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CONTRIBUTED PAPERS

ENGINEERING DESIGN GRAPHICS DIVISION
AMERICAN SOCIETY FOR ENGINEERING EDUCATION

*** COMPUGRAPHICS 91 ***
First International Conference on Computational Graphics and Visualization Techniques

September 16-20, 1991 - "Villas de Sesimbra" - Sesimbra, Portugal
*** in cooperation with ACM SIGGRAPH ***

Conference Scope, Objectives, and Structure

"COMPUTATIONAL Graphics" is an emerging scientific area which combines traditional and COMPUTER Graphics, Technical Drawing, Descriptive Geometry, Computational Geometry and Geometric Modeling. The present conference aims at gathering together outstanding experts, leading researchers, scholars, engineers, scientists, industrialists and all interested individuals in these interrelated fields. The event, the actual first and truly international meeting on "Computational Graphics", is designed to be a large forum for everyone involved, materialized by high-level lectures, papers, and panels, and is intended to be a unique opportunity to discuss the present situation, future directions, research and educational goals. It will lead to a thorough definition and solidification of the discipline and will provide the needed fertilization of ideas and experience.

A number of keynote lectures by especially invited speakers is being prepared to reinforce the overall goals of the event. Confirmed speakers include: Varol Akman, Vera Anand, Joao Cunha, Alain Fournier, Jon Meads, Bob Parslow, Les Piegl, Judson Rosebush, Steve Slaby, Jorge Stolfi, and Daniel Thalmann.

A parallel exhibition of equipment, software, and literature will take place and special demonstrations are being planned, including a slide, film, and video show. Participants are encouraged to bring material of all kinds (publications, audio-visual items, books, etc.) to be displayed. Delegates' software are especially welcome and demonstrations can be arranged.

Contributions and Deadlines

High-quality papers are solicited in, but not restricted to, the following topics:

- Traditional Graphics and Descriptive Geometry
- Engineering Graphics and Computerized Drafting
- Theoretical Graphics and Classical Geometry
- Computer Graphics and Image Synthesis
- Computational Geometry and CAGD
- Geometric and Solid Modeling
- Computer Aided Design and Manufacturing
- Finite Element and Other Numerical Methods
- Scientific Visualization and Supercomputing
- CAD and Engineering Design
- Artificial Intelligence and Expert Systems
- Computer Assisted Instruction and Education
- Standards and User-Interface Methodology
- Physically-Based Modeling and Animation
- Natural Scene Simulation and Fractals

- Authors are invited to submit 5 copies of a summary (preferably extended abstract) by May 3, 1991.
- Notice of acceptance will be given by May 31, 1991.
- Final papers will be due by July 31, 1991.

The Program Committee will select the best papers and will invite the authors to submit revised versions for a planned book to be published by Springer-Verlag.

Contact

Summaries, full papers, and requests for further information should be addressed to:

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Geometric Dimensioning Sentence Structure

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Many mechanical drawings have been dimensioned with the concepts and practices of geometric dimensioning and tolerancing. Complex relationships can sometimes make learning geometric dimensioning and tolerancing a difficult process. However, having the ability to read and speak the geometric dimensioning language is an increasingly important factor for employment in many positions in engineering and technology. One way to start learning the system is to learn how to interpret the dimensioning symbols.

Introduction

Geometric dimensioning and tolerancing (GTD) is an indispensable component of the mechanical drawing. For the parts that require GDT, it can mean a clearer expression of the intent of the design. It can also allow better choices of machining processes to be made for the production of a part and can better indicate how a part should be inspected. In other words, it can vastly improve communications in the cycle from design to manufacture.

However, GDT can be a difficult topic to learn and teach due to the potentially complex relationships within and between different geometric tolerances. A part of the difficulty is being able to interpret the geometric dimensioning symbols. Most of the current textbooks that deal with GDT present information about the symbols, but few present information on how to put the words for the symbols together to form a sentence. Explanations will be provided to assist in the instruction of the basic sentence structure of geometric dimensioning by identifying the substantive language within each compartment of the feature control frame (FCF). Then words will be provided that can be used to connect them. A majority of the information to be described has been derived from experience and the given references[1-5].

The Problem

It may be a formidable task to look at the FCF in Fig. 1 and (a) know what is being specified and (b) know how to relate that information to another person. Luckily, not all geometric tolerances have that many variables. A beginning step to learning GDT is to think of the information in the FCF as the substance of a basic sentence. Then, with a good memory of the symbol names and the information to be presented,

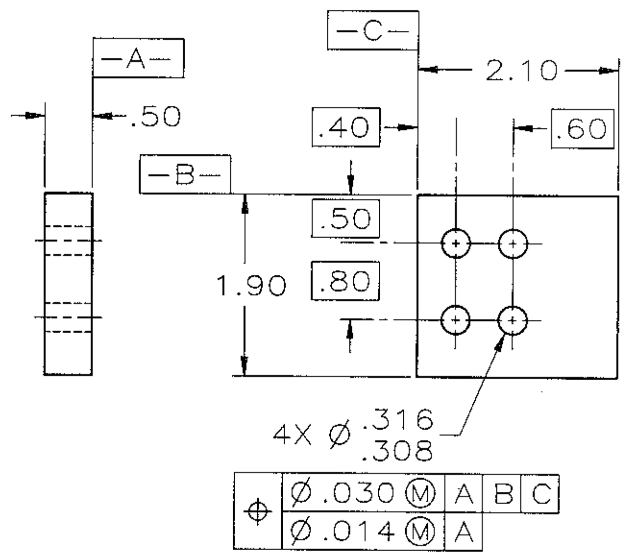

Figure 1. Geometric dimensions.

plus some practice, any person should be able to read what is in the FCF in Fig. 1.

Table 1 contains the names of all the symbols that may appear in an FCF. Remembering the symbol names can be a good beginning in learning how to read the contents of the FCF. But to be able to fully comprehend what is read, the following must be understood: the type of tolerance specified, the type of tolerance zone, the tolerance meaning, and the potential uses. Only the reading of the contents of the FCF will be described.

Before describing the methods of reading the FCF, it is important to understand that the specified tolerance is being used to precisely control the form, orientation, and location of plane or size features. Sometimes changes are made IN the way regular dimensions are drawn. For example, a dimension with a rectangular box around it is a "basic" dimension. This dimension does not give size; it only gives the location of a tolerance zone.

SYM	SYMBOL NAME
—	STRAIGHTNESS
⏥	FLATNESS
○	CIRCULARITY
⌭	CYLINDRICITY
⌒	PROFILE OF A LINE
⌓	PROFILE OF A SURFACE
//	PARALLELISM
∠	ANGULARITY
⊥	PERPENDICULARITY
↗	CIRCULAR RUNOUT
⌰	TOTAL RUNOUT
◎	CONCENTRICITY
⌖	POSITION
Ø	DIAMETER
Ⓜ	MAXIMUM MATERIAL CONDITION
Ⓢ	REGARDLESS OF FEATURE SIZE
Ⓛ	LEAST MATERIAL CONDITION
Ⓟ	PROJECTED TOLERANCE ZONE

Table 1. Geometric symbols.

Beginning Solution

The FCF is divided into two or more compartments. Figure 2(a) illustrates that the first compartment contains the geometric characteristic symbol. The second compartment contains the tolerance information. Additional compartments would contain datum references. These are the variables within the basic sentence structure.

The first descriptive words relate to the feature. For example, a common introductory phrase is, "THE FEATURE MUST BE" (Fig. 2(b)). The lines dividing the compartments indicate where the connecting words are used. The

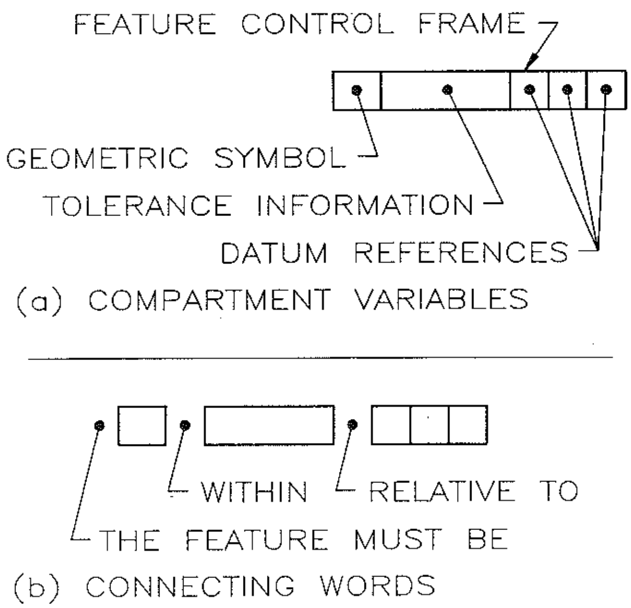

Figure 2. Feature Control Frame.

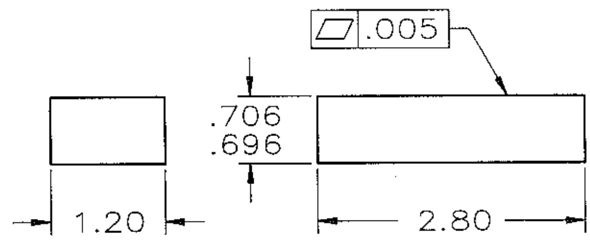

Figure 3. Flatness tolerance.

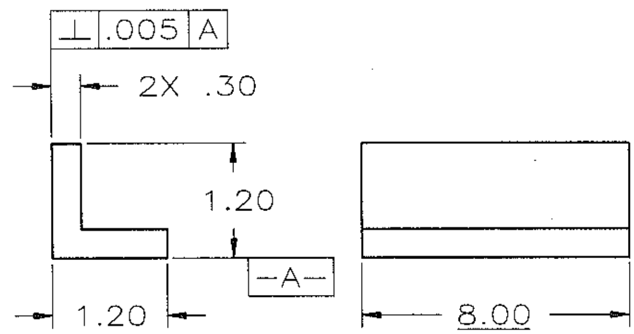

Figure 4. Perpendicularity tolerance.

first connecting word is "WITHIN". The words for the second connection are "RELATIVE TO". These three phrases can remain the same for all geometric callouts, except for a few examples.

