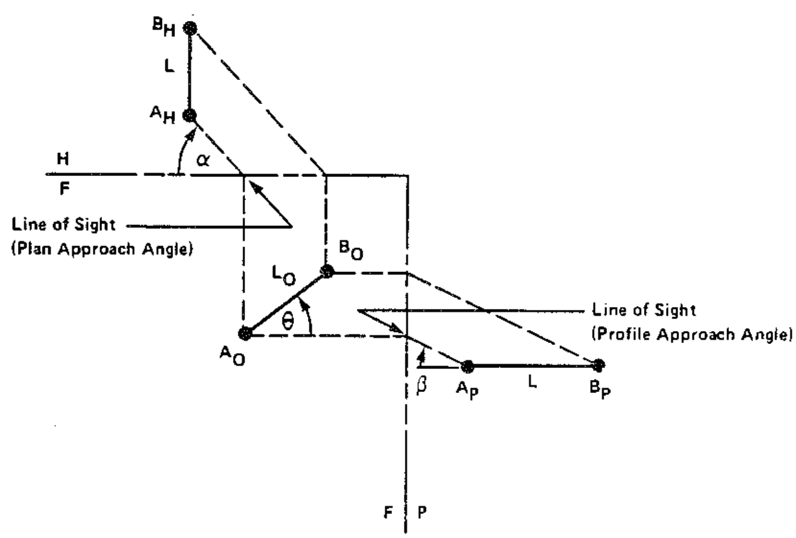


Figure 1. Oblique Projection of Line AB

Theory

Figure 1 shows the oblique projection onto the frontal plane of line AB whose true length is L. The oblique length, Lo, (usually a foreshortened length) and its accompanying receding angle are a function of the oblique line of sight. Orthographically, the line of sight is represented as a projection onto the horizontal projection plane (Plan Approach Angle) and a projection onto the profile projection plane. (Profile Approach Angle) as shown in Figure 1.

The following equations relate the oblique length (Lo) and receding angle ( ) of the line AB to the lines of sight as defined by the plan and profile approach angles and . These angles are formed by the intersection of the lines of sight with the frontal plane edge lines.

(a) Oblique length:

$$Lo = L \; [1+(\tan \;\; \tan \;\;)^2]^{1/2}$$

(b) Receding Angle:

$$= \tan^{-1} [\tan \;\; \tan \;\;]$$

Figure 2 shows the relationship between the Plan and Profile approach angles for constant foreshortening. Figure 3 shows the relationship between the Plan and Profile approach angles for constant receding angle.

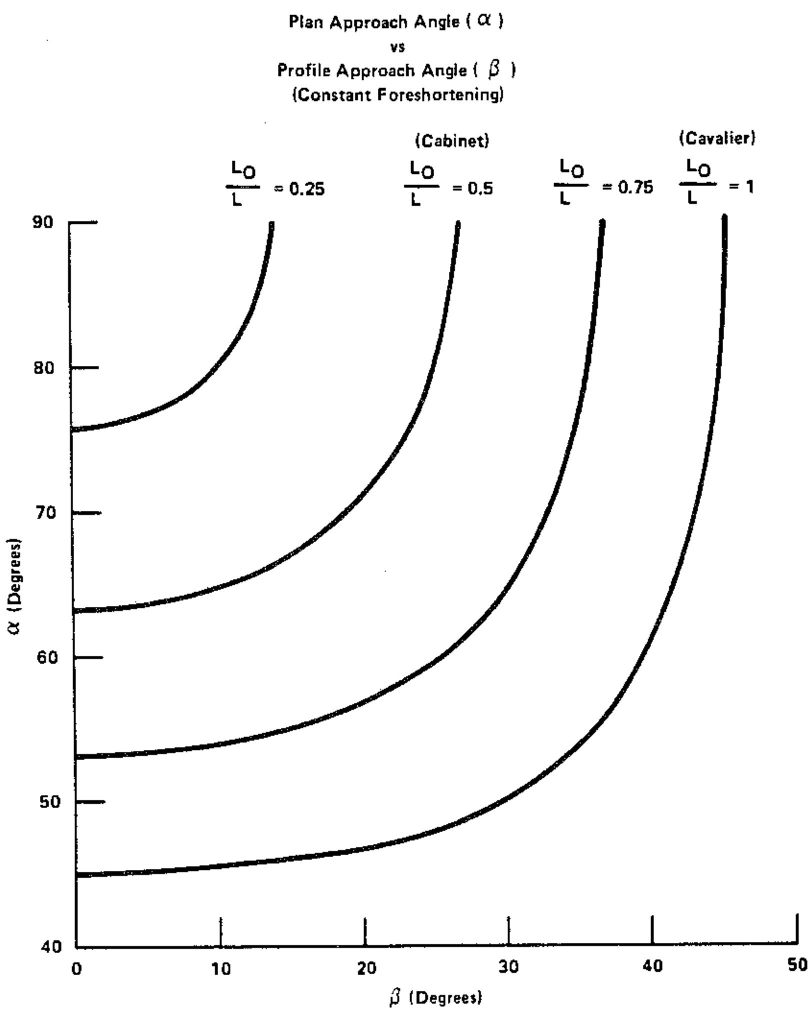


Figure 2. Oblique Length (Foreshortened)

Thus, for a given line of sight as defined by and , the plan and profile approach angles, the resulting foreshortening and receding angle may be predicted.

The process may also be reversed to provide the required plan and profile approach angles for a desired oblique length, usually foreshortened, and receding angle. The equations are as follows:

$$(c) \quad = \tan^{-1} \frac{\frac{Lo}{L} \tan}{(1 + \tan^2)}$$

$$(d) \quad = \mathrm{Tan}^{-1} \left[\frac{\tan}{\tan}\right]$$

Examples

(a) Analysis - It is desired to predict the foreshortening ratio and receding angle obtained from a line of sight whose plan and profile approach angles are: = 70°, = 30°

$$\frac{Lo}{L} = \frac{1}{\tan 70}[1+(\tan 70 \tan 30)^2]^{1/2}$$

$$= 0.682$$

(Estimate from Figure 2: LO/L 0.69)

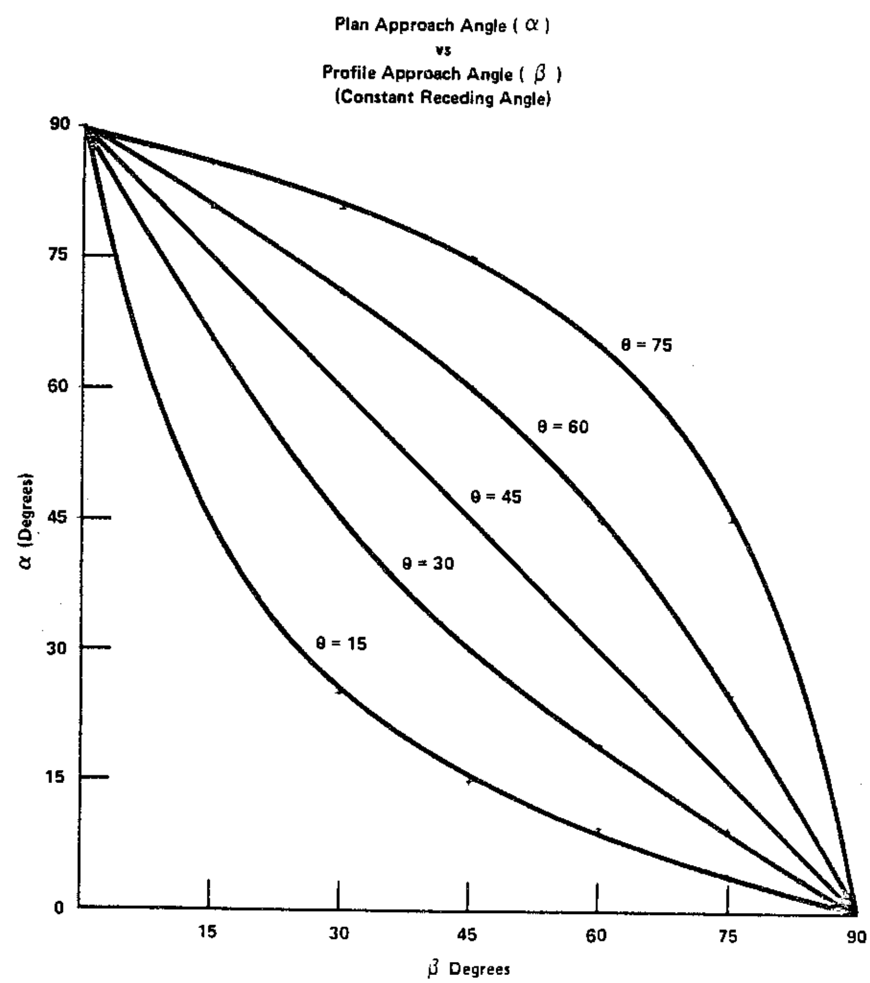


Figure 3. Receding Angle

$= \tan^{-1}[\tan 70 \tan 30]$

$= 57.75$

(Estimate from Figure 3: = 58°)

(b) Synthesis - It is desired to find the lines of sight required to produce an oblique projection with a foreshortening ratio of 0.5 (i.e., cabinet projection) and receding angle of 30°.

$$= \tan^{-1} § [\frac{(0.5 \tan 30)^2}{(1 + \tan^2 30)}]^{1/2} †$$

$= 14.04°$

$$= \tan^{-1}[\frac{\tan 30}{\tan 14.04}]$$

$= 66.57°$

Figures 2 and 3 may be used to verify these calculations.

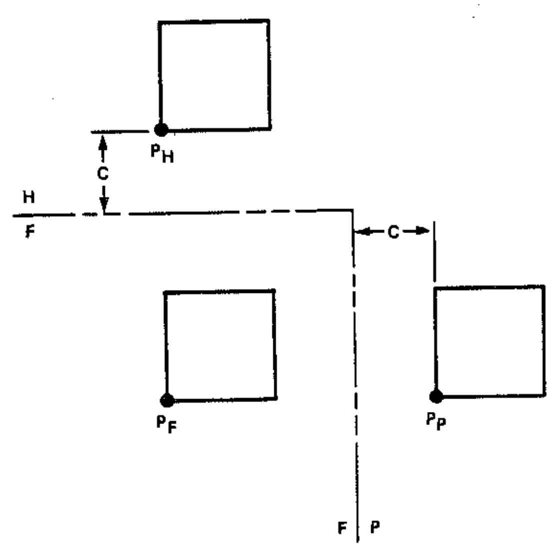


Figure 4. Principal Views of a Cube

Computer Graphics Construction of the Model

In the CADAM computer graphics program, it is necessary for the user to create the working views each of which is orthogonal to its adjacent view and oriented with respect to the adjacent view by a line of sight chosen by the user. Figure 4 shows three principal views of a unit cube.

A line representing the intersection of the plan and frontal viewing planes is created in the plan view at a convenient distance C from the front edge of the cube. Then, in similar fashion, a line representing the intersection of the profile and frontal viewing planes is constructed in the profile view. The lines are relimited and their type is changed to phantom as shown in Figure 4. They are labelled in conventional "hinge" line notation.

Since the front view in an oblique projection is generally the orthographic front view of the model, it may be stored as a detail for use later. Point P_F will be referred to as a "pivot" point for placement of this view.

Next, create a pivot point P_o in the oblique (i.e., frontal) view which locates the lower left front corner of the cube. This point will be used to place the front view in the oblique viewing plane. Figure 5 shows the placement of point P_o in the oblique projection plane.

This requires the selection of the required plan and profile approach angles and which are defined by the desired foreshortening and receding angle. These parameters are usually chosen to minimize distortion of the model in the oblique view.

The procedure is to place a line at angle through P_H in view H. Then create a point in view H at the intersection of this line and hinge line H/O. This point, labelled P_{HO}, will project as a vertical unlimited length line in the oblique plane (already created as view F) as shown in Figure 5.

Follow the same procedure for projecting P_p from the profile view to the oblique view. This will result in the projection of an unlimited length horizontal line through P_{PO}. The intersection of these two lines locates of the pivot point (P_O) for the placement of the front view of the cube. After creating point P_O in view F, the front view may be moved from the detail page to view F, the Oblique view. (Labelled O in Figures 5 and 6).

This procedure can then be used to project the necessary points from the plan and profile views to complete the oblique projection of the cube as shown in Figure 6.

Summary

It is possible to predict the foreshortening ratio and receding angle associated with a given line of sight for an oblique projection. It is also possible to predetermine the plan and profile approach angles required to produce a desired foreshortening ratio and receding angle.

It should be noted that in order to produce a foreshortened oblique length, the plan approach angle must be at least 45° and the plan approach angle must not exceed 45°.

This method allows for efficient computer aided drafting of an oblique pictorial representation of the model when the principal orthographic views are available.

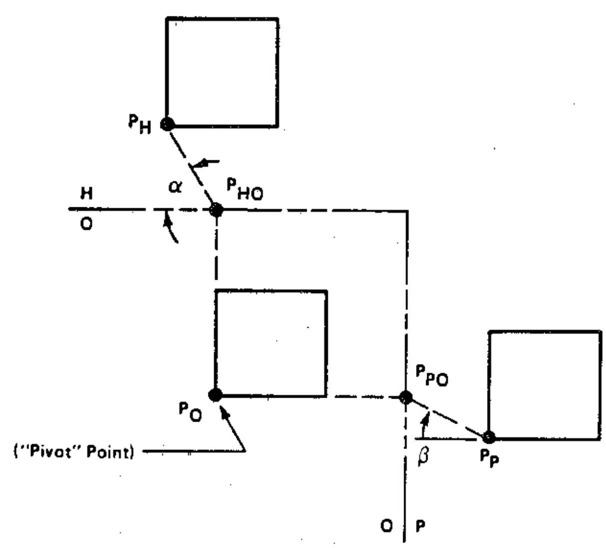


Figure 5. Placement of Front View

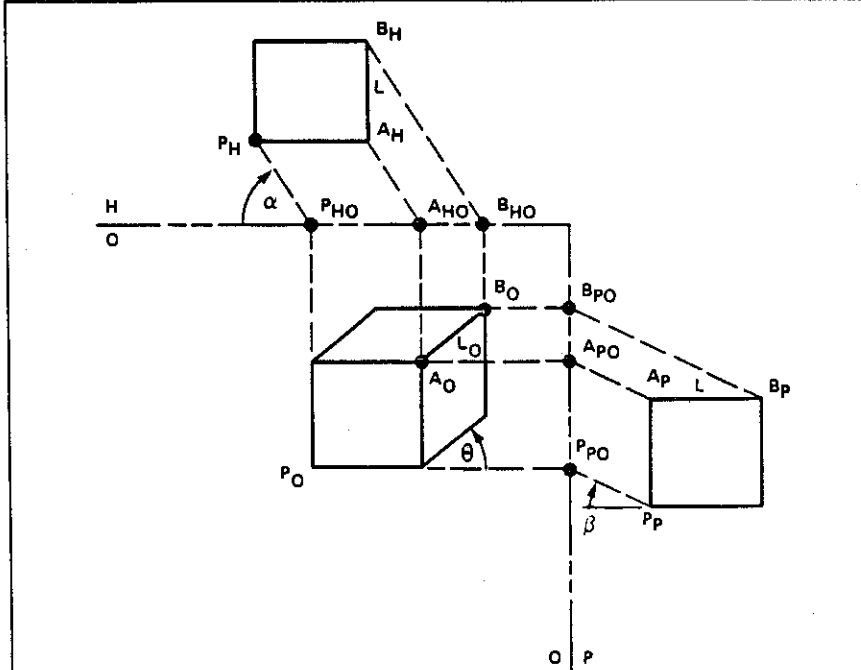
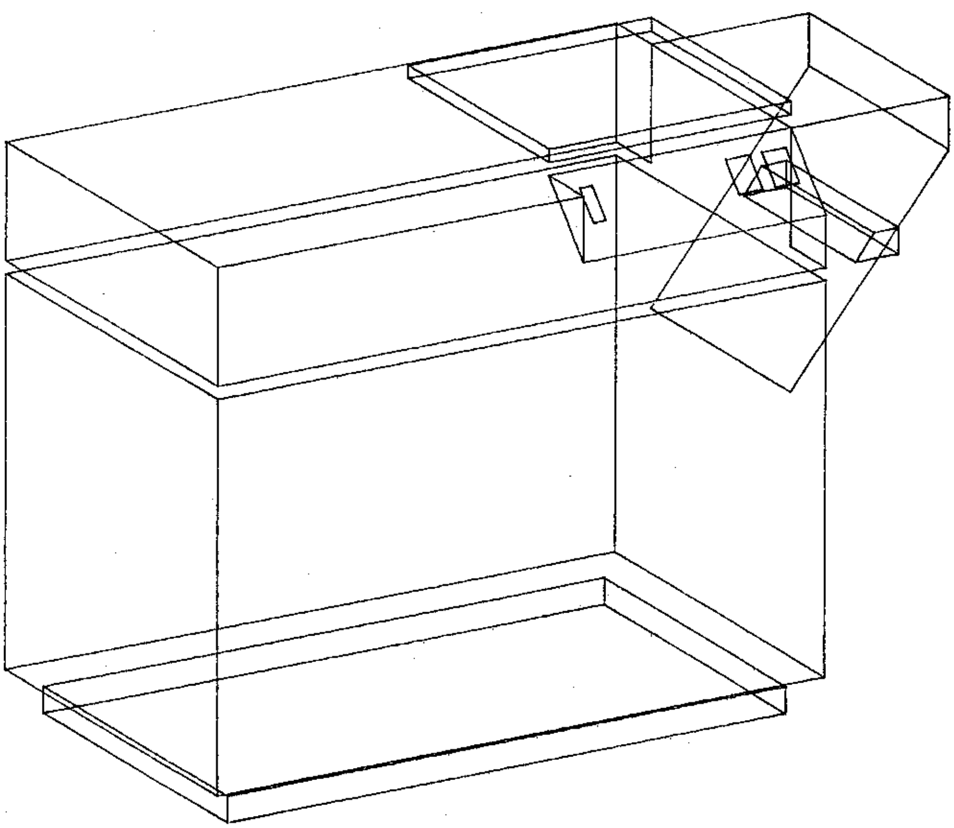


Figure 6. Oblique Projection of Cube



PROPOSALS

PROPOSAL PREPARATION IN ENGINEERING DESIGN

by

Gerard Voland
Assistant Professor
Department of Industrial Engineering and Information Systems
Northeastern University
Boston, MA 02115

The Benefits of Proposal Preparation

Engineers (particularly design engineers) are frequently involved in the development of proposals for project funding. Engineering students should be encouraged to prepare proposals for each project which they undertake in order to have their skills in this vital area of the profession.

The projects may be of two types:

1. internal efforts, i.e., projects which will be financed by the engineer's employer; such efforts include new product development, support for manufacturing tasks, product design modifications, plant layout and equipment purchases, etc.

2. external efforts which are to be supported by outside funding sources (either governmental agencies or other companies).

In either case, a truly professional presentation is needed which will persuade the funding source that the proposed effort will produce valuable, tangible results.

The project proposal, in addition to generating funding for the effort, also provides the following benefits:

(a) a methodology for the project (included in the proposal) which is expected to lead to successful results.

(b) a work/task schedule with distinct milestone events which can be used to both guide personnel and measure progress; the responsibility for specific tasks is allocated to the appropriate person or group.

(c) an initial user evaluation/marketing survey is often performed prior to the preparation of a proposal; such a survey can be used to identify user needs (and, therefore, project goals), existing competition, etc. (It is important to realize that a comprehensive marketing or feasibility study is conducted after the project has been funded and initiated - any surveys conducted prior to the submission of the proposal are preliminary and only provide a general perspective of project goals, specifications, product users, etc.).

(d) the required staffing for the project is specified, with the appropriate areas of expertise provided by company personnel or by outside consultants; in addition, all equipment needs are identified.

(e) finally - and perhaps most importantly - agreement is achieved between the funding source and those conducting the project effort regarding the output which is to be produced by the effort; all parties understand that the project personnel have been contracted to: submit specific reports, generate recommendations, conduct experiments, produce a specified quantity of manufactured units, etc.

After a need has been identified or a problem has been formulated [see Voland (1983a)], the preparation of a proposal should begin. All design efforts can only benefit from the thought and effort which is devoted to the project proposal.

Proposal Preparation

The standard proposal should include the following sections:

1. Title Page - which identifies the title of the proposal, the person or group to whom it is submitted, the person or group submitting the proposal and the date of submission.

2. Table of Contents

3. Technical Proposal - this is the portion of the proposal which focuses upon the technical aspects of the project. A separate 'Business Proposal' (described below) is also included in the total package which is specifically directed toward those who will be responsible for approving the economic aspects of the proposed effort.

   The Technical Proposal should include an INTRODUCTION which identifies the user or group who will benefit from the proposed work and which provides a justification for the effort by persuasively detailing the needs of the user group which will be satisfied by the results of the project. In conjunction with such a justification, a listing of the major results which can be expected from the project should be given.

A proposed METHODOLOGY is then presented which details the procedure to be used to achieve the desired project goals. One should demonstrate his/her familiarity with the project by specifying the particular activities which will need to be performed during the effort, e.g., product familiarization (including literature reviews, patent searches, consultations with experts, existing competition, desirable product characteristics), user group orientation (for which marketing surveys, experiments, observations, interviews and other interactions with members of the user group are designed), the phases of the design process, [including detailed goals' specification, the use of creative techniques in developing feasible alternative solutions [see Voland (1983b)] and the technical analysis of the chosen final design (including the construction and testing of a prototype, if appropriate)], interim and final reports (including a detailed description of the final design/solution, all necessary illustrations and drawings, etc.) and a final oral design review-presentation before the funding agency.

An estimated time interval for each phase of the technical effort should be included. a milestone chart - in which the completion dates for key events during the project are identified - should also be provided in the proposal.

Finally, all references (literature and individuals) should be given.

4. Business Proposal - in which the salaries of the required personnel, equipment needs, travel expenses, overhead costs and other expenditures are identified.

5. Resume - Finally, resumes of all key personnel who will be involved in the project effort should be included in the proposal package, perhaps as an appendix.

Other requirements for a proposal (both in content and style) will often be specified by the particular funding sources. One should, of course, satisfy all of these requirements and "customize" the proposal for the funding agency to which it will be submitted.

A cover letter should always be included with the proposal. This letter should include the following information:

- a statement that the proposal is attached
- the time period during which the proposed work will be performed
- the estimated cost of the proposed effort, together with the amount of funding requested.
- a brief description of the proposed effort, together with the potential users of the results, the benefits which can be expected for the funding source, the methodology to be used and the tangible results (reports, surveys, promotion copy, etc.) to be generated.
- closing remarks in which enthusiasm for the effort is expressed and a telephone number is provided for additional information.

Concluding Remarks and an Example

An example of a proposal (together with a cover letter) - in which the above recommendations have been used - is presented on the following pages.

Proposal preparation is a crucial part of engineering work; in fact, it sometimes requires greater thought, effort and time than the proposed project itself. The design engineer who has developed his skills in proposal writing techniques has also increased his value to his employer and to society. The importance of careful proposal preparation cannot be overemphasized.

REFERENCE

Voland, G., "Initial Problem Formulation in Engineering Design", Engineering Design Graphics Journal, in review (1983a).

Voland, G., "Stimulating Creativity in Engineering Design Efforts", Engineering Design Graphics Journal, in review (1983b).

identify needs–then develop a proposal

IRI

INTEGRAL RESEARCH INSTITUTE, INC.

integrating scientific heritage with creative ability

12 Saddle Drive
Bridgewater, Massachusetts 02324
[redacted]

February 23, 1983

Mr. [redacted] Manager
Sports Research Division
[redacted] Company, Inc.
[redacted]

Dear Mr. Hill:

Enclosed please find our PROPOSAL FOR THE DESIGN OF A NEW THERAPEUTIC RECREATIONAL PRODUCT FOR THE UNDERNOURISHED, WEAK OR AGED. The proposal is for a period of three weeks with a total budget of $ 3846. The proposal has been divided into three parts in order to facilitate your reviewing process: the TECHNICAL PROPOSAL, the BUSINESS PROPOSAL and an APPENDIX.

As noted within the Technical Proposal, hospital patients, inhabitants of many underdeveloped countries and other large population groups have a high incidence of metabolic abnormalities which result in a state of undernutrition. This total population group offers to [redacted] Sporting Equipment Company, Inc. the opportunity to provide therapeutic recreation designed specifically for the members of this group while also generating substantial company profits. In addition, the product should be popular among those who are not undernourished but who have limited abilities (e.g., the aged, the disabled and those who fail to exercise regularly). As a result, the potential exists for substantial profits to result from this product development effort.

The proposed design effort will be accomplished in five phases, as outlined within the proposal. As a result of the activities of Phases I and II (Product Familiarization and User Orientation), the interfaces between (i) the user and our product and (ii) our product and the goal of providing proper therapeutic recreation to the user will be clearly reflected in the design's particular goals and specifications, with the consequence of a comprehensive yet focused effort by the IRI design team and [redacted] Sporting Equipment during the final three phases of the project.

Proven creative design techniques will be used during Phase III of the project to generate unique and feasible designs, after which a final design concept will be selected together with the identification of any areas of needed improvement in this final design. A prototype will then be constructed and clinically tested against the criteria established during the early phases of the project.

Finally, a written report which describes the final design (including fully-dimensioned drawings), test results, a preliminary claims list for patent application purposes, suggested promotion copy for marketing of the product and all other relevant results will be provided to [redacted] Sporting Equipment. In addition, a Design Review before representatives of [redacted] will be scheduled and given.

We at IRI are convinced that the approach to the design and development of this new product in a major marketing arena (therapeutic recreation) outlined in the attached proposal will produce the most successful results within the shortest time. We are anxious to begin work on this project upon acceptance of the proposal by your firm.

If I can be of further assistance, please contact me at the above address or telephone me directly at (617) [redacted].

Very best wishes,

Gerard Voland
President

FIGURE 1

PROPOSAL FOR

THE DESIGN OF A NEW THERAPEUTIC RECREATIONAL

PRODUCT FOR THE UNDERNOURISHED, WEAK OR AGED

TABLE OF CONTENTS

FIGURE 2

MILESTONE CHART

Week	1		2		3	
PHASE I	XXXXXXXXXXXX					
PHASE II	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX		
PHASE III			XXXXXXXXXXXX	XXXXXXXXXXXX		
PHASE IV				XXXXXXXXXXXX	XXXXXXXXXXXX	
PHASE V				XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX

PHASE I - Product Familiarization
PHASE II - User Orientation & Dynamic Analysis of Existing Products
PHASE III - Ideation & Prototype Design
PHASE IV - Construction & Verification of the Prototype Design
PHASE V - Presentation: Dimensioned Solution, Final Report with Claims List & Design Review

Real-time duration of Project: 3 weeks

FIGURE 3

BUSINESS PROPOSAL

PROPOSED BUDGET

The proposed budget is for a period of 3 weeks beginning upon acceptance of the proposals. Payment is to be made in installments as mutually agreed upon.