Combining the Words

Armed with this information, the simple flatness tolerance specified in Fig. 3 can be read, "THE FEATURE MUST BE FLAT WITHIN A FIVE THOUSANDTHS TOLERANCE ZONE". The statement included an introductory phrase (the feature must be), the geometric characteristic (<u>flat</u>ness), the first connecting word (within), and the tolerance value (0.005). The form tolerances require only two compartments in the FCF.

A datum reference is included in the FCF in Fig. 4. The statement for this tolerance may be, "THE FEATURE MUST BE PERPENDICULAR WITHIN A THREE THOUSANDTHS TOLERANCE ZONE RELATIVE TO DATUM FEATURE A". This statement included an introductory phrase (the feature must be), the geometric characteristic (<u>perpendicular</u>ity), the first connecting word (within), the tolerance value (0.003), the second connecting words (relative to), and the letter of the datum feature (A). Many geometric tolerances are controlled relative to one or more datum features.

Due to the unique characteristics of the profile tolerances (line and surface), the introductory statement is usually different. Also, it is fairly common for the tolerance to be specified between points. The geometric tolerance in Fig. 5 may be read as, "EACH FEATURE LINE PROFILE MUST BE WITHIN A TEN THOUSANDTHS TOLERANCE ZONE RELATIVE TO DATUM FEATURES A AND B BETWEEN X AND

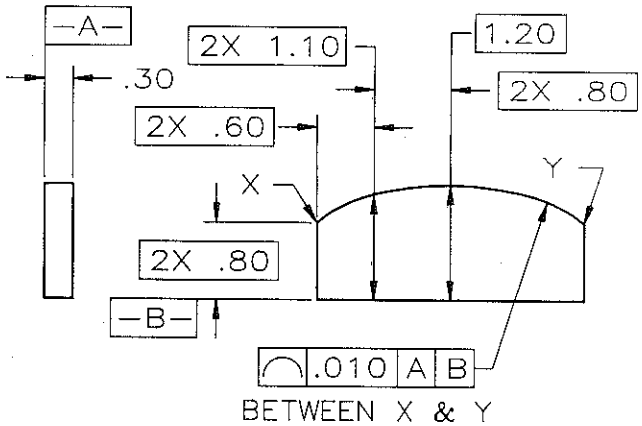

Figure 5. Profile tolerance.

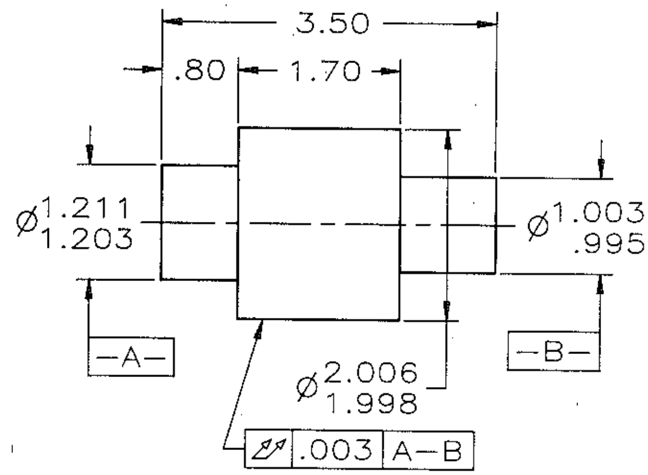

Figure 6. Runout tolerance.

Y". Here the word for the geometric characteristic is included in the introductory phrase. Profile tolerances can control irregular surfaces and as such are different in some ways from the other geometric characteristics.

The example in Fig. 5 also reveals that when additional information in needed for complete understanding of the tolerance, that information if printed below the FCF. If the information is lengthy, a reference to an explanatory note is given.

The proper geometric call-out for Runout can also be slightly different from the other call-outs. The example of Runout shown in Fig. 6 has a multiple datum. This tolerance controls a surface of revolution relative to two bearing surfaces that together form an axis of revolution for the part. The sentence for the example in Fig. 6 may be, "THE TOTAL RUNOUT OF THE FEATURE MUST BE WITHIN A THREE THOUSANDTHS TOLERANCE ZONE RELATIVE TO MULTIPLE DATUM A, B".

The American National Standard Institute Y14.5M-1982 Dimensioning and Tolerancing Standard has specified that when using Position tolerancing, condition modifiers must be stated for the tolerance value and for any size datums. Therefore, the maximum material condition, least material condition, and regardless of feature size symbols are used primarily with the position tolerancing (refer to Table 1 for the symbols). The diameter symbol is also used primarily with position. Some of the sentences for position can be very long. The tolerance in Fig. 7 can be read as, "THE FEATURES MUST BE POSITIONED WITHIN FIFTEEN THOUSANDTHS DIAMETER TOLERANCE ZONES, AT MAXIMUM MATERIAL CONDITION, RELATIVE TO DATUM FEATURES A, B, AND C".

Figure 8 illustrates an example where the position tolerance and datum are controlled regardless of feature size. The sentence for the geometric call-out in Fig. 8 may be, "THE FEATURE MUST BE POSITIONED WITHIN A FOURTEEN THOUSANDTHS DIAMETER TOLERANCE ZONE, REGARDLESS OF FEATURE SIZE, RELATIVE TO DATUM FEATURE A, REGARDLESS OF FEATURE SIZE". The

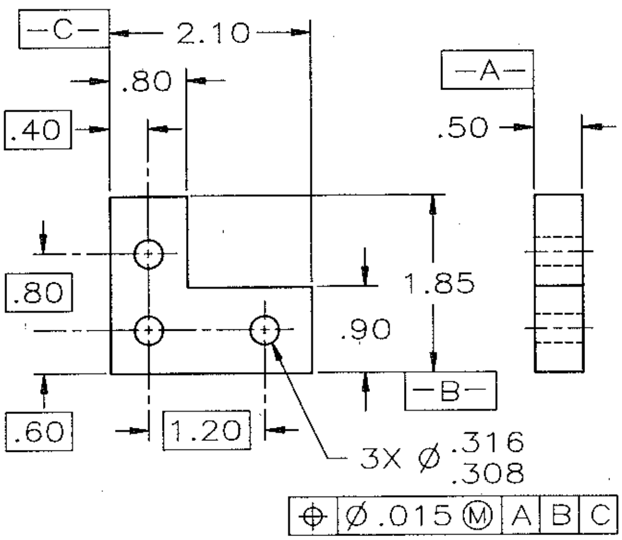

Figure 7. Position tolerance.

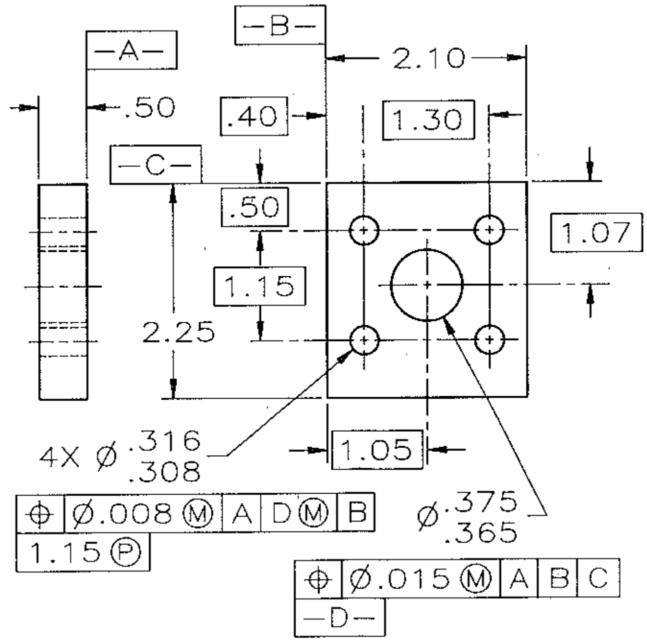

Figure 9. Projected tolerance.

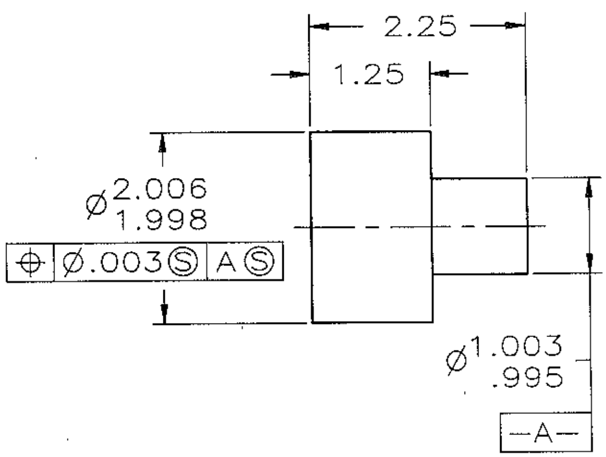

Figure 8. Position RFS.

material condition must be stated for each tolerance and size datum separately.

The example in Fig. 9 illustrates one large hole positioned relative to the three plane concept. The hole then is used as a datum to help locate the four small holes. The four holes are also controlled within a projected tolerance zone. This tolerance zone can be read as, "THE FEATURES MUST BE POSITIONED WITHIN ONE AND FIFTEEN HUNDREDTHS TALL BY EIGHT THOUSANDTHS DIAMETER PROJECTED TOLERANCE ZONES, AT MAXIMUM MATERIAL CONDITION, RELATIVE TO DATUM FEATURES A, D AT MAXIMUM MATERIAL CONDITION, AND B".

Feature Control Frames with Two Lines

With the understanding of the variables and constants of the geometric dimensioning system, the previous few instructions will suffice for most one line geometric tolerances. Occasionally, two or more different geometric characteristics must be specified for the feature. The second line tolerance is usually thought of as a "refinement" of the first line tolerance. When this occurs, the word "AND" or "WHILE" is placed between the two tolerance sentences and the introductory phrase is removed from the second sentence. The tolerance in Fig. 10 could read, "THE FEATURE MUST BE CYLINDRICAL WITHIN A ONE THOUSANDTHS TOLERANCE ZONE AND STRAIGHT WITHIN A FOUR TEN-THOUSANDTHS TOLERANCE ZONE".

Composite tolerancing is a particular type of position tolerancing where a two line tolerance can occur. In composite tolerancing, the first line of the tolerance relates to all the features as a group. The second line of information is also a refinement of the proceeding tolerance. The example in Fig. 11, which is a copy of Fig. 1, is a composite tolerance. It may be read as, "THE PATTERN OF FEATURES MUST BE POSITIONED WITHIN THIRTY THOUSANDTHS DIAMETER TOLERANCE ZONES, AT MAXIMUM MATERIAL CONDITION, RELATIVE TO DATUM FEATURES A, B, AND C, WHILE THE FEATURE TO FEATURE RELATIONSHIP MUST BE POSITIONED WITHIN FOURTEEN THOUSANDTHS DIAMETER TOLERANCE ZONES, AT MAXIMUM MATERIAL CONDITION, RELATIVE TO DATUM FEATURE A". This represents one of the more complicated sentences in geometric dimensioning. This type of tolerance is often used with bolt hole patterns.

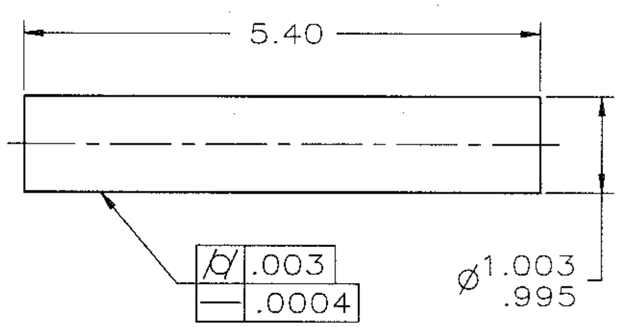

Figure 10. Two line tolerance..

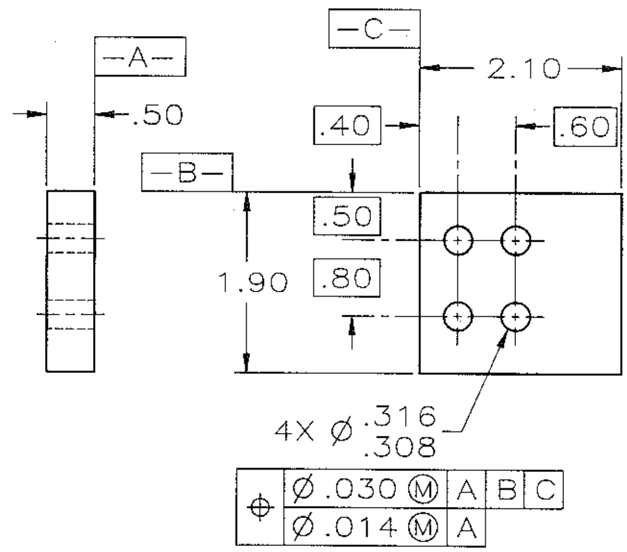

Figure 11. Composite tolerance.

Practical Concerns

By now an appreciation should have developed for the amount of space saved on the face of the drawing due to the use of the symbols in the geometric dimensioning system. Using this system increases the white space on drawings which improves readability.

Prior to the 1973 release of the Y14.5 standard, the use of geometric symbols on drawings was not common practice, except for the companies that developed the standard. Drawings of the past were, and still are, subject to misinterpretation due to the use of English words on the drawing. This situation has changed due to increasing international interaction which has forced the use of universally understood languages, such as geometric dimensioning. Also, the complexity of modern designs has given rise to a more precise language to explain them.

The engineering graphic language receives a relatively low priority in many engineering colleges in the United States. Therefore, it should not come as a surprise that GDT is rarely taught well in university courses. It is common for new engineering and technology graduates to enter the work place functionally illiterate of this essential communication system. This has removed a part of the basic engineering education from the university and forced it onto the industrial sector.

Conclusion

The geometric dimensioning and tolerancing language is a way of specifying precise feature form, orientation, and location. A beginning step toward learning GDT is to acquire the knowledge of how to read the information in the feature control frame. A reliable and consistent method of being able to form an English sentence with the information in the feature control frame of a geometric dimension has been presented.

The widespread use of GDT to precisely define the intent of a design from initial engineering activity through final verification makes it a vital link to the quality of the products produced in the United States. The education of the topic should not be left to chance. It should be a required part of the education of engineering and technology students.

References

[1]American National Standards Institute, "Y14.5M-1982 Dimensioning and Tolerancing", American Society of Mechanical Engineers, New York, NY, 1982.

[2]Foster, L. W., *Modern Geometric Dimensioning and Tolerancing*, National Tooling and Machining Association, Washington, DC, 1982.

[3]Foster, L. W., *Geo-metrics II: The Application of Geometric Tolerancing Techniques*, Addison-Wesley, Reading, MA, 1986.

[4]Marrelli, R. S., *Geometric Tolerancing: A Text-workbook*, Glencoe, Mission Hills, CA, 1984.

[5]Whitmire, G. and Swarthout, J., *Geometric Dimensioning and Tolerancing Simplified: In Compliance with ANSI Y14.5M-1982*, TAD Products, Beverly, MA, 1984.

A Comparative Study on the Effectiveness and Influence of Required Supplemental Video Teaching Upon Students' Grades, Course Completion, Visualization Proficiency, and Course Attitudes

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An experimental study was conducted on two groups of a students in an introductory engineering graphics class. One group (experimental) was required to watch thirty mini-video tapes presenting basic concepts of engineering graphics. The second group (control) was not allowed access to the video tapes. No differences were revealed between the groups for four hypotheses postulated.

Introduction

Since 1980, the author has experimented with an independent study course in beginning engineering graphics. The course topics included: (1) basic geometric constructions, (2) multiview sketching and drawing, (3) isometric sketching and drawing, (4) basic dimensioning, (5) sections and conventions, (6) primary auxiliary view drawing, and (7) detailed production drawings. Also included in the normal semester schedule of fifteen weeks were two formal quizzes and an examination. Although the six class sections used for the study were organized on an independent study format, all student work was graded immediately upon completion of each course topic and was assigned an A, B, C, D, or NC (no credit) grade. The quizzes and exam were similarly graded.

The basic concepts, procedures, and content of the course topics were video-taped. There were thirty mini-cassettes varying from nine-minutes to twenty-five minutes in length (Fig. 1). The video tapes allowed selected students to:

1. Receive additional supplementary help at their convenience.
2. Review the subject matter as much as necessary to master it.
3. Progress through more difficult topics at individual rates.
4. Visually reinforce subject material that had been read in the textbook.

Research Design

Six random class sections were selected to participate in a one-semester classroom research pro-

LIST OF VIDEO TAPES, E101
(Mini-Lectures)

Tape No.	Title	Plates
1a	Care and Use of Equipment	
2a	Points of Tangency and Alphabet of Lines	
2b	Scales; Combination	
2c	Scales; Metric	
3a	Introduction to 3-Dimensional Pictorial Sketching; Isometric	
3b	Isometric Sketching; Example Problem	6-7, 9-10
3c	Isometric Sketching; Example Problem	6-8 (Self Test)
3d	Sketching Ellipses and Example Problems	6-11 (Conics)
4a	Irregular Curves and Sections in Isometric	6-11(Bushing)
5a	Introduction to Multiview Drawing	6-8
5b	Space Dimensions and Multiview Variations	7-2
5c	Object Orientation and Line Identification	
5d	Surface Ident. and Alt. View Construction	7-5
6a	Alternate View Construction and Proj. Method	Self Quiz (1, 9)
6b	Example Problems; Explanation & Discussion	7-5 (1, 2, 4)
6c	Example Problems; Explanation & Discussion	7-6 (2, 4)
7a	Introduction to First Auxiliary Views	
7b	Drawing Partial Auxiliaries; Example Problems	8-4
7c	Curved Auxiliary Surfaces; Example Problems	8-4, 8-3
7d	Complete Auxiliary View; Example Problem	8-5 (Octogonal)
8a	Introduction to Second Auxiliary Views and Example Problem	9-1 9-2
8b	Example Problem; Explanation and Discussion	9-3
9a	Introduction to Sections and Conventions	
9b	Types of Sections	
9c	Conventional Practices	
10a	Conventional Practices (Con't.) and General Comments on Work Plates	10-1 10-2, 10-3
10b	Conventional Practices (Con't.) and General Comments on Work Plates	10-4
11a	Introduction to Basic Dimensioning and Dimensioning Standards	
11b	Dimensioning Practice; Example Problem	
12a	Industrial Dimensioning Examples	

Fig. 1 List of Video Tapes; Mini-Lectures

ject. Three of the sections were considered control groups and were denied access to the video tapes. The other three sections, the experimental groups, were <u>required</u> to watch <u>all</u> video tapes. At the beginning of the semester a system was developed between the main library Media Center and the instructor to allow only those students who presented a Video Tape Authorization slip (Fig. 2) to have access to the video cassettes. No control students were allowed to watch the tapes. Also, at the start of the

Video Tape Authorization

Student ______________________

Section Number __________

Tapes to be Reviewed:

________ ________ ________ ________

________ ________ ________ ________

________ ________ ________ ________

________ ________ ________ ________

Date ________ ______________________
Instructor's Signature

Date ________ ______________________
Signature, Media Center

Fig. 2 Video Tape Authorization Slip

Video Tape Memo
Graphic Communications, GC101
Dr. William J. VanderWall

Section __________

Subject: Graphic Communications, GC101 Video Tapes; Rules.