- SALARIES

Engineering & Design (Principal Investigator: Gerard Voland) @ $400/day - 2 days per week for 3 weeks	$2400
Drafting & Model Maker @ $18/hr - 8 hours	$ 144
Machinist @ $20/hr - 3 hours	$ 60
Technical Assistant (Questionnaire effort) @ $ 5/hr - 3 hours	$ 15
Computer Programmer (data manipulation; analysis - as needed) @ $15/hr - 8 hours	$ 120

- EQUIPMENT

Instrumentation, mock-up items, lab supplies	$ 50
Computer time	$ 150

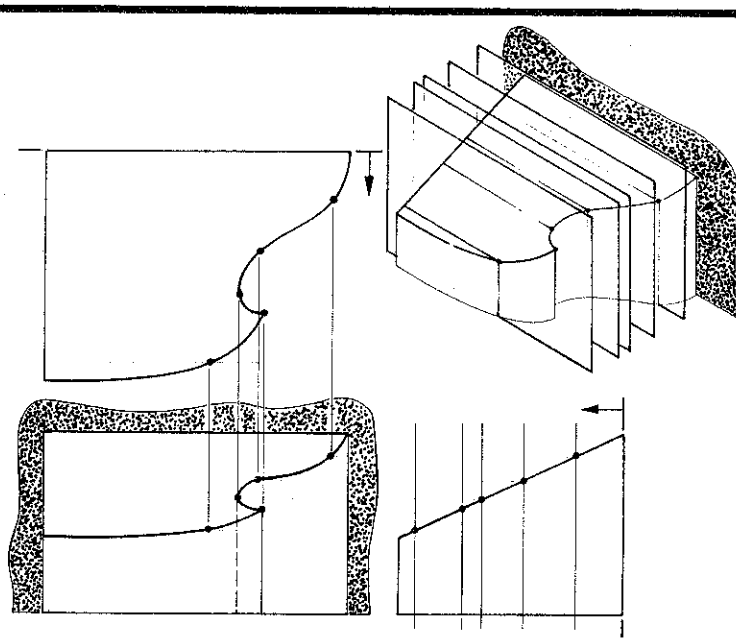
- TRAVEL (to local hospitals & suppliers)

@ 20¢/mile - 100 miles	$ 20
Sub-Total: DIRECT COSTS	$2959

- OVERHEAD

Secretarial, telephone, supplies, space, etc. @ 30% of Direct Costs	$ 887
TOTAL:	$3846

FIGURE 4



FUTURE GRAPHICS

MICROCOMPUTERS IN ENGINEERING GRAPHICS IMPLICATIONS FOR THE FUTURE

Dr. Leonard Nasman
Engineering Graphics Department
The Ohio State University

Background

We have now reached the year 1984. Some are surprised that we made it at all, while many are reflecting on Orwell's book, trying to determine the relative accuracy of his projections. A few, however, have noticed that it is just ten years since an electronics magazine published the plans for a personal computer based on a relatively new microprocessor chip. The response to the article was amazing. The magazine got more requests for reprints of this article than any that had gone before. A couple of kids in California worked up a kit they called the Apple, and Radio Shack, Commodore, and Atari, started marketing microcomputer systems for less than $1000. A couple of college boys put together a spread sheet analysis program that they called Visicalc, and thousands of small businesses decided that they just had to have a microcomputer. In spite of the demonstrated usefulness of microcomputers, the computer science folks remained aloof for awhile, and tried to pass the machines off as toys. The entry of IBM into the market, however, seems to have made believers out of most of the holdouts.

In less than ten years, the computer business has moved from a situation where computers were only accessible through computer specialists, to a point where nearly every toy store, catalog distributer, department store, and even neighborhood supermarkets are selling computers. And the computers they are selling are in some ways more powerful than the big expensive machines of a few years ago.

The big question for us is just how will microcomputers affect the way we conduct engineering graphics education? What are the implications for us now, and in the foreseeable future? For my discussion of microcomputers in the context of engineering graphics education, I will be talking about three diffeent areas in which I see significant impact. The three areas are: Microcomputers as engineering graphics tools; Microcomputers as part of the instructional delivery system; and Microcomputers as an instructor's aid.

A Graphics Tool

Within the last three or four years, microcomputers have made it feasible for every educational institution to consider purchasing one or more computer aided graphics systems. If you have anywhere from five to fifty thousand dollars to spend, you can get a reasonably sophisticated graphics tool. As a matter of fact, you might even find some instructional applications for hardware in the $1000 range. The real problem is not finding the funds to purchase the hardware (although that is a problem). No, the real problem is deciding just what the instructional objectives are for having computer graphics hardware in the first place, and deciding just where computer graphics fits into the curriculum. Should we be teaching prospective engineers how to operate equipment? Many would argue against this on the grounds that equipment operation requires more training than education, and that training does not belong in the university's academic environment. Well then, should we be teaching engineers how computer graphics hardware or software works? Some would argue that it doesn't matter how they work as long as the end user can make them work. Should we be teaching engineers how to design computer graphics systems, or write computer programs that generate graphics? If we do, what percentage of our students will find such knowledge useful in their work?

What about the question of just where computer graphics fits into our curriculum? I don't know what has been happening to engineering graphics at your institution, but at Ohio State engineering graphics over the last ten or twenty years has been pushed into a fairly small piece of time in the curriculum. What was once a primary foundation course in most colleges of engineering, does not even appear in many engineering college catalogs at all. The competition for time in the curriculum is intense, and is not likely to ease up in the foreseeable future. Well then, can we bite the bullet and replace some of our graphics course content with computer graphics material? One thing stressed by nearly every industrial representative that I have heard speak about the use of computer graphics, is the importance of having a strong background in the fundamentals of engineering drawing before trying to get a machine to do the drawing for you. As an individual that spent a good part of his life in drafting and design, I have been both amused and appalled by some of the stuff that the computer science wizards consider representative of engineering drawing.

We face a significant challenge in finding a place in our curricula for computer graphics without short changing our students in their exposure to the traditional communication language of the engineering profession. We are in the middle of a revolution. Perhaps we need to do some revolutionary thinking about just what constitutes an effective educational background for engineers that are destined to spend most of their working lives in the twenty first century. We have on hand a remarkable new tool for doing graphics. This microcomputer graphics tool, however, is not just some kind of clever electric pencil as some would have you believe. The same device that allows you to make and change drawings with amazing speed and accuracy, is also capable of data analysis, word processing, and project management, not to mention playing great games. To think of microcomputers strictly as new graphics tools, is extremely short sighted. To think of them in the larger context of the total engineering curriculum is frightening.

It appears to me that engineering education is suffering to some degree from over specialization. At least we are guilty of spending too much time within our disciplines, and too little time communicating with our colleagues. As a result, discussions of what hardware should be purchased, or what progamming languages should be taught, or just which department will take on what part of the instruction, are sure to get very interesting when everyone suddenly realizes that they all need to incorporate microcomputers in some way into their curriculum. So, we started out by wondering about the implications that microcomputers have for engineering graphics, and end up wondering how we can deal with the problems inherent in revising the entire engineering education curriculum. Oh well, revolutions rarely allow for easy times for the people living through them. Let's move onto another exciting area.

An Instructional Delivery System

The idea that individualized instruction is more effective than the traditional lecture method is not very new. I remember a journal article that I critiqued back in my graduate school days. The author's research demonstrated that in a typical lecture class about 40% of the students were ahead of the lecture, and were relatively bored. Another 40% were behind, and were missing the points being covered. Only about 20% of the students at any particular time were effectively receiving instruction. The author then presented a strong case for the need for individualized instruction. The date on this article, by the way, was 1917. The fact is that economics has had more effect on our instructional strategies than research on instructional effectiveness.

In the 1960's, a great deal of money was spent on developing computer assisted instruction, also know as CAI. Much of this was spent on developing a wonderful mainframe-based system called PLATO. I was an account director for a PLATO installation for awhile, and got a feel for the tremendous potential of CAI. By taking advantage of the computer, we can develop instructional software that actually monitors student progress, and adjusts content delivery accordingly. Now I would not advocate that instructors be totally replaced by computers, but I do believe that properly designed software can allow us to individualize a percentage of our curriculum. The major problem with systems such as PLATO is cost. Two years ago a full subscription for one PLATO terminal was $1200 per month. The cost is lower for multiple terminal systems, and it may have come down recently, but it is not conceivable to supply every one of our students with very much time on such a system. It is important to realize, however, that projects such as PLATO have demonstrated the instructional effectiveness of CAI to all reasonable investigators.

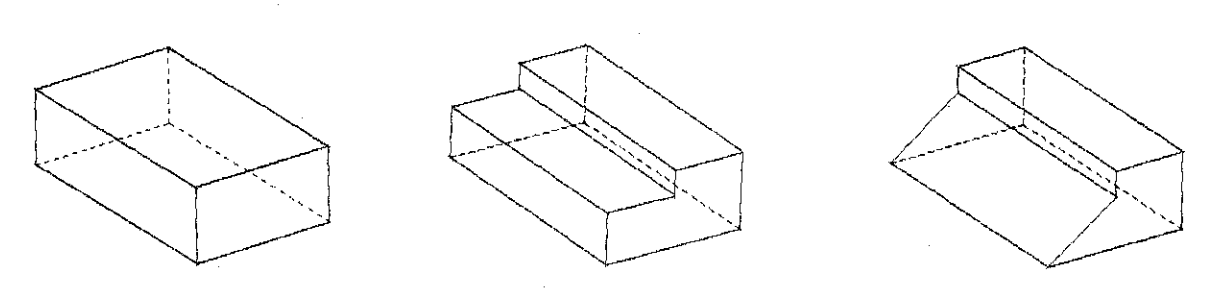


FIGURE 1

The good news for CAI fans is the microcomputer revolution. As the cost per student station gets down below $1000, we must seriously consider using microcomputers as a major instructional delivery system. In some ways microcomputers are superior to mainframes for CAI. Hardware without software, however, is absolutely worthless. Now for the bad news. There is very little currently available software designed to deliver instruction in engineering graphics. Now for some more bad news. It is unlikely that very many instructors at colleges and universities will be developing instructional software for engineering graphics in the near future. I'm not referring to little units here and there, by the way. There will be plenty of these. I'm referring to materials that would be the equivalent to the introduction of the first edition of French or Giesecke. Here is why I believe this to be true.

I recently directed a $200,000 Department of Education sponsored software development project at the National Center for Research in Vocational Education. The project was to adapt career education materials for delivery by microcomputer to mainstreamed handicapped junior high students. We ended up with 127 separate computer programs occupying 30 floppy discs all linked together and running as one (as far as the user is concerned). I mention this here because that project taught me a great deal about developing computer assisted instruction materials. The folks in the business, for example, know that it takes about 300 to 500 hours of effort to develop one student contact hour of computer assisted instruction materials. It takes much more than a subject area expert to do the job. It also requires a subject area expert, an instructional design expert, and a sharp programmer working together to develop good CAI materials. I submit that most of us in engineering education have neither the time, expertise, or resources to do the job.

Is there no hope then for using microcomputers to help increase the effectiveness of engineering graphics instruction? Not at all, I see microcomputer as a significant part of the engineering graphics instructional delivery system within the next three to five years. What must happen, however, is that institutions pool their resources to spread development costs that we must come to some consensus as to curriculum content. I predict that microcomputers will do more to standardize curricula across the country than any previous device or scheme. This will be true not just in engineering graphics, but will occur throughout education. The day when an individual instructor had the luxury of being absolute dictator over course content may become history because of the use of microcomputers as an instructional delivery system.

Before leaving this area, I must make mention of a related instructional technology that will be a part of the revolution in education in the near future. Videodisc technology now allows us to randomly access, and view, any of up to 54,000 separate high resolution color displays in less than 3 seconds. I have on my office desk right now a Pioneer laser disc player attached to an NCR microcomputer. This combination allows me to write interactive programs that combine the power of computer assisted instruction with the large storage capacity of the video disc. Imagine, if you will, having access to every engineering graphics visual aid you every conceived of within less than three seconds. I have dreamed of such an instructional aid every since I first saw a demonstration of laser disc technology. Before this particular dream of mine comes true, however, someone has to develop the master videodisc. At OSU we are working on a proposal to find a sponsor for the development of this master disc. We'll keep you informed by way of the Engineering Graphics Journal.

An Instructor's Aid

Much of what I have had to say so far about microcomputers in engineering graphics education has been future dream stuff. How about something that could have immediate benefits for instructors. If you have the desire, microcomputers could have a positive impact on your work right now. There are a number of applications of microcomputers that are at your disposal for a minimum expenditure of dollars.

Inexpensive hardware can be used in a number of ways to help make an instructor's life easier. One application is simply to use it in place of a slide projector or overhead projector. It takes quite a bit of fooling around to prepare title slides for a presentation. Even if you know a fair amount about photography, and use the fast developing slide films that are now available, I find that it's easier to prepare the equivalent of a set of color slides with the Atari. All I need to do is load my slide making software, and type the words I want. I also can type in scrolling bulletin board messages to my class quicker than I can write them on the chalk board. With a little more effort, I can develop visuals for various grahics topics. some degree of animation is possible, even on an inexpensive system.

There are other applications in the area of instructional management. With the addition of a $100 modem, and a $25 software package, I have been using my Atari to access the OSU Amdahl to manage my student programming accounts without having to leave my office. Within the year, I predict that all OSU engineering graphics faculty will have this capability through desktop personal computers. I suspect we may be behind many of you in this regard. Other applications of microcomputer abound when it comes to the many clerical functions required of instructors. When it comes to calculating student scores and grades, the micro shines. If you are at all bothered by security of your records, or by being a slave to big system schedules and maintenance problems, then you will be quickly spoiled by the relative freedom the use of a microcomputer allows.

I must digress and tell you how Fred (my home Atari) finally convinced my wife that the computer was worth the expense and space it occupied. My wife teaches English as a Second Language at OSU. Every quarter, she has to make a calculation to determine the grade for each student. The students write several papers each of which is awarded a C+, B, A-, etc., and each of which is given a different weighting factor for the final grade. Her problem is to translate the letter grades to numbers, apply the weighting factor, and translate the resulting number back to a letter grade. Needless to say, she did not find this fun on her pocket calculator. Well, it only took about 20 minutes to write a program to do this on Fred the Atari. Now she simply types in the letter grades for each paper, and Fred does the translations and tells her what letter grade the student has earned. There are a lot of clerical tasks like this that we can do now that microcomputers are so inexpensive that we can afford to have one at home and one at the office.