1. You must watch all video tapes on Graphic Communications, GC101, beginning with Tape 1a and ending with Tape 12a.
2. You must have a tape authorization slip signed by the instructor for all tapes viewed.
3. You must present the authorization slip to Media Center Personnel in order to check out and view tapes.
4. You must obtain the signature of the Media Center Specialist when you have viewed the tape(s) and return the signed authorization slip to the instructor in order to receive credit and complete the unit of work.
5. Video tapes will be on reserve in two different locations at the hours shown.

Main Library Media Center (Room 2305)

Mon. thru Thurs.	8 am-10 pm
Fri.	8 am- 6 pm
Closed Saturdays	
Sunday	1 pm-10 pm

Poe Hall Curriculum Materials Center (Room 400)

Mon. thru Thurs.	8 am - 9 pm
Fri.	8 am - 5 pm
Closed Weekends	

Fig. 3 Video Rules Sheet

semester the students of the experimental groups were given a Video Rule Sheet (Fig. 3), describing the procedures that would be followed in progressing through the course. Five major points were listed:

1. Each student would watch all video tapes beginning with tape 1a and ending with tape 12a.
2. Each student would have a Video Tape Authorization slip signed by the instructor for all tapes viewed.
3. The signed Video Tape Authorization slip would be presented to the Media Center specialist in order to check out video tapes and view them.
4. The Video Tape Authorization slip would be submitted with completed graphics work in order to receive credit for the unit of work. Each slip would also contain the signature of the Media Center specialist.
5. The location of the video tapes and the hours for viewing them were included: each day between 8 am and 10 pm except Saturdays.

Four null hypotheses were advanced concerning the required use of supplemental video tape instruction. It was postulated that there would be no statistically significant differences between experimental and control groups in the following areas:

1. Final numerical grades.

2. Number of students who (a) completed the course ahead of schedule, (b) completed the course on time, or (c) failed to complete the course, thereby receiving incomplete (IN) or no credit (NC) grades.
3. Visualization proficiency.
4. Student course evaluations.

Data Analysis and Findings

Hypothesis One

To test the hypothesis concerning group final numerical grades, all plate grades and quiz grades were recorded numerically. Section mean scores were calculated for plate grades, quiz grades, and final grades for each of the six sections. These section means were tested within the six sections and between the experimental and control groups by analysis of variance. The F-value and significance levels were calculated for all comparisons. No statistically significant differences were revealed in any of the comparisons. The data indicated that the difference among and between groups varied greatly. Hypothesis one was accepted.

Hypothesis Two

To compare the numbers of students in the experimental and control groups who (a) completed the course ahead of schedule, (b) completed the course on time, or (c) received incomplete (IN) or no credit (NC) grades for the course, it was necessary to calculate group means for each category (a, b, and c) for both study groups. No attempt was made to compare these mean scores between all six sections. No statistically significant differences were revealed between the groups on the three variables cited. Hypothesis two was accepted.

Hypothesis Three

To compare the visualization proficiency of the experimental and control groups, it was necessary to administer a pre- and post-visualization test[1] (Fig. 4). All tests were scored in total points. Points were received for the number of lines successfully drawn for each of the incomplete orthographic problems shown. Group means were calculated for all individuals and for the six sections based upon the pre- and post-visualization scores. These mean scores were tested by analysis of variance. F-values and significance levels were calculated for all comparisons. No statistically significant differences were found for any of the comparisons made between individuals, or within and among the experimental or control groups. According to the data analysis, the differences varied greatly for the different group comparisons made. Hypothesis three was accepted.

Hypothesis Four

Group course evaluation means were calculated to test hypothesis four concerning the way groups evaluated the course overall. The course evaluation scores were obtained from departmental Course and Instructor Evaluation forms, that were supplied to all instructors at the

Drafting Achievement Test

The following problems are designed to test your ability to solve problems using the principles of orthographic projection. There are three given views for each problem: the top, front, and right side. There may be lines missing in one, two, or three views. You are to sketch the missing lines in each view, both hidden and object. There is no time limit but work as fast as you can.

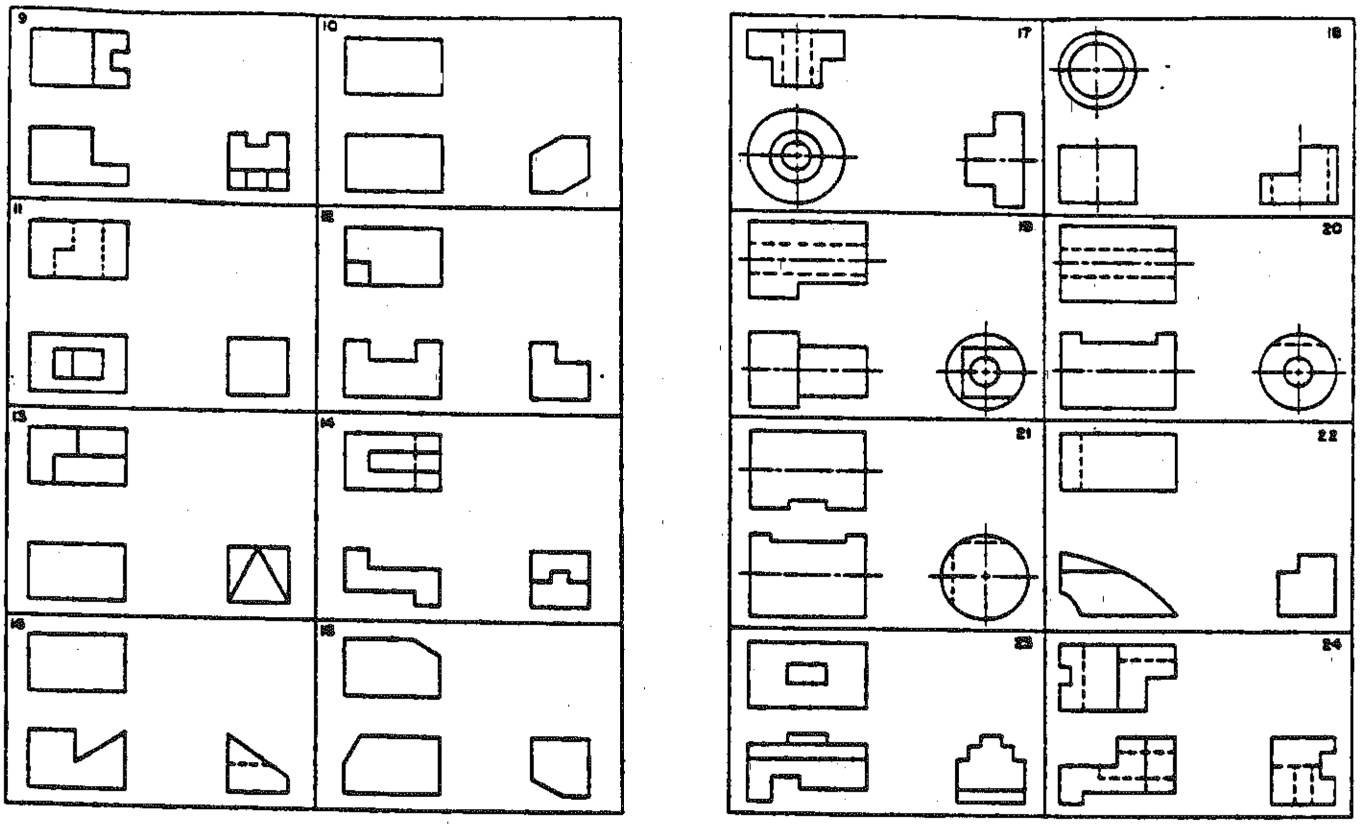

Fig. 4 A Portion of the Pre- and Post- Visualization Test

end of each semester. Each student was asked to evaluate the course by way of a rating scale on specific criteria: (1) objectives, (2) content, (3) textbooks, (4) reference materials, (5) requirements, and (6) other items the student considered pertinent. The group means were then compared by analysis of variance. No statistically significant differences were found for the course evaluations made by the groups. Hypothesis four was accepted.

Students' Reaction to Required Video Teaching

The students' reaction to required video teaching was both interesting and revealing. The comments which follow were taken from course evaluation forms completed at the end of the course by each student. Of course, not all students took the opportunity to react to required video teaching, but those that did made some very valid points. Listed are the most commonly made comments by at least two or more students and paraphrased here for clarity.

1. The Media Center is not designed for drawing while watching video. Because of the physical characteristics of the individual student viewing carrels, a student is hampered in doing any drawing while watching the screen. However, the video could be stopped at will when necessary.

2. Video is very valuable to a student with no background and/or limited visualization ability.

3. A student who has prior drawing experience or natural drawing ability will find that although the tapes are informative, he can master rather quickly what is required in each topic area and really doesn't need to watch video teaching. (In fact, there were a number of similar comments made by students on the final course evaluation form.)

4. For a student with limited experience and drawing ability, video teaching is extremely helpful.

5. The subject matter is more than adequately covered, although on some topics there are some minor technical problems such as poor lighting, camera vibration, background noise, etc.

6. A student with experience and/or innate ability to solve drawing problems easily, actually works the problems first and then watches the video so that he can receive the credit, thereby circumventing or defeating, if you will, the real purpose of video instruction.

7. A student who is not a proficient reader but more visually oriented in his learning, tends to watch the video first before attempting the drawing problems.

8. Videos are worthwhile in the more difficult portions of the course, i.e., pictorials, sections, auxiliary views, and dimensioning.

9. Purchase machines (monitors) that play at a faster speed for students who comprehend quickly.

10. Video tapes tend to wear quickly and should be periodically replaced (an expensive proposition).

11. Make tapes shorter and to the point.

12. Monitors (12" diagonal) are too small for adequate comfortable viewing. (NOTE: The tapes were originally made for a 25" diagonal monitor, not the 12" diagonal type the Media Center uses.)

13. Produce tapes so the material is covered at a slower pace.

14. Allow each student the option to watch video if he wants to and to select only those tapes he wishes to view.

Conclusions

The concept of using video tapes for supplementary instructional purposes is a good one. The idea of using television teaching, particularly for students experiencing difficulty in one or more segments of a course, allows the instructor to continue teaching the course as outlined in the syllabus, but affords the students requiring more time on a particular subject to replay the video as many times as necessary to master the work. Instructional video also allows the instructor to concentrate on helping those students experiencing more profound difficulties in the course while at the same time permitting others in the class to proceed individually to and through other or more advanced material at their own rate.