Summary and Conclusions

I have discussed three general areas in which I believe microcomputers will have an impact on engineering graphics education. The first was their use as a graphics tool, the second as a part of the instructional delivery system, and the third as an instructor's aid. The advent of microcomputer technology has many of the attributes of a true revolution, and there are many serious implications for those concerned with engineering education. We need to prepare ourselves to deal with quetions such as:

* Where do microcomputers fit as engineering graphics tools?
* How do we incorporate these tools into our engineering graphics curriculum?
* How can we best work with our colleagues in engineering education to design the best approach for preparing future engineers to utilize microcomputer technology?
* Where will the software come from that will enable us to take advantage of the potential of microcomputers as an instructional technology?
* How can we obtain the time and resources necessary to develop the applications software we need to take full advantage of microcomputers as instructor's aids?

These are but a few of the many questions we must deal with as a result of this revolution we are living through. The prospects are a little frightening, but at the same time very exciting. I expect that by 1994, all of us in engineering education will find that our jobs have been significantly changed because of the advent of microcomputers. I, for one, am optimistic about these changes, and believe that we will be doing a better job of preparing future engineers by taking advantages of these wonderful machines.

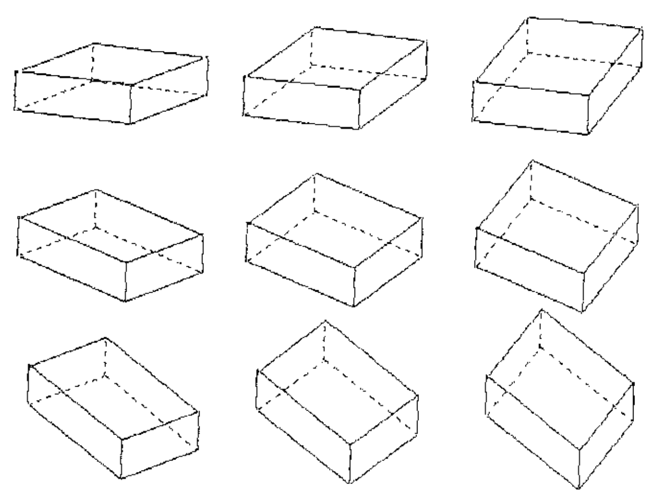


FIGURE 2

TESTING TIME

TESTING TIME-ENOUGH MAY NOT BE ENOUGH

by

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Introduction

Teaching any course requires administering tests to measure student performance. This performance measurement could also be considered as a means of providing positive or negative reinforcement toward the course. An instructor usually prepares a test and sets a time limit for it. The test time is normally chosen to give the average students sufficient opportunity to complete the test. This practice of selecting test time was analyzed to determine if a relationship exists between the grade earned on a test and time allowed to complete the test.

TEST 8 | ENGINEERING DESIGN GRAPHICS 106 | Geo2
A Version | 46-49 (Vectors, skewed lines)

File No. ________ Name ____________________________ Section ________ Grade ______

_____ 1. The notational method of labeling the spaces between structural members and the loads applied to them is called (A) Bow's notation, (B) Maxwell's notation, (C) Funicular notation, (D) joint notation.

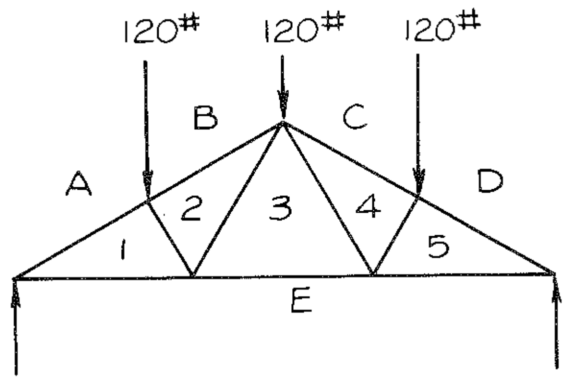
_____ 2. If a beam supported at each end is loaded with vertical forces of 200 pounds and 800 pounds, what would the support at the right end support if the one at the left end supported 500 pounds? (A) 800 pounds, (B) 500 pounds, (C) 1000 pounds, (D) 600 pounds.

_____ 3. The shortest distance between two skewed lines is found in the view where (A) one of the line appears true length, (B) one of the lines appears as a point, (C) both of the lines appear true length, (D) both lines appear as points.

_____ 4. The shortest distance between two skewed lines is a line that is (A) perpendicular to one of the lines, (B) parallel to one of the line, (C) parallel to both of the lines, (D) perpendicular to both lines.

_____ 5. The first part of a Maxwell diagram that should be laid out are the (A) internal loads, (B) the external loads, (C) the tension loads, (D) the compression loads.

6. Construct a Maxwell diagram to find the forces in the members of the truss below. Diagram—14 pts, forces—3 pts each, and tension or compression—3pts each.



SCALE: 1" = 100#

LOAD CORT

A-1
1-E
B-2
2-3
3-E
2-1

Method

A study was conducted during the spring semester of 1983 to evaluate the various weekly open book quizzes of a freshman Descriptive Geometry course, (EDG 106), to determine the effect of testing time on the grades of the students. In other words the study was to determine if there existed a relationship between the grades earned and the time taken to complete the test. The author collected the data for the amount of time the students took in completing the test. Sufficient time was given for each test to a maximum of forty minutes. The normal time given for these tests is fifteen minutes. An example of the test is shown in Figure 1. The experimental subjects were 51 students in the author's classes. Analysis of variance was conducted for all the collected data. The analysis was performed using the Statistical Analysis System (SAS) computer program.[1,2] Data from each quiz and all quizzes combined was analyzed for the following polynomial tests.

1. Linear Correlation: time vs grade
2. Quadratic Correlation: time vs grade
3. Cubic Correlation: time vs grade

These polynomial curves are shown in Figure 2. These standard distributions were anticipated for the collected data.

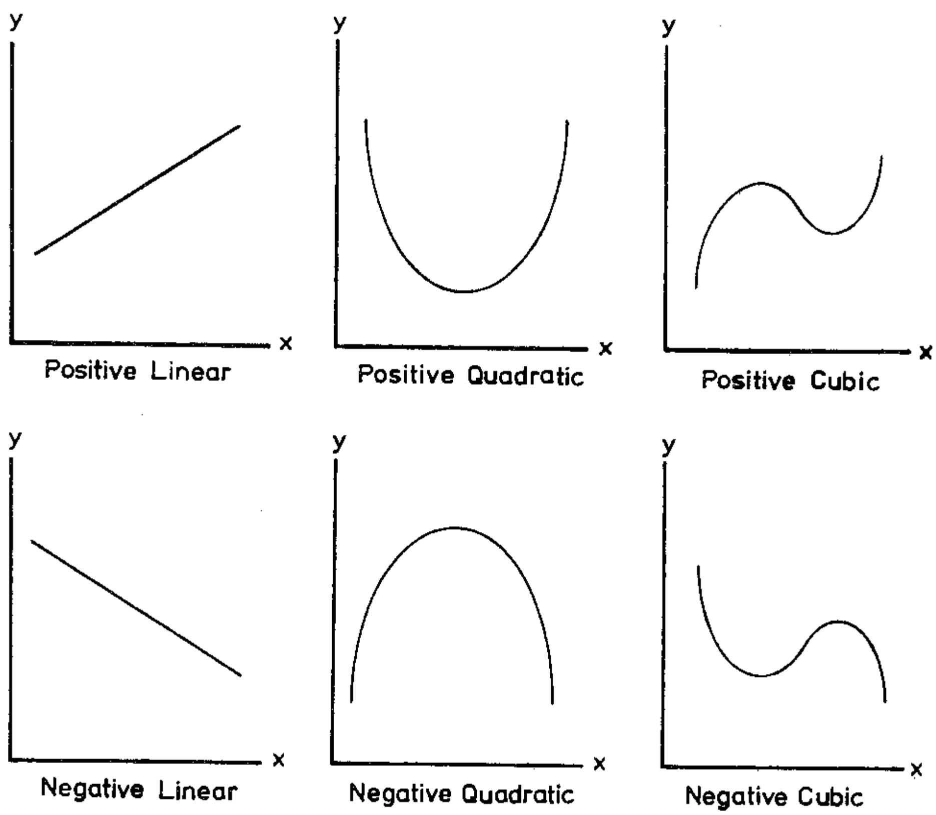


Figure 2 Typical polynomial curves.

Observations and Conclusions

Contrary to the author's anticipated mathematical distribution of polyinomial form shown above on the collected data, a scatter diagram was obtained for the combined data of all quizzes. This scatter diagram for time versus grade had a unique v-bucket distribution. As shown in Figure 3, initially there were larger number of high scores and small number of low scores as shown at the left of the bucket. The right side of the bucket is initially composed of low scores and as more time is given the number of high scores increases. Thus potential A students are found to have the widest range of time in which they complete the tests starting with as low as ten minutes to as high as forty minutes. The students with a potential of earning a B grade have a shorter range of time in which they complete their tests, starting from fifteen minutes to thirty minutes. The students who are potentially in the range of C,D, or F operate in the smallest range of time, and are closest to the median time of twenty-six minutes for the tests. Therefore it can be said that providing more time helps the potential A student the most and the potential F student the least. The potentially poor student may not want to be helped in terms of giving him extra time, while the potentially good student may make use of the time and hence earn a better grade.

It is noticed that high scorers, on top of the bucket, are most in number. In the middle of the bucket are moderate scorers, which are less in number. The low scorers at the bottom of the bucket are least in number. It is therefore shown that if one wants to help the potentially poor students, giving extra time to complete a test is of lesser significance while extra time provided to the potentially good student is helpful.

In analyzing the individual quizzes it was found that, for most of the quizzes, there appears to be no correlation between the student grade and time of turning in the test. Some tests however, did show significant positive quadratic, and positive or negative cubic correlation for time versus grade.

It is therefore recommended that for each test which is administered on a continuing basis, similar data should be collected to determine if there exists a mathematical relationship between the time allowed for testing and grades. If there exists a mathematical relationship the instructor can draw his own conclusions regarding the time to be allocated. If no mathematical distribution is found, the conclusions drawn by the author appears to be valid and would provide a guideline for instructors to set time limits for their tests irrespective of their philosophy of education. Further studies could be conducted with a control group included. Additional studies could provide answers to questions like these: (a) Does the

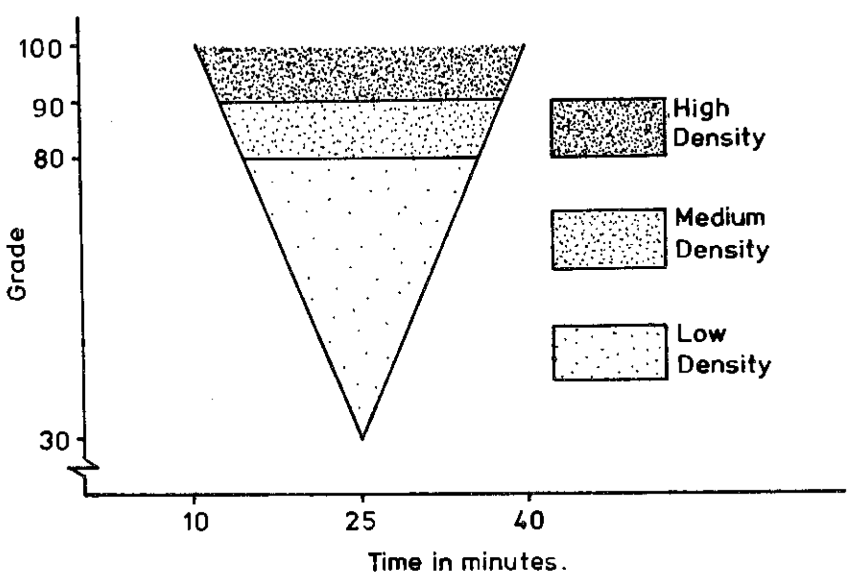


Figure 3

DELIVERY METHODS

A-T GRAPHICS -- NEW HYBRID YIELDS BIG RETURN

by

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Background

This year I am celebrating my silver anniversary as a classroom teacher of technical drafting and design, and it is a milestone of which I am proud. Ten years ago, however, I was not very certain about my future in the teaching profession as I began sensing some symptoms of "mid-career burnout". The pleasure and excitement of teaching was rarely felt anymore, I was becoming bored with the repetition required in the traditional lecture-lab (L-L) format, and I was usually tired. During the next couple years more definite signs followed and I knew I would soon be faced wtih a choice. Clearly, it was time for a change, not only for my personal health and satisfaction but also for the sake of my students and of my institution.

Two possibilities were obvious: (1) leave the teaching profession and make a career change or (2) seek ways of reversing the situation so I could again enjoy my work. For a number of reasons I ruled out the first option and decided to remain in the educational arena. The challenge of designing a different teaching approach which would permit both myself and my students more flexibility and freedom with less repetition was exciting. I had turned the corner, and felt good!

In 1971 I was granted a "developmental leave" of absence from UND. Concurrently, I was afforded the opportunity to attend Purdue University and study educational technology and individualized instructional design. Since the early 1960's Sam Postlethwait and his many followers have recorded significant progress with their experimentation and application of the audio-tutorial (A-T) individualized teaching approach. The A-T method has since been adopted for use in a variety of subject areas, class sizes, and types of institutions. During my internship with Sam Postlethwait I not only had the chance to study the educational psychology and philosophy behind his A-T system, but also the content and workings of various other individualized instructional systems which had been designed and used elsewhere.