This study, conducted with required video viewing as the essential variable, was revealing in a number of ways. There seems to be no adverse or negative effect upon final grades overall, nor does it seem to affect either the time needed for students to complete the semester's work. There was also no effect on the number of incomplete (IN) or no credit (NC) grades. In addition, the study indicated that there seems to be no loss in the level of visualization proficiency by using supplemental video instruction, although at times irritation was expressed by some of the students having to view certain parts of the course topics they considered easy. Student reaction to video was quite positive for the harder, more difficult or "rough" parts in the course. The results of this study dealing with visualization proficiency supported a similar, but less encompassing piece of research conducted in 1977 with another sample of students[2]. In the 1977 study, a longer and more elaborate visualization test was administered involving sections of two different instructors. The thrust of this research was to determine whether video presentations improved students' 3-D visualization ability. It was concluded from data collected that video did not affect students' 3-D visualization proficiency during the course of the semester. Consequently, both studies tend to support the idea that visualization does not suffer because of video instruction.

Video instruction is useful but should not be considered the best, or only, way to present subject matter for an independent study course. The use of video tapes is only a supplemental method, just as are texts. Such use should be augmented with good, concise, topical handout sheets, well constructed or fabricated 3-D models, various visual teaching aids and short, on-the-spot instructor demonstrations, along with other reliable teaching techniques. Ideally, the most beneficial arrangement for video instruction is to make it available to all students, but not on a mandatory or required basis. In addition, the video tapes and viewing equipment should be located in the classroom where students meet with the instructor periodically throughout the semester.

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A Computerized Method of Distortion Analysis of Simultaneously Drawn Mirror Image Figures

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Individuals have been observed simultaneously drawing mirror image figures with their right and left hands indicating that this ability might relate to personality traits and/or creativity. A computerized method is described whereby a mirror image pair simultaneously drawn by the right and left hand can be compared. The mirror image figures are collected as digital data from two digitizing pads interfaced with a personal computer. The program computes the mean relative size and a measure of the distortion of one figure relative to the other. The distortion measure is based on the departure from a condition of rigidity employed in the physics of rigid bodies. This program should be applicable to a variety of psychological studies.

Introduction

Most individuals appear to have a natural ability to move their arms and hands in a mirror image fashion. One only has to imagine directing an orchestra and his hands and arms will move in a mirror image fashion with the plane of the mirror being the symmetry plane of the body. The clapping of one's hands is another example of this mirror image movement. Dunn[1] made practical use of this innate ability by drawing enantiomers (mirror image molecular structures) on the chalkboard while covering the subject of stereochemistry in his organic chemistry class. Drawing enantiomers of complex molecules is a complex task when one attempts to draw them one item at a time with the dominant hand, but drawing mirror image figures simultaneously with both hands is an easy task. When students were asked to draw enantiomers with both hands simultaneously, most could do it easily. A few students, however, tended to draw similar (non-mirror image) figures, moving their hands in synchronous, parallel movements rather than in mirror image fashion. Casual observation could lead one to believe that these students were of the less creative, more methodical type. This observation suggested that perhaps creativity and/or personality characteristics might be correlated with the ability to draw mirror image figures using both hands simultaneously.

Luçat[2] had 560 right-handed and 50 left-handed elementary school students draw a model of a cycloid or a spiral using both hands simultaneously. Luçat reported that left-handed students tended to move both hands in the same direction more frequently than right-handed students. No results were reported in regard to the measurement of the distortion of similar or mirror image figures.

A quantitative study of simultaneously drawn mirror images was conceived to provide a basis for the correlation of left-brain and right-brain activity with motor response. For example, artists and non-artists could be compared in analogy to the auditory comparisons of musicians and non-musicians[3]. Springer and Deutsch[4] present an excellent summary of the literature pertaining to brain asymmetries.

A computerized method for the collection of digitized sets of data representing simultaneously drawn mirror images is described. In addition, a method of analyzing the mirror image data is described, including computations of an average size ratio and a measure of distortion. However, the detailed psychological studies suggested, using the application of this method, are left to other investigators.

The Data Collection System

The developmental work for collecting and analyzing data related to the simultaneous mirror image phenomenon has been accomplished on commonly available personal computer hardware and software. Although originally designed for an IBM microcomputer, further studies may be pursued with compatible equipment which has comparable display and input/output capability.

At the heart of the experimental apparatus is a microcomputer capable of direct conversion of analog signals to digital graphic display, with a general purpose package that can be programmed to complete the analysis which has been derived. The developmental configuration consists of an IBM personal computer running advanced interpreted BASIC (BASICA) using a medium resolution color display (CGA, 320 x 200 pixels) and equipped with a game adapter. Although named for the purpose of providing input for entertainment software, the game adapter has provision for four analog and four digital inputs. The analog inputs are modified by the use of variable resistors between a reference voltage and the input channels, and the digital inputs are momentary contact switches between the signal lines and ground.

Two Koala pads were connected to the game adapter using a "Y" connector which was custom built for the task. Each Koala pad had two analog inputs (X and Y locations on the pad) and two digital inputs (trigger or event switches); therefore, two pads working together used the full input capacity of the game adapter. Each Koala pad served to record the data for either the left or right hand as prescribed figures are drawn by the subject. In designing an experiment for additional study, custom input devices could be designed and built which would interface with the game adapter, or the same commercially available hardware used in the developmental work could be employed.

Program support for the input

device is provided through the STICK and STRIG functions and statements of IBM's BASICA, or through GWBASIC on compatible systems. Sampling of all four analog inputs occurs simultaneously with the STICK(0) statement. STICK(1) through STICK(3) do not actually sample the inputs, but rather assign the previously sampled data to variable names. This provision of the advanced BASIC language assures precise timing and identical intervals for the sampling of all the analog inputs.

Each experimental figure is displayed in a side-by-side manner on the computer display screen and is programmed to be stored in a uniquely named data file on a diskette. The storage of the experimental data is under control of the individual running the experiment. The data files may be retrieved for analysis either during the experimental session or at a later time when the subject is no longer present.

The final operation of the developmental work is to have the analytical data and the original experimental images routed to a printer for filing as hardcopy output from the experiment. The printing operation has been programmed so that it appears to be an automatic function which is available by simply pressing a single key or trigger switch.

The electrical schematic in Fig. 1 illustrates the wiring hookup for constructing the "Y" connector which adapts the two Koala pads to a single game adapter. The 15-pin "D" shell connectors should be available at most electronic supply houses. Some compatible microcomputers or third-party boards containing game ports have two six-conductor modular telephone connectors instead of the 15-pin "D" shell connector and will not require

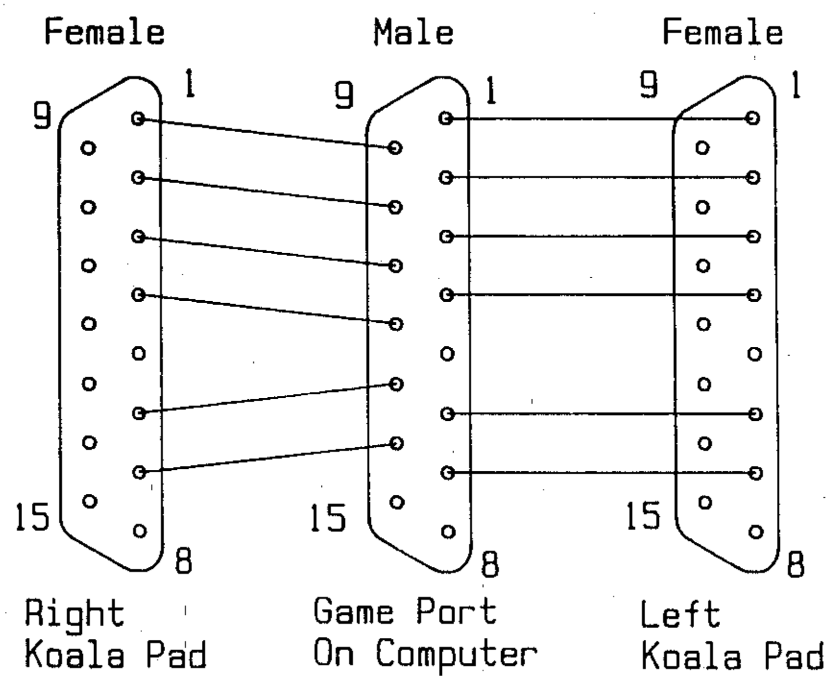

Fig. 1 Schematic for "Y" Connector Between Koala Pads and Game Port Adapter

that an adaptor be constructed.

A method was developed to measure the distortion of one image relative to the other of two left-right mirror images specified by a numerical data set of the image points. The measure obtained, to be significant, must be independent of any rotation or displacement of one image relative to the other.

The rigidity of a material body is expressed by the condition that the distance between any two identifiable points be a constant independent of any displacement or rotation of the body. Figure distortion could therefore be measured by a computation based on a departure from this condition of rigidity. The two mirror image figures are specified by correspondingly indexed arrays of the image point coordinates. The points on the two figures specified by the same index value were generated simultaneously when the figures were drawn. These can be taken as corresponding to an identifiable point of a body which is represented by both figures. The distances separating corresponding points of the two figures can then be compared for the study of distortion.