The Instructional Design

My goal while at Purdue was to design (and prepare to implement) an individualized system which would effectively assist me in conveying the traditional graphics content in a non-traditional manner. The general objective was to improve the quality of instruction in engineering graphics; in other words, to improve the "climate" for teaching and learning. The design of my new modified A-T Graphics approach was based largely on Postlethwait's philosophy, which suggests that "learning must be done by the learner", and therefore the instructional strategy must be matched as closely and carefully as possible with the needs of the learners. I was also influenced somewhat by the psychologies of B.F. Skinner and Benjamin Bloom. The following three premises were understood at the outset:

1. The familiar saying "a picture is worth a thousand words" strongly suggests that the best way to teach about pictures (drawings) is to use pictures (visuals) fairly extensively. This "learn by seeing" philosophy, when combined with the traditional "learn by doing" method, was analyzed as being a logical and highly viable foundation for any effective approach to teaching graphics.

2. Teaching is hard work. The A-T approach was not designed as an easier way to teach, but was intended to make learning more meaningful and interesting for both student and

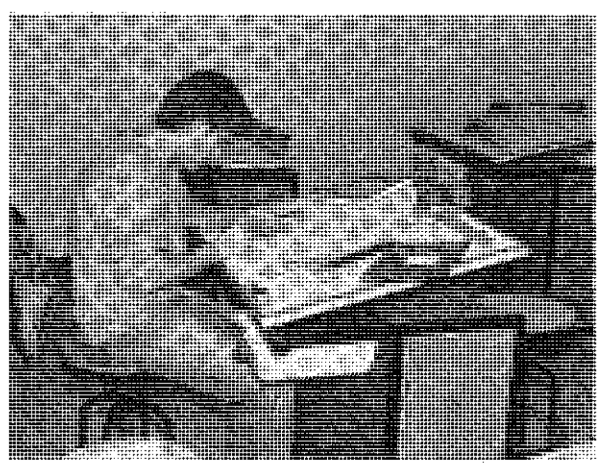

FIGURE 1

The fact that many students do drop out of their basic graphics course very early in the semester, often after having attended only one to two classes, does distort the statistical picture of attrition. It is also a fact that most students who are enrolled in an individualized course approach feel even less comfortable during the first weeks of school because it is usually a completely new experience for them. Many feel like walls are closing in around them, they are lonely, and the logical answer is to find a way out. This has been a weakness of the A-T graphics approach at UND and the attrition statistics point this out very clearly. Greater efforts are needed to offset the circumstances which lead to premature decisions by good students, but much progress has been made during the past two years. Figure 3 shows that the A-T and L-L attrition statistics are much closer now than when the A-T program was in the early stages of development. The shift toward a "hybrid" instructional strategy has been a significant asset in helping reduce the attrition for the A-T classes, although it has also tended to increase the attrition in the L-L courses, as Figure 3 shows.

Questionnaire Results

Flexibility and Freedom: When the 247 students who had studied a graphics course at UND via the new A-T individualized approach were asked what they liked about it most, 95% agreed it was "the FLEXIBILITY of scheduling my lab time and the accompanying freedom." A majority of the A-T students did not seem to worry about the lack of structure. They responded with "no" when commenting on the statement: "in general, I would have preferred more structure than the A-T graphics course required or permitted". Only 16% indicated that they felt more structure would have been helpful.

Sixty-three percent of the A-T students felt that their experiences in the A-T graphics course/courses improved their own general ability to organize their study time and budget their time. However, 9% did not feel the A-T experiences helped them very much regarding the organization of study time, while 28% did not indicate feelings in either direction.

Nearly a third of the A-T students indicated they "had strong reservations about being enrolled in such an open-ended drawing class when it was first explained" to them. However, 47% did not indicate any strong reservations, and the remaining 22% did not appear to care one way or the other, since they responded neutrally.

A majority of the students questioned who had studied via the A-T approach (62%) said they much preferred "the individualized A-T approach for taking both elective and required courses in engineering". Thirteen percent did not prefer the A-T approach, and the remaining 25% did not have preference since they responded in the "neutral" column.

Sixty-two percent of the students who had studied via the structured L-L approach said they much preferred "the traditional L-L teaching approach for both elective and required courses in engineering". Only 10% stated that they did not prefer the L-L approach, with 28% responding in the "neutral" column.

Performance levels: Sixty-four percent of the students surveyed in April 1983 did not think the performance levels required for the various grades were too low. Only 9% felt it was too easy to get a good grade in graphics, and the remaining 27% did not have an opinion about it. In responding to the statement "I felt somewhat less worry and concern about my grade in A-T graphics than I generally do when enrolled in a more structured learning type course", about one-half of the A-T students said "yes" and one-half said "no".

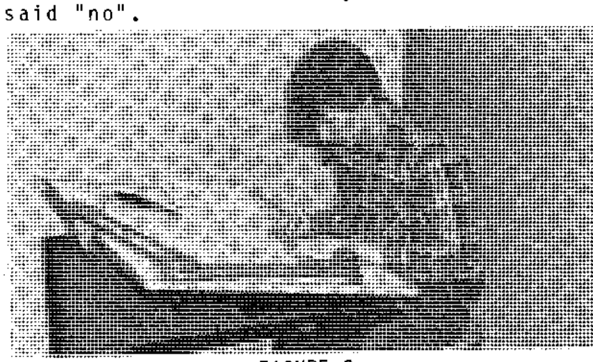

FIGURE 2

Seventy-eight percent of the students surveyed considered the grading of the assigned technical sketches and plates to be "quite fair", but 6% did not agree and the remaining 16% did not respond. Likewise, when asked if they felt the "examinations given in the graphics course/courses were based on the printed objective and were evaluated fairly, 88% said "yes". Eighty-four percent also felt "the examinations were quite well integrated with the topic material".

Study Helps: Eighty-nine percent of the A-T graphics students surveyed felt the written study guides for the graphics course/courses they had taken were "fairly thorough, quite clearly presented, and generally were very helpful." This compares to 79% of the L-L students who gave the study guides a high rating. In another question asked only of the A-T group, 72% of them agreed that "probably the one most helpful ingredient of A-T graphics" was the study guide, and only 6% disagreed.

Seventy-five percent of the A-T students surveyed responded they felt "the audio-visuals (tapes, slides, and/or video tapes) used in the A-T graphics and/or descriptive geometry course were satisfactorily presented annd integrated fairly well with the sequence of the course units, and were generally effective in contributing to my understanding of the subject and my ability to draw." However, even though many felt that the audio tapes, slides, and video tapes were fairly well integrated with the courses, the self-study center did not rate very high in another question which was asked. Only 27% of the A-T students said it had been "quite helpful" to them, and 49% of all the A-T students surveyed did not think they had been helped that much by the tapes and slides in the self-study center. Twenty-four percent were neutral.

Value of Lectures: When the 163 students who studied graphics via the traditional L-L approach responded regarding what they liked about it most, 79% agreed that it was "the lectures and the accompanying structure". Only 4% disagreed, but the remaining 17% were "neutral". But when asked if they would have "preferred to hear more lectures, possibly one hour of lecture for each two hour lab session," only 15% of the L-L students said "yes", and 50% of the respondents who had studied via the L-L approach said "no". The other 35% were "neutral". The A-T students were also asked if they would have preferred to hear more "minilectures" at the weekly A-T graphics meetings, and 40% of them said "no". However, 31% said "yes" and 29% were "neutral".

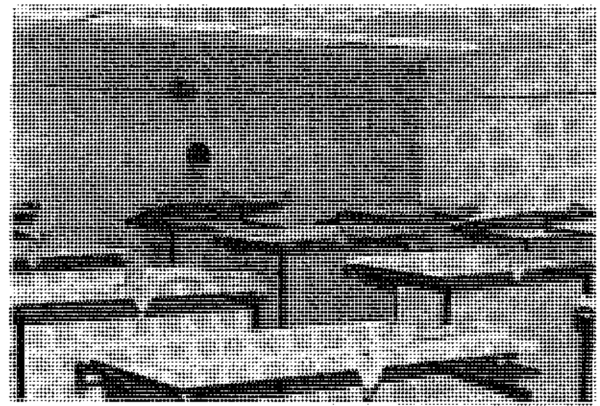

FIGURE 3

Tutors and Faculty: Eighty-eight percent of the 394 students surveyed indicated that they "always felt free to seek out their instructor or one of the GTA tutors for assistance in solving problems when bogged down." Interestingly, however, 29% of the students responded that they had "received as much or more help from other students in the same class than they had obtained from the instructor and/or tutors combined". Forty-eight percent disagreed with that but 23% were neutral.

Only 12% indicated they agreed with the statement "in my opinion, the method and manner in which the A-T graphics course was taught greatly reduced the instructor-student contact and therefore it is not a viable teaching approach". The majority of the A-T graphics students (65%) responded with a "no" answer, indicating that they feel it is a viable approach.

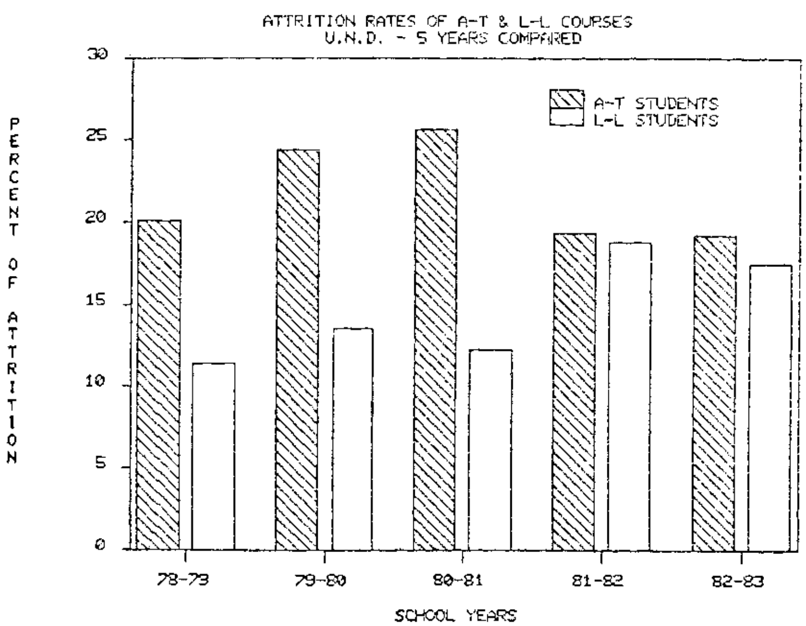

Fig. 3

In evaluating the tutors who had been assigned to the graphics courses, 53% of those surveyed felt the tutors "were usually friendly, patient, understanding, and generally quite helpful to me when explaining things". Only 2% of the students did not find the tutors helpful, and a large group, 45% were "neutral" about their response. In the same vein, when the students were asked to rate the faculty involved with teaching engineering graphics and descriptive geometry, 91% agreed that "graphics teachers were generally around to help and demonstrated adequate patience in dealing with the students enrolled in their courses." The responses to the statement: "in retrospect, I feel very good about what I learned in my UND graphics course/courses, and enjoyed the experiences," were very favorable. Eighty-five percent answered with a "yes", 15% were "neutral", and only 3% said "no". Only 12% of the A-T students responded that they would not select the A-T approach again, but 56% of them responded by saying "yes", they would select A-T again. The others, almost one third of the students, did not offer an opinion.

Adapting To Individualization

Students who are not familiar with individualized instruction have a more difficult time adjusting. It usually takes two or three weeks for these studens to feel comfortable in such settings, and some never do reach that point! I have also found that students who have completed an individualized course, either in high school or another college, tend to adapt more easily to the A-T graphics approach. Also, five years of observation have shown that students who have had at least one semester of technical drafting in high school tend to do better in A-T than students with comparable ACT scores who did not have a drafting course. Likewise most students who have taken their basic graphics course via the A-T approach at UND tended to re-enroll for the A-T descriptive geometry course, and they generally did better than those who completed their basic graphics course via L-L. The new hybrid design helps students with less experience in individualized instruction by offering them some familiar, more traditional ways in which to work. When they are ready for more freedom and flexibility it is available to a limited degree.

Minilectures

Another problem I have encountered with individualized instruction is that many students expect lectures because they are conditioned to learning that way. In fact, some do not feel that they are getting their money's worth if they cannot listen to lengthy lectures! Some even use the lack of lectures as a reason for failing. Also, many parents expect that when they pay so much tuition, their students are entitled to lectures -- and some demand them; they had to listen to them while in school so their children should have to do the same! After all, the technique worked then so why change it?

The answer to this problem has been to borrow a traditional teaching technique and deliver some shorter lectures, or "minilectures," sprinkling them in whenever there is a need for additional technical explanation or clarification. the term, "minilecture" vs. "lecture" has several positive aspects: (1) it is shorter in duration, (2) since it is shorter, it is probably less boring, (3) the term itself has a "modern" connotation, and is readily accepted by students.

Cost Effectiveness

Upon reviewing faculty teaching loads, based solely on student credit hours generated each semester, the statistics revealed that faculty members using the A-T approach were nearly 25% more productive per year than L-L colleagues. However, other factors are not as easily and readily measurable, such as the costs of purchasing and maintaining the audio-visual equipment, the life expectancy of said equipment, the costs of software generation (audio and visual tapes) and the fringe benefits paid to personnel. But in spite of these elusive areas, student credit hour loads indicate that a 25% to 40% savings should be possible for an institution over a ten-year period.

The A-T approach accommodates a much larger number of students, but to keep the attrition rate from becoming too undesirably high, it also requires a correspondingly greater number of qualified tutors and checkers. Therefore, much of the real savings is in the difference between the salaries required for student assistants and those required to engage professional faculty members who would otherwise be needed for the L-L sections.

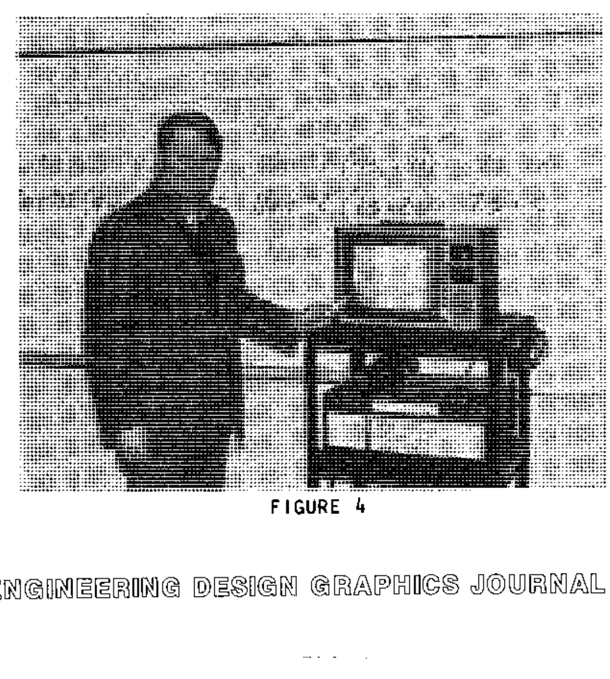

FIGURE 4

The lack of new qualified engineering graphics faculty who are willing to teach for the comparatively low salaries offered in academia is also an important economic consideration. Because of faculty shortages, it may be that in the near future the choice students presently have between the A-T or the L-L teaching approaches may have to be lifted purely for economic reasons. Institutions may be forced to utilize more student tutors and checkers just to keep their classroom doors open. The hybrid design might prove to be the best answer for getting the job done without sacrificing quality. In such a move toward semi-individualized teaching, administrators could easily justify higher salaries for a more productive faculty, plus an increase in the number of tutors.

New Directions Explored

Some universities and professors around the country have experimented with various methods of individualized instruction in engineering, and many have been quite successful. Individualization can work quite effectively in many more of the engineering classes, but the personnel involved must be willing to make the change and have the desire to make it work!

Trends indicate that future emphasis in basic graphics may be less on the "Techniques of technical drafting" and more on computer graphics delivery systems. Video-tapes used for the hybrid graphics approach can be combined with computer generated graphics illustrations and used in the classroom for demonstrations and minilectures. An added advantage is that video-tape equipment and computer graphics terminals located in study centers of dormitories, student unions, and libraries, add flexibility by permitting busy students to work after hours.

In areas of continuing education and TV delivery of technical subject matter, the potential for use of the hybrid approach is unlimited, except for economic constraints. At UND, the A-T individualized study approach is being used to a limited degree in the UND Division of Continuing Education for the engineering graphics and descriptive geometry correspondence courses. A wide educational TV network which would deliver engineering education to military bases, smaller colleges, hospitals, jails, and homes could be organized in much the same manner as the University of Mid-America Network. The technology is here, ideas are fresh, but money is limited.

Summary

The blending of the most desirable features of both A-T and L-L instructional approaches which has resulted in this new "medium range" hybrid approach continues to show much promise for the mid and late 1980's. Already we are seeing some cross-over students; many L-L students now use the A-T self-study center and some A-T students sit through lectures in L-L sections. Both A-T and L-L students work side by side, often borrowing learning techniques from each other and exchanging ideas about how to complete common assignments. Learning more responsibility and self-discipline are valuable fringe benefits for students who enroll in individualized courses.

The changes described above are occurring at UND not only because of research data, but also because of the practical problems involved in economically teaching traditional and computer graphics to a large number of students. Everyone involved is quite excited about it, and the teaching/learning struggle has been lessened to a considerable extent because of new directions and obstacles that have

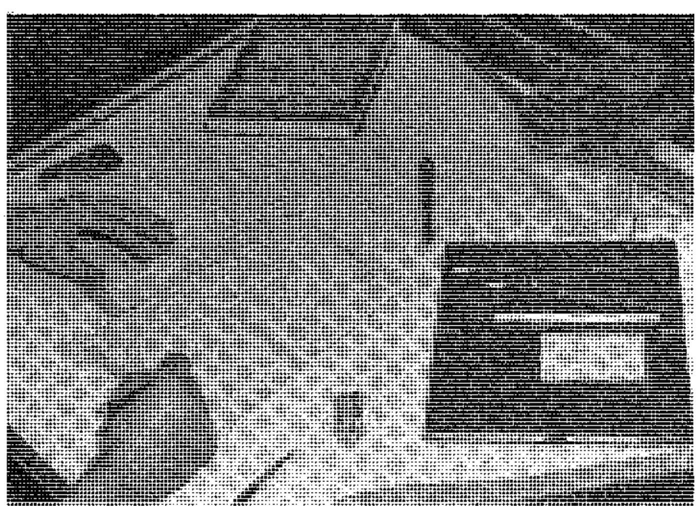

FIGURE 5

teacher. It is most important that this point be remembered because there is the danger that, with the use of audio-visuals and machines, the program may be expected to "run itself", and that rarely happens!

3. Learning is a very personal matter. The most important ingredients in A-T teaching and learning are the people involved: teacher, tutors, and students. The machines, tapes, slides, books, study guides, and drawing assignments are only tools which may help facilitate learning, but they were never meant to take the place of the teacher. The individualized design must permit the teacher more time to help those students who really need help.

I returned to my teaching duties at the University of North Dakota in 1978 and implemented the experimental A-T Graphics program for a group of 84 students. (The details and findings of that research were reported previously at the 1980 North-Midwest Section ASEE Annual Meeting, and are published in the proceedings of that conference under the title: "A-T Graphics at UND - An Individualized Approach"). Since that time over a thousand freshman engineering students have elected to study engineering graphics via the individualized route. The A-T graphics approach has met the test of time and is no longer considered experimental, but viable as a teaching approach. That does not mean, however, that it is without some problems, or that the L-L approach has nothing to offer. Many students continue to benefit from it, perhaps even more than some studying via the A-T approach. As a result of the on-going evaluation and student feedback some significant changes have been made in both the experimental individualized method and in the traditional L-L structured format during the past five years. An instructional design is now evolving which incorporates the most functional and desirable features of each teaching strategy in a manner complementary to both. The result is a new "hybrid" design which serves a larger variety of student needs.

Evaluating The Approach

A basic problem has been to measure the degree of effectiveness of two quite different teaching approaches, and the answers have not always surfaced quickly or easily. Statistical data for the evaluation was obtained by comparing grade point averages of basic graphics and descriptive geometry courses during the past five years. To determine which students may be more suited for the individualized approach and which should be advised to study via the traditional L-L format, I also compared attrition rates of students enrolled in both A-T and L-L sections. In an attempt to assess the cost effectiveness of each approach, I reviewed faculty teaching loads, class sizes, and counted students who had successfully completed the course via both routes.

More statistical data was obtained from a graphics questionnaire, circulated in the Spring of 1983. Responses were obtained from 394 students who had completed the basic engineering graphics and/or the descriptive geometry course at UND. Three upper level courses from each of the six engineering disciplines at UND were surveyed, providing a representative sample of students from the various majors and years. The fifty questions which were asked covered a wide range of topics relating to the effectiveness of both A-T and L-L teaching styles, as well as the degree to which each approach was enjoyed by the students.

Observations from colleagues also contributed to the evaluating. Not only have many of my colleagues in the School of Engineering and Mines been interested in and candid about what has been happening, but my peers from all around campus have also been supportive of the overall direction our graphics program has taken. Therefore, some of what I report are my personal "gut-level" feelings, the results of my experiences as the instructional designer, tempered by comments and reactions of both students and my colleagues.

Findings

Demographic Data: During the five year period that the A-T teaching approach has been used for engineering graphics and descriptive geometry at UND, 730 students successfully completed the basic course via the individualized route and another 281 received descriptive geometry credits via the A-T approach. During the same period, 567 students successfully completed their basic graphics course via the structured format, and another 291 received descriptive geometry credits via the L-L route. (See Figure 6)

GPA's Compared: From analyzing Figure 2, a five year comparison of the grade point averages for the basic graphics A-T and L-L students at UND, two significant findings are apparent. First, it is safe to assume that approximately the same amount of learning has been taking place in all classes. The 2.89 GPA for the A-T students as compared with the 3.03 GPA registered for L-L students is not a significant difference because the personal expectations and grading standards of different instructors and checkers vary somewhat. Also, most of the major examinations which were given to both the A-T and L-L groups have been identical for the past five years. The drafting plates assigned have also been the same. Therefore, it is safe to state that criteria for evaluations have been similar enough to rule out any significant differences in the amount of learning which took place.

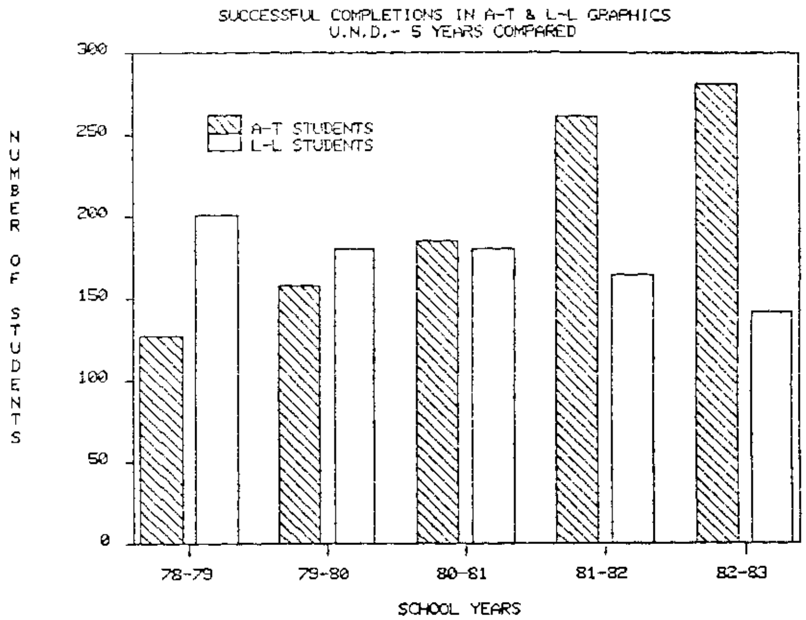

FIGURE 6

The second fact that can be gleaned from studying Figure 7 is that UND is experiencing a period of "grade deflation" in the basic engineering graphics course. In view of the high enrollments which have been experienced during the past three years this statistic is not alarming, but may even be viewed as a healthy sign, showing that the standards have not been relaxed.

Attrition Concerns: During the same five year time frame the attrition rate for each of the teaching styles was derived by combining the number of "W" grades and the "F" grades for each group. The results show an average attrition rate of 21.5% for all of the A-T sections compared to only 14.5% for the L-L sections. The overall attrition rate for both A-T and L-L courses was 18.4%, and the descriptive geometry courses consistently showed a 2% lower rate of attrition than the basic graphics courses. (See Figure 8)

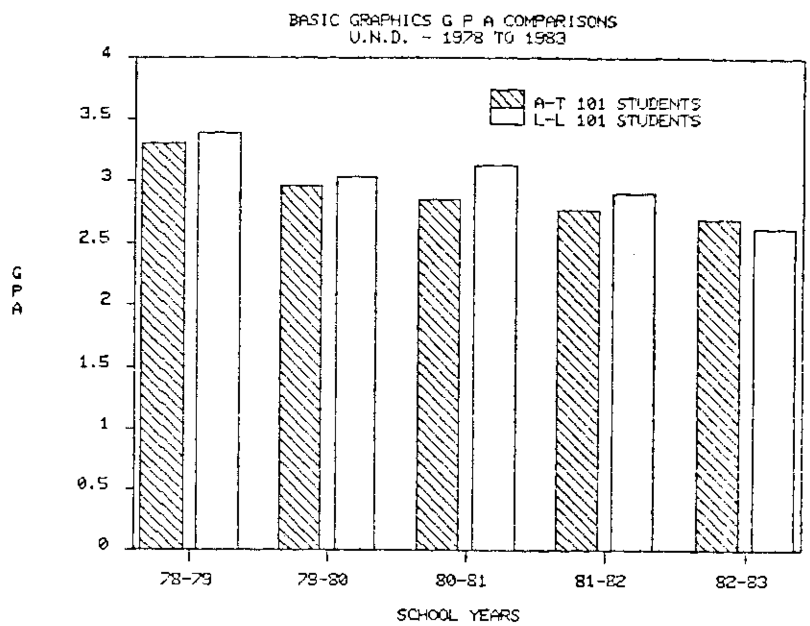

FIGURE 7

been overcome by using the hybrid approach. As more pragmatic changes are made in both approaches, the new hybrid design shows promise for improved yields with each additional school year as we move through the 1980 decade.

Many of my personal feelings about the typical expectations, limitations, frustrations and hopes of teachers are very aptly expressed in the poem "Small Gains" and it seems a fitting way to conclude. The poem was written by the late John R. Phillips, a Professor of English at Western Michigan University, and is printed with the permission of Mrs. Polly Phillips who still resides in Kalamazoo. I trust that your analysis of the philosophy provided will stimulate both animation and comfort as it has for me over the many years since I first read it.

Small Gains

Some workman faltered in the task; no hutch
Is small enough, no plan so Clear, no sight
So true that every Joint and plane falls right.
I eye The slit where porch slabs failed to touch:
One edge is three-eights high, The gap too much
To tolerate. I've Cleared the seam and stand,
A little Frustrated, wrong trowel in hand,
Aware that what I'm making is a crutch.

Who owns a house admits that he's a mug;
And so I brood, a greying college wit,
Revolving in my mind the lack of fit
In hourses, teaching, counsel--Till I shrug
It off and, working slowly, soothe my soul:
At least the Patch is better than the hole.

BIOGRAPHICAL NOTE

Professor Snortland has been teaching engineering graphics at the University of North Dakota since 1963. Prior to that date he taught technical drawing at the secondary school level in California and also worked as a detail and layout draftsman in the aerospace industry. His bachelors and masters degrees are in industrial education and were earned from the University of North Dakota. Post masters work includes a year at Kansas State University studying in the area of college student personnel work, a year at Purdue University studying educational technology and individualized instructional design and a workshop in Computer Graphics at the University of Texas.

instructor allocate time for testing keeping in mind an average student? (b) How does he know that the time limit set by him will be sufficient for the average student? (c) Is it a good practice to set time only for average students? (d) Can we motivate students by providing ample time for testing? (e) Are we making students think slow by providing more time to write the test?