The computation of a correlation coefficient between the corresponding point-to-point distances of the two figures was considered, but rejected because it would weight the widely separated point pairs more heavily than the closely spaced ones. It was apparent that the ratios of the point-to-point distances between the two figures would provide a measure of the relative size of one image to the other. It also appeared that the variation of these ratios as given by their standard deviation would provide a measure of the relative distortion. These computations were selected as the basis for the project. If for two different index values, the coordinates of the left image points are designated (X_1,Y_1) and (X_1',Y_1'), and those of the corresponding right image points as (X_2,Y_2) and (X_2',Y_2'), the point-to-point distances are expressed

$$DL = [(X_1 - X_1')^2 + (Y_1 - Y_1')^2]^{1/2}$$

$$DR = [(X_2 - X_2')^2 + (Y_2 - Y_2')^2]^{1/2}$$

for the left and right images, respectively. The desired left to right and the right to left ratios are RLR = DL/DR and RRL = DR/DL. The computation involves calculating these values for a large number of point-to-point combinations, from which the following are computed: the average of each ratio, the standard deviation of each ratio, and the geometric mean of one ratio, left to right.

The standard deviation of each distance ratio, left to right and right to left, is converted to the percent variation of the associated average values. The average of these two percent variations is calculated to represent the percent distortion of one figure relative to the other. The relative size of the left image to the right image is taken as the geometric mean of the left to right ratios. These results can be further averaged over different point sets, if desired.

An initial test program was

written in the BASIC language to generate a numerical data set to represent left-right mirror images geometrically constructed by points taken from lines and several types of arcs. Provision was made for distorting, displacing, and rotating the left image with the right image left unaltered. The left image is divided into two sections, and each section can be expanded or compressed by a specific fraction, both horizontally and vertically, to obtain the desired distortion. These artificially constructed figures were used as control test figures to study the method proposed to measure the mirror image distortion and size ratio.

A second program was written, also in BASIC, for the proposed size and distortion analysis of the digitized mirror image figures. A mirror image data file, either from hand-drawn figures or from a constructed file from the test program, is read into an indexed array for processing. The hand drawn figures frequently generate a few obviously spurious points. Consequently, the program was provided with a means for locating and rejecting the spurious points. The program has provision in this stage for displaying the images on the CRT.

The program then carries out a test to distinguish whether the image pair consists of similar or mirror images. This test is followed by the computation of relative size and the distortion analysis, as described. However, it was considered that the distortion computation would be abnormally weighted by very close point-to-point pairs occurring where the figure intersects itself; consequently, the very close point-to-point pairs are rejected. It has been verified that these results are independent of any relative rotation or displacement of one figure to the other.

Results

The results for a mirror image figure pair generated by the test program are presented in Table 1 and are shown by Fig. 2. The left image upper section was expanded horizontally by 40% and reduced vertically by 20%, and the lower section was reduced horizontally by 20% and reduced vertically by 40%.

The principal results in Table

Distortion Analysis Results
for a
Computer Generated Test Figure Pair

Data Set	Number of Points	Relative Size Left to Right	Percent Distortion
1	25	.843	22.9
2	25	.844	22.8
3	25	.839	22.9
4	25	.834	22.7

Table 1

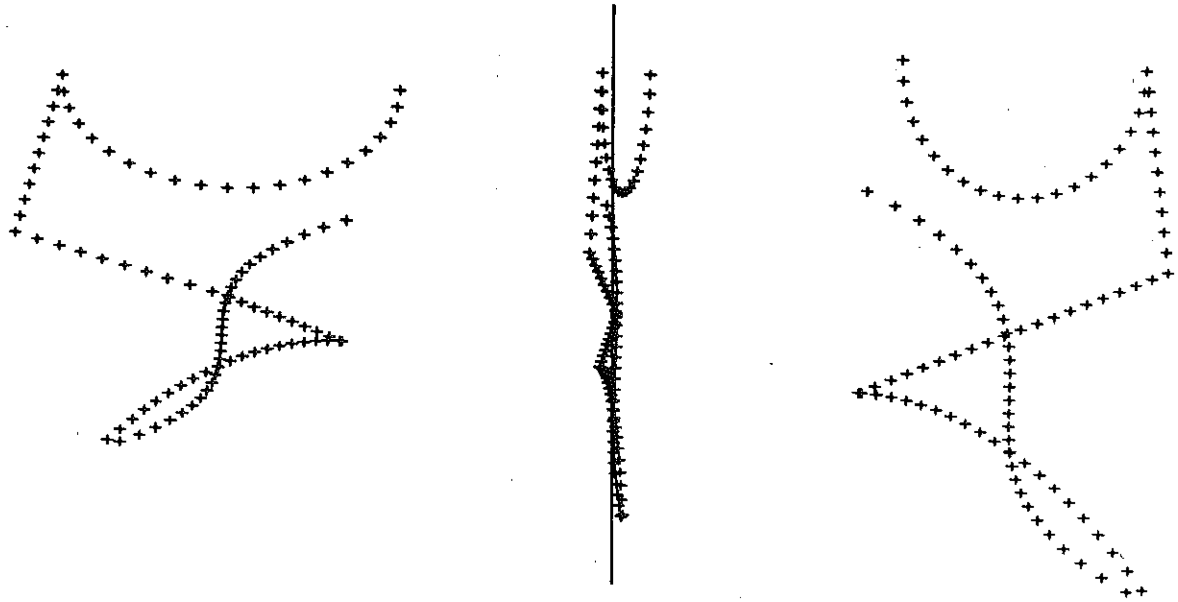

Fig. 2 Mirror Image Pair Generated by the Test Program

Distortion Analysis Results
for a
Hand Drawn Test Figure Pair

Data Set	Number of Points	Relative Size Left to Right	Percent Distortion
1	24	1.130	23.8
2	24	1.142	22.2
3	24	1.152	25.2
4	24	1.110	24.3

Table 2

1 are based on four sets of all point-to-point combinations of twenty-five selected points at equal intervals, with very close combinations rejected. The left-to-right relative size ratios vary from 0.834 to 0.844, with an average of the four being 0.840. The percent distortions vary from 22.7% to 22.9%, with an average of 22.8%. These values appeared quite favorable for consistency.

The mirror images are shown as plots in Fig. 2 with a plot of their averaged points between them. For perfect mirror images with no relative rotation, the average points would lie on a vertical line. The distortion can be seen by their variation from a line fit obtained by an orthogonal least-squares calculation[5].

The results for a hand drawn mirror image pair are presented in Table 2 and shown in Fig. 3. The results are less consistent, which should probably be expected

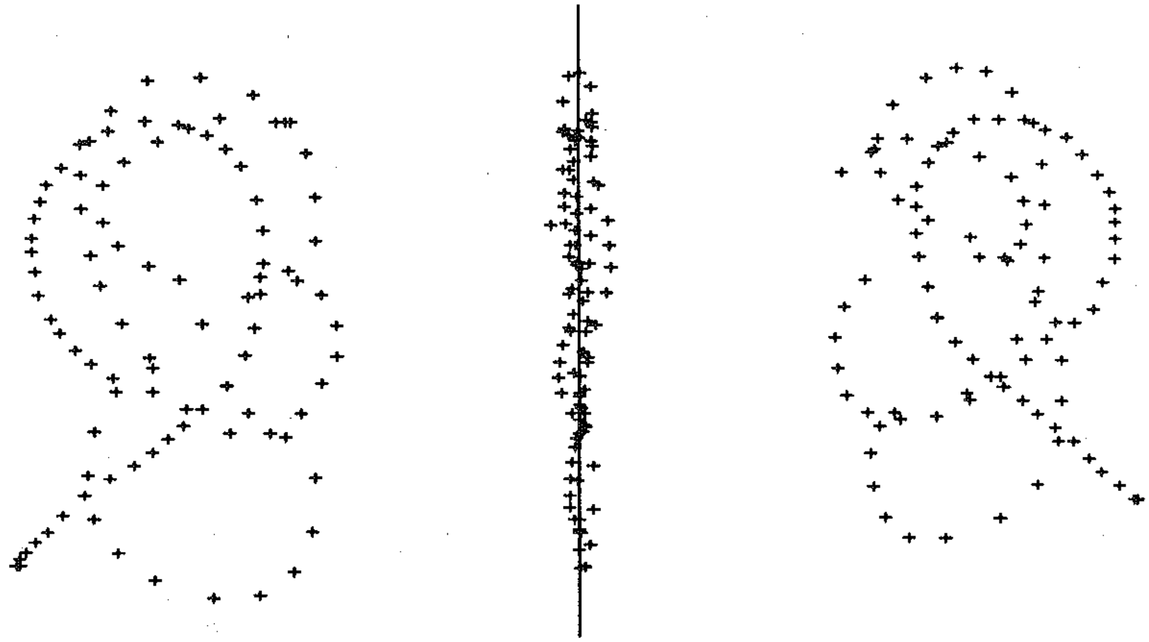

Fig 3. A Hand Drawn Mirror Image Pair

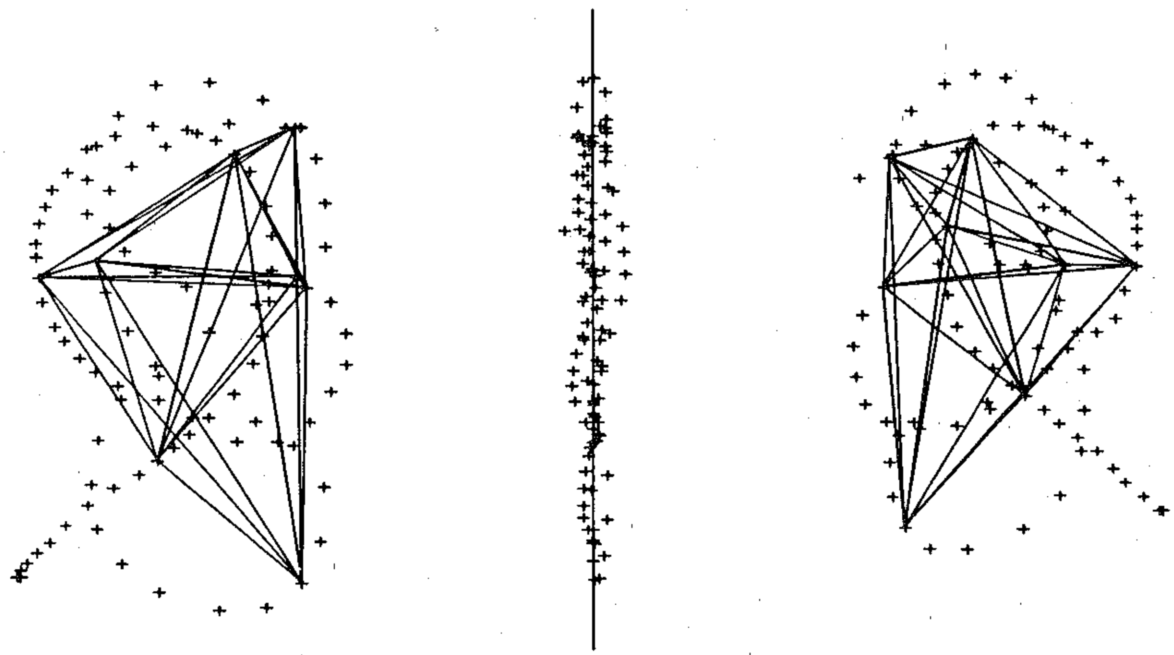

Fig. 4 A Repetition of Fig. 3 Including Lines Drawn Between Some of the Point-to-point Combinations Used for the Calculation

for a figure of this complexity. The results are based on four sets of all point-to-point combinations, excluding very close values, for twenty-four selected points at equal intervals. The left-to-right relative size ratios vary from 1.110 to 1.152 with an average of 1.134. The percent distortions vary from

22.2% to 25.2%, with an average of 23.9%.