In conclusion it can be said that testing time in education and especially in graphics education is an area open for investigation. It should be noted that testing time will also depend upon the mix of questions pertaining to various categories of Bloom's Taxonomy[3] on a specific test. Knowledge, comprehension, and application oriented questions would require less time than analysis, synthesis, and evaluation type questions. Although many questions, including the ones mentioned above remain unanswered, the author believes, the study conducted is surely a step in the right direction in determining time for testing students.

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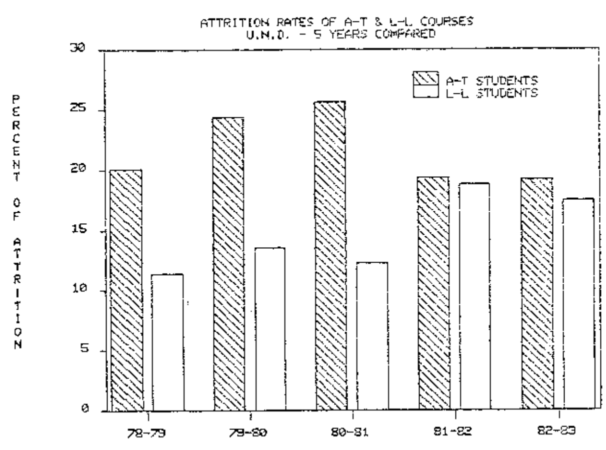

FIGURE 8

GRAPHICS

TANGENCY

Those familiar with the works of Gaspard Monge (1746-1818) will recognize the "Tangent Circles Problem" (Engineering Design Graphics Journal, Spring, '83) as one of the degenerate cases of Apollonius' famous tangency problem (see p. 154, Heinrich Dorrie's book, 100 Great Problems of Elementary Mathematics, Dover Publications, Inc., New York, 1965), to which Monge apparently devoted some attention. Using Gergonne's construction (see Dorrie, p. 160), the solution can be expressed in a single sentence:

> Drawing the chordal, y, and similarity axis, x, of points A and B, find power center O and pole P of x in relation to the given circle and A or B, following which the connecting line through P and O will cut the given circle at the two points, T_1 and T_2, at which it is tangent to the sought-after circles.

In somewhat greater detail, the steps used in the construction and the resulting figure are as follows:

STEP 1. Draw a line through points A and B, calling this line the x-axis. This line, according to the theorem of d'Alembert (Dorrie, p. 155), is the similarity axis of the given circle (call it C) and the two points A and B, each point A and B being looked upon as a degenerate circle.

STEP 2. Construct a line perpendicular to and bisecting the line segment AB, calling this perpendicular bisector line the y-axis. The two centers being sought (to be called C_1 and C_2, and from which eventually can be drawn the two required tangent circles) will each be located on this y-axis. Also, according to the theorem of the chordal (Dorrie, p. 153), this y-axis line is the chordal (or power line) of the two degenerate point circles A and B.

OBSERVATION: Because of symmetry, it is apparent that center c of given circle C can be transferred (using compass and straight-edge only) to its mirror position on either side of the y-axis. Also, the plane of the paper containing the problem can be rotated to whatever degree is desired. Therefore, without loss of generality, this problem can always be posed with center c located somewhere within the first quadrant of a conventional x-y plane, with the y-coordinate of c being taken greater than r.

STEP 3. To construct the chordal of the two nonintersecting circles C and A (degenerate) or C and B (degenerate), first draw an auxiliary circle, such as D, that cuts C and passes through one of the two points A or B. A line drawn through the two cut points is the chordal of C and D, whereas a line drawn tangent to D at the point A or B through which it passes is the chordal of D and that point. These two chordals intersect at point i in the accompanying figure. Now a line drawn through this intersection point and perpendicular to the line of centers (LOC) between c and B (or between c and A for the other point) is the desired chordal of C and that point.

STEP 4. Since the theorem of Monge (Dorrie, p. 153) states that the three chordals of three circles pass through a point known as the power center of the three circles, extending the chordal just constructed in STEP 3 to its intersection with the y-axis chordal line locates the power center, O, of the three given circles C, A (degenerate), and B (degenerate).

STEP 5. Pole point P is found as the conjugate (see Dorrie, p. 157) of base point I where a perpendicular dropped from center c intersects the similarity axis (x-axis).

STEP 6. A line drawn through power center O and pole point P will cut the given circle, C, at two points, T_1 and T_2. These are the tangent points where the two required circles, each passing through points A and B, will meet the given circle C TANGENTIALLY.

STEP 7. LOC's drawn through c and T_1, and through c and T_2, will locate on the y-axis the two sought-after centers C_1 and C_2, respectively.

STEP 8. Finally, with C_1 as center and length C_1T_1 as radius, the (larger) circle passing through points A and B, tangent to C at T_1, and containing C within, can be drawn. Likewise, with C_2 as center and length C_2T_2, as radius, the (smaller) circle passing through A and B, tangent to C at T_2, and exterior to C, can be drawn.

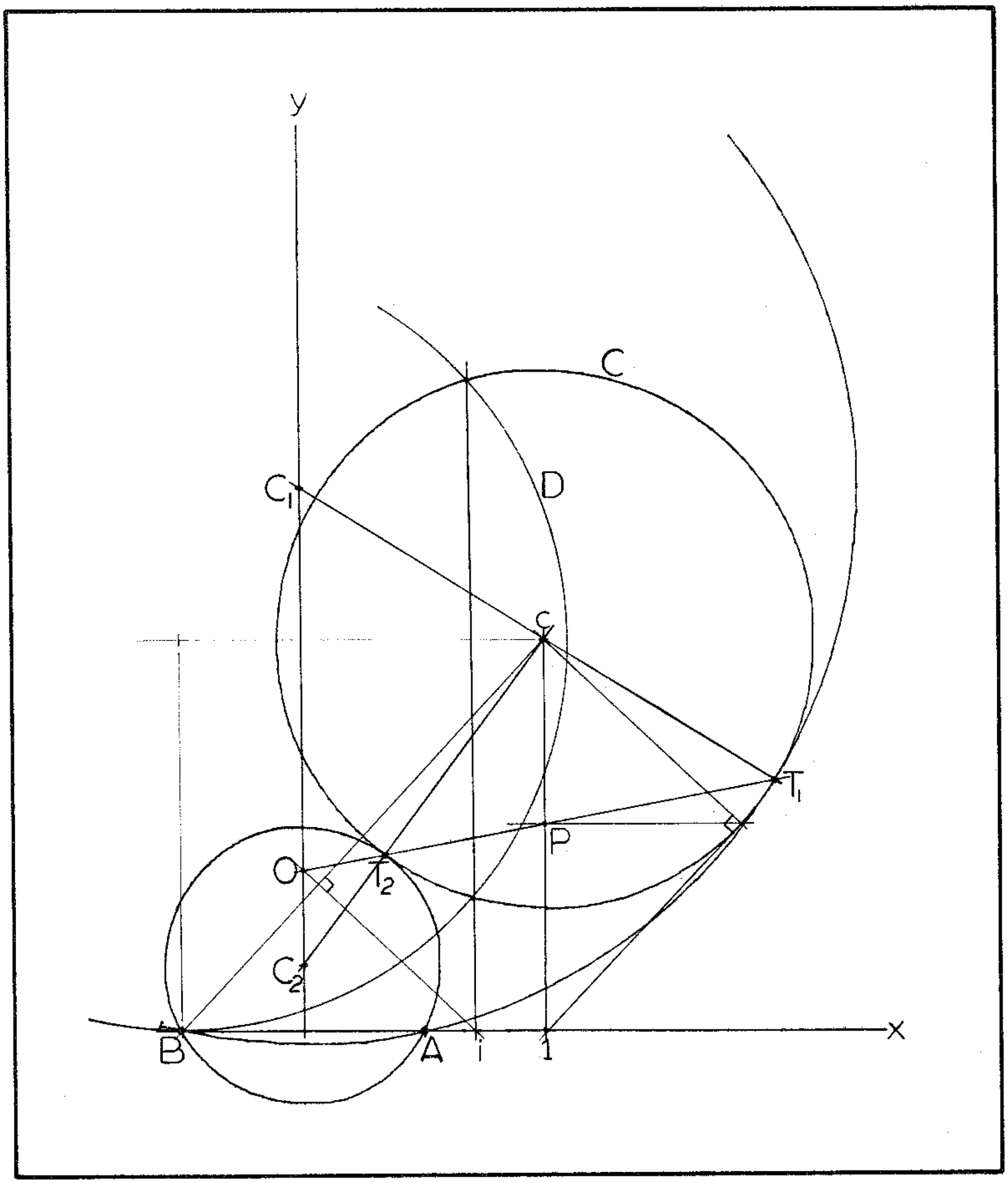

FIGURE 1

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Fundamentals

ENGINEERING ANALYSIS

TEACHING GRAPHICS FOR ENGINEERING ANALYSIS

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INTRODUCTION

The computer's impact on the theory, practice, and teaching of engineering graphics is reshaping engineering curricula today. Soon after World War II, engineers began to replace graphical methods of analysis such as descriptive geometry and nomography by applied mathematics. Engineering graphics usage became primarily limited to design documentation. However recently, engineering graphics again has become an integral part of the analysis process. Demonstrations include: applications of the finite element method to structural and thermal analysis; remote sensing and image interpretation; and analysis of fit, tolerance and mass properties. Graphics is now as much associated with engineering research as it is with engineering practice and so become a part of graduate study.

Engineers perform analysis and develop models by some combination of empirical and analytical methods. Empirical models are formulated from relationships between variables deduced from reducing experimental data. Statistical methods are used to isolate relevant information from background noise and formulate algebraic relationships between variables. The major drawback to empirical models is that their validity in predicting results of future experiments is limited to regions where experimental measurements have been made. For example, empirical models are impractical for predicting the conditions for failure of a bridge radically different from bridges presently in service. Analytical models, on the other hand, are based on governing relationships between variables that are usually formulated as partial differential equations valid over regions extending beyond that which is known experimentally. This means that analytical models can be used to predict the behavior of structures that have a design departing radically from past designs. The weakness of analytical modeling is that closed form solutions exist only for models with simple geometry, material properties, and boundary conditions. If any one of these is complex, numerical solutions must be obtained.

Before the widespread availability of digital computers, most engineering models were either empirical or semi-empirical. This is because most engineering problems have complex boundary conditions, complex geometry and complex material properties. Hand calculations using numerical methods are too tedious to be used for any but an extremely limited number of problems. Numerical methods were first extensively used in the aircraft industry where the social consequences of design failure justified the cost. As a result of the decreased cost of computing, this has dramatically changed. Numerical methods, especially the finite element methol are being widely used. Last year, for example, one of my industrial colleagues used the finite element method to analyse stress contours in a bathtub.

Digital computers have also dramatically altered the techniques of empirical modeling. Statistical methods for isolating relevant data from background noise are now being used to reduce enormous quantities of digitally recorded information. Using these methods, image enhancement software produces images recognizable by humans from data which has no easily recognizable patterns. Pattern recognition software identifies features that would be otherwise lost in a sea of irrelevant information. These techniques make possible empirical models of

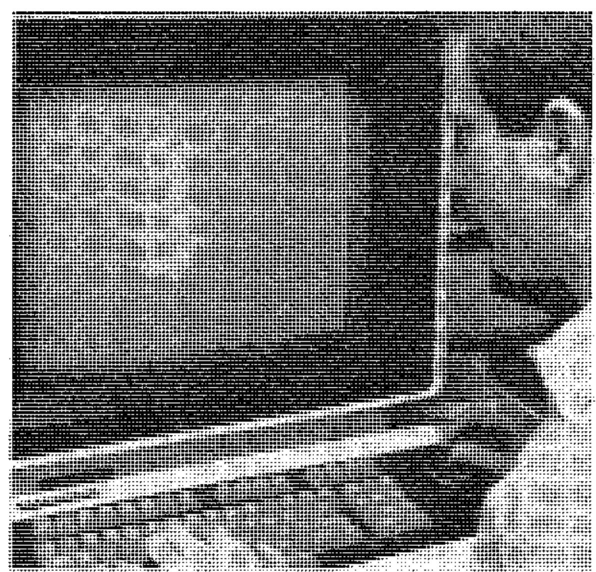


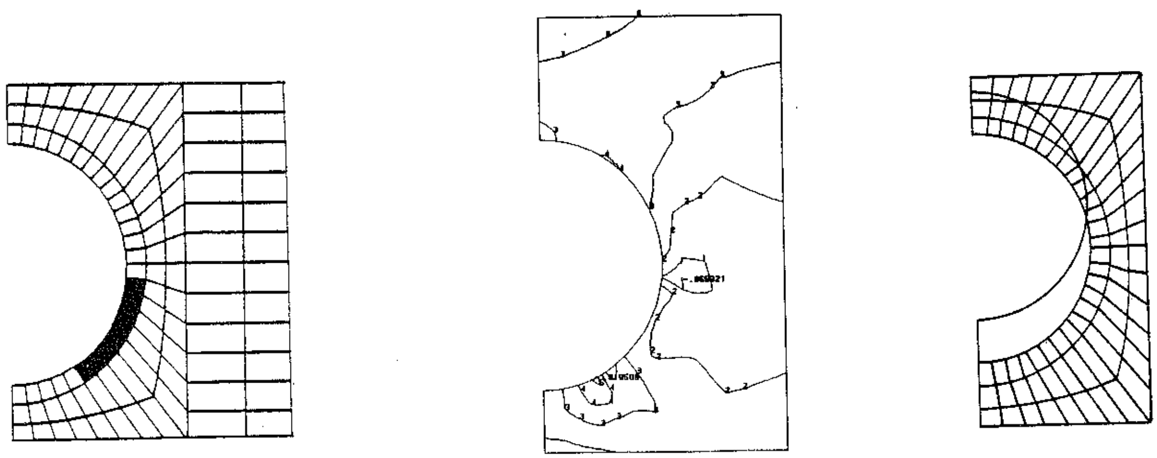
FIGURE 1

A model of a Bridgeport milling machine is displayed on the graphics system students developed as part of their study of graphics for engineering analysis. In creating this system, students wrote a device driver linking PADL-2 solid modeling software, running on a VAX 11/750 minicomputer, to a Lexidata 2410 color graphics terminal.

phenomena once too complex to be understood.