These same images are repeated in Fig. 4 with lines drawn between some of the point-to-point combinations used for the calculation. The ratio of the lengths of the lines joining each corresponding pair of points of the two figures provides the basis for the calculations of relative size and distortion.

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Authors' Note

The program listings, in BASIC, for collecting and analyzing the hand drawn mirror image data sets are available from the authors.

Static vs. Dynamic Visuals in Computer-Assisted Instruction

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An experiment was conducted to determine which of two methods of presenting graphic images (static or dynamic) would enhance student achievement and spatial abilities. The objectives of the study were to ascertain if a series of static or dynamic visuals would allow students to achieve higher performance test scores and/or higher mental rotation test scores. The results of the experiment revealed that the students who viewed the static presentation achieved slightly higher scores on performance tests while students who viewed the dynamic presentation made larger gains on the mental rotation tests.

One of the main goals of teaching orthographic projection, and specifically descriptive geometry, is to increase the ability of students to "think in three dimensions". This ability is especially necessary in design related courses where visual conceptualization is paramount. Highly developed spatial abilities are also good predictors of successful engineering or scientific careers.

The dilemma is that engineering schools seem to be placing less emphasis on courses, such as engineering graphics, where spatial abilities may be developed. Additionally, many remaining graphics courses are being converted to computer-aided design and drafting classes. Spatial concepts so far have not been well learned when students are taught to achieve end results only by manipulating computer commands. The result of using the computer to teach orthographic projection may be that newly graduated engineers could be functionally illiterate in regard to spatial abilities.

If spatial abilities are to be taught, they first must be understood. The culmination of many research efforts[1-5] has provided a clear understanding of what is required for mental imagery. Relative to an actual object, a person must first be able to form a mental picture of the object (visualization) and then, place the object in space relative to himself (orientation).

In regard to understanding orthographic projection, Stea and Blaut[6] stated that the student must be able to perform three tasks mentally: (a) rotation of the object to another plane, (b) changing the visualization of the object from two to three dimensions, and (c) changing the size of the object. To be able to do this a person must have developed some type of spatial schema. The level of sophistication of a person's spatial schema skills, as defined by Piaget and Inhelder[7], is dependent upon a person's ability to: (a) think abstractly, (b) operate within a reference coordinate (XYZ) system, and (c) use Euclidean measurements.

If spatial abilities and a fuller understanding of descriptive geometry rests on the development of a mental schema, then it may be important to present concepts in a way that they may be easily internalized. Salomon[8] stated, "the external system which one adopts is somehow internalized or interiorized to serve in a representational capacity". The aim of such events as stated by Gagne[9] is, "to make the new material readily subsumable under previously learned ideas and at the same time distinguishable from them".

The computer may be able to help in this regard. Kiser[10] stated, "The microcomputer offers unique capabilities for computation, motion simulation, color and sound cuing in visual learning strategies, pacing of visuals, graphing, and dynamic shading in the classroom". This area of computer usage is called computer-assisted instruction (CAI).

While there has been conflicting research results concerning some of the different structural aspects of CAI, several meta-analytic studies have reported that using CAI in classrooms has caused significant learning increases, in less time, with more positive student attitudes toward the topics being taught[11-15]. Relative to the study of computers and spatial abilities, Kiser[10] noted, "even though computer use in classrooms is more widespread, there has been limited research into the pedagogical effectiveness of computer technology as it is related to strategies for visual learning and individual-difference variables (such as spatial visualization)".

If descriptive geometry concepts, which rely on orthographic projection techniques, are used to enhance student spatial abilities, students may be hampered by the conceptual nature of descriptive geometry. However, if this type of information were presented in smaller sequential steps, students may be able to understand it more easily and thus develop spatial abilities. It may be possible to present these sequential steps via a CAI lesson.

Purpose and Hypotheses

The purpose of the study was to determine which method of presenting graphic images (static or dynamic) in a CAI lesson would generally enhance student achievement and specifically increase spatial abilities. To enhance the viability of the study, it was conducted in the natural learning environment of the subjects. Also, the content of the computer lessons was meaningful to the subjects in that it was an integral part of the course in which the students were enrolled.

The following research hypothesis was tested at $\alpha = 0.05$:

(a) students who learn descriptive geometry concepts from dynamic visuals within a CAI lesson will not increase their understanding of the information, as noted by achieved scores on performance tests, when compared to similar students who are taught the same topic from the static visuals within a similar CAI lesson, and

(b) students who learn descriptive geometry concepts from dynamic visuals within a CAI lesson will not increase their ability to mentally rotate objects, as noted by achieved scores on tests of mental rotation, when compared to similar students who are taught the same topic from static visuals within a similar CAI lesson.

Methodology

The quasi-experimental research design was chosen as the most appropriate method for this study. Sowell and Casey[16] stated that this design was applicable when control of all the conditions for an experiment are not possible, especially in educational research conducted in schools. Specifically, the research design employed could be termed non-randomized experimental-group pretest-posttest.

Concepts and Tests

The selection of descriptive geometry concepts were chosen relative to previous findings of the most important concepts and also from the concepts presented in the classroom. Earle[17] surveyed twenty-four educators and administrators who were experienced in the field of engineering graphics and compiled a prioritized list of recommended descriptive geometry concepts to be taught.

This survey list was compared with the descriptive geometry concepts regularly scheduled to be taught. The concepts that matched were selected for inclusion in the CAI lessons. The concepts that matched were: (1) true size of plane, (2) piercing point of a line and a plane, (3) point view of a line, (4) angle between two planes, and (5) intersection between two planes (or angle between two planes). One additional concept was added - true length of a line.

In order to show the relationship of a simpler concept to a more complex concept, the concepts were paired to make three lessons. The point view of a line was paired with the angle between two planes. The true length of a line was paired with true size of a plane. The piercing point of a line and a plane was paired with the intersection between two planes. By pairing like concepts, overlapping theories between lessons were reduced. Therefore, it was not necessary for the students to view a previous lesson to understand a current one.

Non-evaluated adjunct test questions (used as an interactive tool) were placed within the CAI lessons to allow the subjects to check his or her understanding of the material presented. A paper-and-pencil performance test was given after each individual concept. The first part of the pencil-and-paper tests was presented to determine if the student could emulate what the lesson had presented. The second part of the tests was similar to the first except the lines and planes within the given views were different lengths and sizes and oriented differently.

Face validity of all lessons and tests was achieved by review of the engineering design graphics (EDG) facility at Texas A&M University. During lesson development, testing was conducted with students not involved in the study.

The Mental Rotations Test by Vandenberg and Kuse[18] was given to all subjects in the manual drawing rooms. This spatial ability test was chosen for its simple three-dimensional images that are different only in their degree of rotation of like objects. The test was administered prior to the experiment as a pretest and again after the experiment as a posttest. A sample question is presented in Fig. 1.

As reported by Vandenberg and Kuse[18], product moment correlations of the Mental Rotations Test with a number of other spatial abilities has generally been high. As noted in the *Directory of Unpublished Experimental Mental Measures*[19], the validity correlations with other spatial ability tests ranged from 0.31 to 0.68 (n's were either 456 or 3435). Vandenberg and Kuse[18] recounted only low correlations with tests of verbal ability.

The *Dictionary of Unpublished Experimental Mental Measures*[19] also certified that reliability ratings with the Kuder-Richardson 20 was 0.88 (n = 3268 adults and adolescents), while test-retest correlations were: 0.83 (n = 336, one year or more interval); 0.70 (n = 456, one year or more interval).

The opinions and preferences of the participating students were obtained by means of a thirteen-item opinion questionnaire. The questionnaire used a five-level Likert-type scale. It was administered on the day following the last CAI lesson, directly after the posttest.

Instructional Strategy

Once in the computer rooms, initial directions were given by the classroom instructor. After these directions, the instructor was not directly involved with the lesson. The students viewed the lessons, took the tests, and returned to the manual drawing rooms via printed directions in the CAI lessons.