Graphics has become a part of both analytical and empirical methods by creating a wide and rapid communications channel between human and the machine. Using modern graphic systems, engineers can view 3-dimensional by rotating, translating and magnifying the projection of the model on the graphics terminal. Color, highlighting, and shading facilitate visualization of shape. Color also serves as a fourth dimension to display the results of analysis, or to code parts. Animation is a natural way to display models of time dependent phenomena.

When using analytical methods, engineers begin by creating geometrical models using interactive graphics application programs. Analysis software which accesses the model's geometric data base is then used to evaluate mechanical, thermal, or electrical response of the modeled system to applied boundary conditions. With access to this same geometric data base, graphics software can be used to interactively display numerical results from analysis in a variety of ways including color contouring and animation. Interactive display of results allows to the analyst to evaluate assumptions made during model creation and revise the model so that it more closely approximates the physical system under analysis. Anyone who has tried to assimilate pages and pages of numerical results from finite element analysis appreciates the use of graphics in model evaluation.



Finite Element Model of Culvert System

Maximum Principal Stress

Distorted Geometry

FIGURE 2

Laboratory exercises for the course sequence on graphics for engineering analysis included evaluation of finite element mesh generation schemes. One student used a culvert subject to gravitational loads from surrounding soil as a test case for the evaluation. Weak soil elements were included to evaluate the mesh geometry's effect on the model's response to discontinuities in material properties. Maximum principal stress on the culvert system is displayed as stress isobars. Displacement of the culvert system with weak soil elements is displayed as distorted geometry.

Using empirical methods, engineers model systems by deducing relationships between variables from numerical measurements. Interactive display of the relationship between variables is even more important to empirical modeling than analytical modeling because of the judgement required in making empirical modeling assumptions. Graphics makes possible recognition of patterns in data that would go undetected when evaluated by non-graphic methods. For example, evaluation of features on the earth's surface using reflectance measurements recorded from satellites would be nearly impossible without graphics.

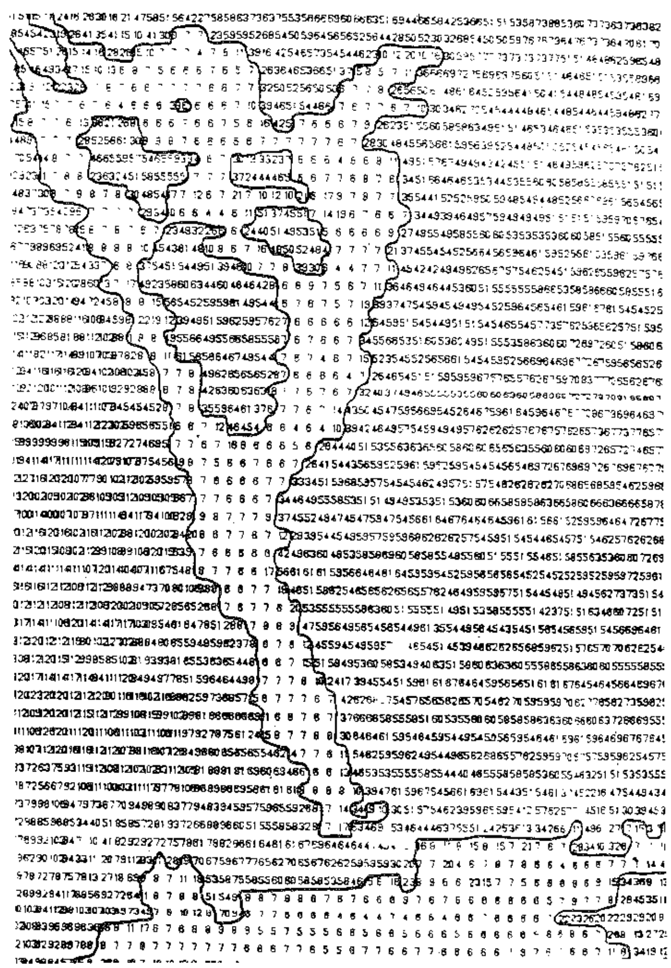


FIGURE 3

Digital reflectance measurements of the earth's surface recorded by satellites are displayed numerically. Graphical identification of the discontinuities in the reflectance measurements is used to identify features on the earth's surface.

COURSES IN GRAPHICS FOR ENGINEERING ANALYSIS

Recognizing that graphics had become an important part of engineering analysis and as such an essential part of graduate study, we began developing graduate curriculum in graphics during the 1982 - 83 academic year (1). The first product of this curriculum development was two courses that presented the analytical capabilities of computer-based engineering graphics to advanced undergraduate and graduate students.

These courses objectives were the following: development of skill in interactive graphics programming; experience in using commercial graphics systems for engineering design and analysis; ability to evaluate graphics systems performance with respect to a specific engineering or scientific function. These objectives were achieved through a series of laboratory and field projects.

In the first course, students learned to write two-dimensional interactive graphics application programs using a FORTRAN addressable graphics code. Students learned about graphics systems by interviewing engineers using graphics in their work and by preparing technical memos based on these interviews. Laboratory projects were assigned to give students experience in working with commercial graphics systems and to develop skill in graphics application programming.

In the second course students learned advanced graphics application programming and analyzed several commercial graphics applications programs and "turn-key" systems. For example, as a class project students used PADL-2 (2), a solids modeling language, to develop a graphics system. For this they wrote a graphics application program using PADL-2, FORTRAN77, and DCL (command language for Digital Equipment Corporation's VAX 11/750 operating system), and linked a Lexidata 2410 high resolution color graphics terminal to a Vax 11/750.

During the first offering, theory was intermeshed with application. Student comments revealed that the opportunity to code a device driver and write basic graphics application programs gave them a detailed understanding of the subject matter and the confidence to use what they had learned in their graduate research. Students also said that understanding the theory and the algorithms underlying graphics application programming was important to their successful use. Small enrollment permitted tailoring of the courses to meet individual needs. However, as the number of students requesting enrollment in the courses increased, we recognized the need for a better definition of the scope of graphics for engineering analysis as well as an understanding of how this subject meshes with the engineering curriculum.

CURRICULUM DEVELOPMENT

As I began to search literature, interview engineers using graphics, and talk to developers of graphics systems, I realized that graphics for engineering analysis is found in many academic disciplines and is rapidly expanding in all engineering fields. In order to catalogue the work, I segregated theory from application. Applications were divided into three categories: graphics for analytical model building, graphics for empirical model building, and graphics for simulation display.

finite method is widely used

Graphics Applications

Graphics that are used to help engineers reduce data and formulate empirical models has become important for image analysis. Engineers from a multitude of disciplines utilize image analysis. Civil reduce remote sensing data using image analysis. Metallurgists analyze electron micrographs of crack propagation in metal parts. In addition to static two dimensional image analysis, three dimensional and dynamic image analysis is becoming important in biomedical engineering. Analysis of X-ray and ultra-sound scans of the human body is used to detect tumors or developmental deficiencies in unborn babies. Dynamic image analysis helps engineers understand time dependent phenomena such as beach erosion or accelerated motion of fluids.

An important illustration of image analysis may be found in the broad area of remote sensing by satellite. Engineers are able to gather vast amounts of data for the earth's surface using multispectral scanners on board satellites. The scanners record reflectance "signatures" of the earth. Each measurement contains reflectance information for a section on the ground in several wavelength intervals. Software has been developed which is capable of correlating digitally recorded reflectance data from the satellite with known ground features such as water and foliage.

Displaying digitally recorded reflectance signatures is an essential part of remote sensing data analysis. Color contours of reflectance isobars, for example, have proven highly effective in aiding engineers to develop empirical terrain models. Identification of mineral deposits by remote sensing techniques, for instance, have decreased the financial risk of oil exploration (3).

Geometric models are a necessary part of all analytical modeling. Used alone, geometric models have aided in the design and analysis of such diverse structures as three dimensional integrated circuits and chemical plants by permitting engineers to easily identify interferences. Geometric modeling has dynamic as well as static applications. Mechanical engineers use geometric models for mechanical simulations of motion especially robotics. Geometric models are also used to create valid geometric data bases for numerical analysis.

The finite element method has become a widely used means of numerical analysis. The graphics for finite element analysis has become so intermeshed with the analytical method it supports that it has become part of the analytical technique. The finite element method's strength lies in generating numerical solutions to problems with complex boundary conditions and material properties. For example, to analyze the stress distribution in a culvert, the culvert drawing is subdivided into a mesh of small elements and each element in the mesh is analyzed. The solutions at the boundary of adjacent elements are matched at a finite number of discrete points. The analyst can control solution accuracy by altering the mesh's design. To achieve the optimum solution, the analyst must visualize the model's geometry and display numerical results. For structural analysis, this is done by interactive display of stress contours and distorted geometry superimposed on the mesh.

Display of numerical results is not only essential for effective finite element modeling but is an important part of all analytical and empirical engineering modeling. Without graphics it is nearly impossible for humans to assimilate a multitude of measured or calculated numerical results. For example, Figure 2 shows lines of constant maximum principal stress and distorted geometry resulting from a soil gravitational load on a culvert. Using interactive graphics, the analyst can identify regions of stress concentration and redisplay magnified views of these regions to evaluate the structure's behavior in detail. As another example, Figure 3 shows discontinuities in reflectance "signatures". These discontinuities outline ground features making them easy to identify.

Advances in graphics displays and a dramatic lowering in the cost of computer memory give promise of color and animation's common use in tomorrow's display of simulations. Color can be used as a forth dimension in mapping numerical results on three dimensional surfaces. This is commonly done by displaying color isobars. Animation is a natural means of displaying simulations of time dependent phenomena.

Graphics Theory

During our first offering of courses in graphics for engineering analysis, students had the opportunity use a variety of commercial graphics systems. The students found that understanding the theory and algorithms underlying graphics application programs was important to understanding these systems and ultimately to their successful application. However, in our first offering of these graphics courses, theory was presented in bits and pieces. We needed to better define the bounds of the theoretical basis of graphics for engineering analysis. Part of the theory pertinent to computer graphics is also relevant to engineering graphics but other areas such as theories of tolerancing also should be included. We have formulated the following partial list of eight theories that underly graphics used for engineering analysis.

1. Theories and algorithms for development of pattern recognition software are important to the development of software to analyze images (4).

2. Statistical techniques for enhancing images are the basis for human interpretation of scattered optical data (5).

3. The central features of modern graphics systems are communicating graphic information between human and machine and managing a geometric data base shared between many processing programs. The first method of managing geometric data bases was pre- and post-processing. Now algorithms for managing geometric data directly are being developed so that the inefficiencies of pre- and post-processing can be eliminated (6). Graphics language development is important for the interface between human and machine. C. Fritsch (7) of Bell Laboratories found that graphics languages were far superior to text command languages used in interactive graphics application programs.

4. Core graphic representations of objects is the basis for geometric modeling. This field includes algorithms for graphics primitive representations as well as algorithms for creation of sculptured objects, solids bounded by quadric and toroidal surfaces (8).

5. Theories of tolerancing are important to geometric modeling. Tolerancing is the link between mathematical models where surfaces are defined exactly in space and engineering models where surfaces are approximated within the limits of the design. Presently tolerancing is imprecisely defined and relies on engineering judgement. The ambiguities of present tolerancing theories must be eliminated before algorithms to incorporate tolerance in computer graphics can be formulated (9).

6. Graphics application program development is an area that includes program structure, user interaction, and application dependent algorithms such as finite element mesh generation (10).

7. Some aspects of computer display graphics are also important to understanding analytical graphics. These include: screen control by panning, zooming, and paging; editing features; and graphic input.

8. Understanding of graphic devices and their operation is necessary for critical evaluation of graphics systems. This area includes system architecture as well as operation of individual devices (10).

With the subject of graphics for engineering analysis more clearly defined, we turned our attention to effective teaching. Since students responded favorably to the mix of theory and practical experience presen in the first offering of the course sequence we plan to continue this basic approach to teaching in subsequent offerings of the course sequence on analytical graphics. However, we plan to introduce a variety of new projects and change the presentation of old projects to find ways to teach more effectively.

CONCLUSIONS

Computer technology made practical the application of numerical methods to engineering analysis in the 1960's. Today, low cost digital display technology is making practical graphics' inclusion as an integral part of engineering analysis. A dramatic example is the full color, interactive creation of finite element models using graphics applications programs such as SDRC's SUPERTAB and PDA Engineering's PATRAN-G.

Experience in the use of graphics for engineering analysis and understanding of the theories underlying this discipline are becoming an essential part of an engineer's education.

Faculty in the Department of Engineering Graphics at The Ohio State University have begun teaching graphics for engineering analysis to advanced undergraduate and graduate students. The development of courses in graphics for engineering analysis was challenging because the theory and practice of this important and rapidly growing aspect of engineering graphics it are found as a part of many diciplines. In defining the discipline of graphics for engineering analysis we identified eight topics underlying the theoretical development of this discipline: pattern recognition, image enhancement, data base management, core graphics for geometric modeling, tolerancing, graphics application programming, digital display technology, computer architecture.

It is essential that we begin to incorporate new graphics in the engineering curriculum at all levels. Some aspects of graphics for engineering analysis can be taught at the entry undergraduate level, but others must be postponed Until students attain sufficient understanding of numerical methods to use interactive graphics as an integral part of analysis.

It is our expectation that the addition of graphics to the graduate curriculum at The Ohio State University will give our graduates the knowledge, skill, and confidence to use graphics for engineering analysis throughout their career and expand the technology in this vital area.

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