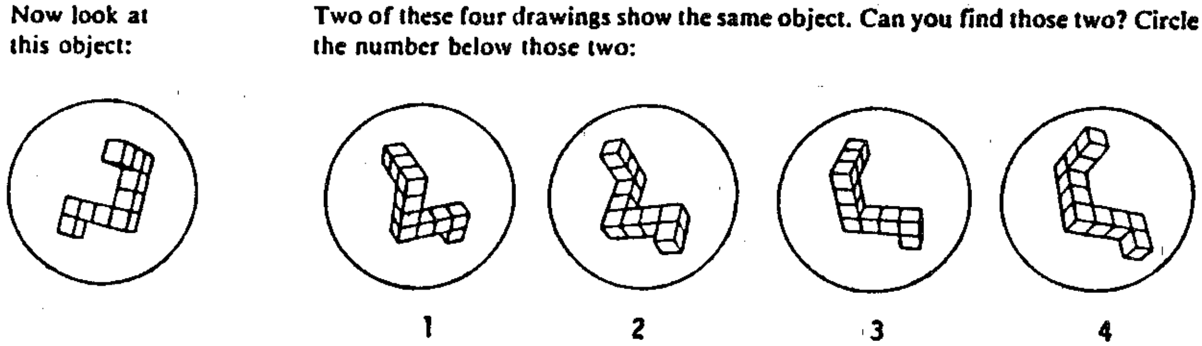

Fig. 1 Sample question from Mental Rotation Test

Computer Assisted Lessons

Six CAI lessons were developed (three static and three dynamic) that presented the descriptive geometry concepts. They were created so that they were independent of one another. Each of the lessons was identical in its structure. They consisted of an introductory section, two parts with two presentation segments each, and a closure. The first section of each part of each lesson illustrated, in three dimensions, the solution of the problem using sequential steps. The second section of each part of each lesson illustrated the same problem solved in two-dimensional sequential steps as the student normally would on paper. The test and graphic color, size, and placement, as well as the general form and format of the computer frames was consistently controlled.

The static lessons used motionless three-dimensional images with text explanations to illustrate the concepts. The dynamic lessons used the same images as the static lessons but also used sequentially rotated images (animation) to show the problem solution. The rotational parts of the dynamic lessons used the DVIEW (dynamic view), AXROT (axis rotation), and UCS (user coordinate system) commands in conjunction with other commands in Release 10 of the AutoCAD software[20]. These commands allowed the three-dimensional objects to be rotated about different axes to produce the desired views. The AutoLISP[21] programming language was used to combine the various commands to automatically generate many of the individual frames within the rotational sequences. The individual drawings were converted to slide files and then combined within the Autoflix[22] authoring language. Copies of the CAI lessons are available from the author.

The development and viewing of the CAI lessons were completed on Hewlett-Packard Vectra computers. These computers used 80286 microprocessors operating at 8 Mhz. Each was equipped with a 80287 math co-processor and a color EGA monitor. The two experimental environments contained thirty-seven computers each.

Population and Sample

The population for this study was the entire ENDG-105 Spring Semester 1989 student enrollment at Texas A&M University. Four class sections (twenty-four possible) were chosen to participate in the study. This provided a total of 137 student participants.

These classes were chosen to control instructor, time, and classroom biases. The classes were on the same hourly schedule and each met Monday, Wednesday, and Friday. Two of the classes were taught by one instructor while the other two were taught by a different instructor. The assignment of the sections into either static or dynamic test groups was random.

Statistical Measures

A $\underline{t}$ statistic was used to test the differences between the mean scores of the performance test sets. A paired $\underline{t}$ statistic was used to compare the means of the differences of the pretests and posttests scores. The analysis of variance was used to evaluate the differences in the mean responses of the students to the opinion statements. When significant differences were found in the opinion statements, Duncan's multiple range test was used to determine which of the mean responses were statistically different.

Results

The data presented reports the differences in mean performance test scores, differences in pretest and posttest mean scores, and results of the opinion questionnaire. The performance test data was analyzed relative to the upper twenty-five percent, lower twenty-five percent, and total group mean scores.

Performance Tests

An analysis of the pooled individual tests revealed that there was a significant difference (α = 0.025) in the lower twenty-five percent of the sample. The static group mean score was 9.87 percentage points higher than the dynamic group mean score. Neither the upper twenty-five percent nor the total group mean scores showed a significant difference. The means, standard deviations, and *p* values are presented in Table 1.

Pretest/Posttest Scores

An analysis of the mental rotation pretests and posttests revealed significant differences (α = 0.025 and α = 0.005) in the lower twenty-five percent and total group mean differences. The differences in the upper twenty-five percent were not significantly different. All group categories increased their mean scores except for the upper twenty-five percent of the static group. The largest gain in mean scores occurred in the lower twenty-five percent of the dynamic group. The means of the differences, standard deviations, and *p* values are presented in Table 2.

Opinion Questionnaire

Both static and dynamic test

Group	n	M	SD	p Value
Lower 25 Percent				
Static	36	86.25	14.21	
Dynamic	36	76.13	19.64	2.448
Upper 25 Percent				
Static	38	91.78	8.95	
Dynamic	38	91.23	12.21	.215
Total Group				
Static	174	89.84	11.96	
Dynamic	174	88.33	15.28	1.037

Table 1 Analysis of Pooled Mean Scores from the Three Performance Tests

Group	n	M	SD	p Value
Lower 25 Percent				
Static	11	6.73	9.73	2.294
Dynamic	9	13.44	4.75	8.498
Upper 25 Percent				
Static	11	2.45	8.38	.971
Dynamic	9	.67	2.24	.894
Total Group				
Static	44	3.84	7.74	3.291
Dynamic	36	7.62	7.05	6.479

Table 2 Analysis of Pretest/Posttest Comparison

groups preferred learning from the CAI lessons over reading the textbook. On a scale of one to five (one = strongly agree, five = strongly disagree) the students in the static group registered a mean response of 1.52 with a standard deviation of 0.74. The students in the dynamic group recorded a mean response of 1.32 with a standard deviation of 0.57.

There was less agreement concerning the preference of the CAI lesson over a lecture. The students on the static group posted a mean response of 2.27 with a standard deviation of 1.12. The dynamic group entered a mean response of 2.07 with a standard deviation of 1.01. This question had the highest mean response and standard of all thirteen questions on the opinion questionnaire.

Discussion

The results of the experiment revealed that, overall, the students who viewed the static presentation achieved slightly higher scores on the performance tests while the students who viewed the dynamic presentation made larger gains on the mental rotation tests. A most interesting result was the increase that the lower twenty-five percent of the dynamic group made on the mental rotation posttest. This group more than doubled their mean score from pretest to posttest. One may surmise that the ability to mentally rotate objects does not guarantee the ability to make high scores on performance tests and vice versa.

While much speculation may be made regarding the interpretation of the responses from the opinion questionnaire, it was clear that during the actual testing and from their comments afterwards, they favored the use of CAI in the classroom. It was also clear, however, that there was some disagreement as how to best use the technology.

Recommendations

Dynamic presentation methods should be implemented where increased spatial skills are desired and additional research should be conducted to determine the specific aspects of static contributed to their respective increases. Studies are also recommended in the areas of how and when CAI lessons should be given.

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Applying the Mean Proportional Principle to Graphical Solutions

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Many relationships encountered in the study of mechanics can be modified as geometric identities between shapes. For relationships involving the identity between rectangles of equal area, such an identity is shown to be uniquely related to the 'mean proportional' of a triangle formed by two adjacent sides of the rectangle or square. A graphical illustration is presented indicating how the mean proportional, once established, for one set of conditions of an identity, can be used to generate any other set of conditions for the same identity. Examples presented are just a few of many in which the mean proportional principle has been or can be applied in developing graphical solutions to engineering problems.

Introduction

Many graphical solutions, particularly in the field of mechanics, rely on geometric constructions where the conversion of one geometric shape to another of equivalent area is desired. Granted that such a conversion may be a small part of a more complex graphical procedure, however without it, the procedure cannot be considered totally graphical. There are many textbooks where geometric procedures are described to convert one polygon to another of equal area. However, when the conversions between rectangles are involved, such graphical constructions are noticeably absent in most books on geometry.

The Mean Proportional

The principle on which the rectangle conversion is based is that of the geometric mean, or so-called "mean-proportional", which is defined as follows:

The mean proportional[1] is the altitude on the hypotenuse of a right triangle, or the length of a perpendicular dropped from the right angled vertex to the hypotenuse.

It is so termed because it divides the hypotenuse into two line segments proportional to the two adjacent sides of the triangle and, consequently, its scaled length is the geometric mean of the scaled lengths of the two segments. In terms of the right triangle FTE (Fig. 1), this means that the mean proportional, which is given by the line TD, is related to line segments FD and DE by the expression:

$$FD/TD = TD/DE \qquad (1)$$

or

$$(FD)(DE) = (TD)(TD) \qquad (2)$$

Once the mean proportional of a rectangle is found, it can be used to convert that rectangle to any other rectangle of equal area. The following constructions will illustrate the method.

Construction A: Rectangle to Rectangle Conversion

Let $A_0 \times B_0$ (Fig. 2) be any rectangle having a base OB_0 and height OA_0. Find another rectangle, $A_1 \times B_1$, of equal area having a base OB_1.

Procedure (Fig. 2):

1. Extend the side OA_0 of the given rectangle and, with O as center and OA_0 as radius, de-

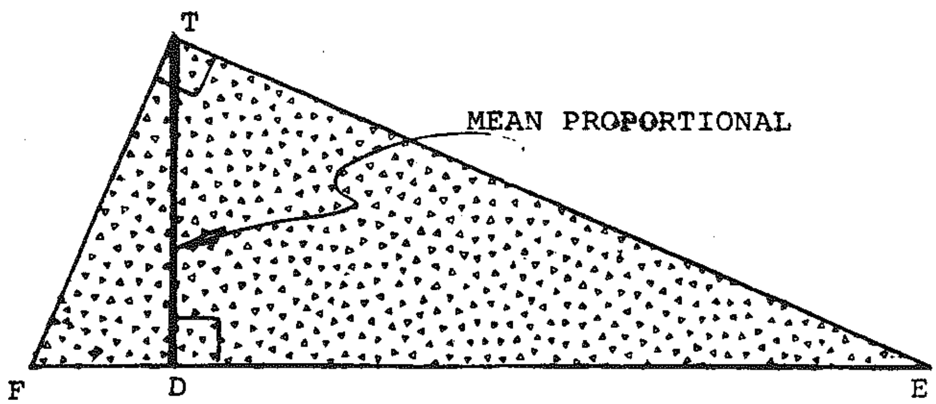


Fig. 1 Mean Proportional

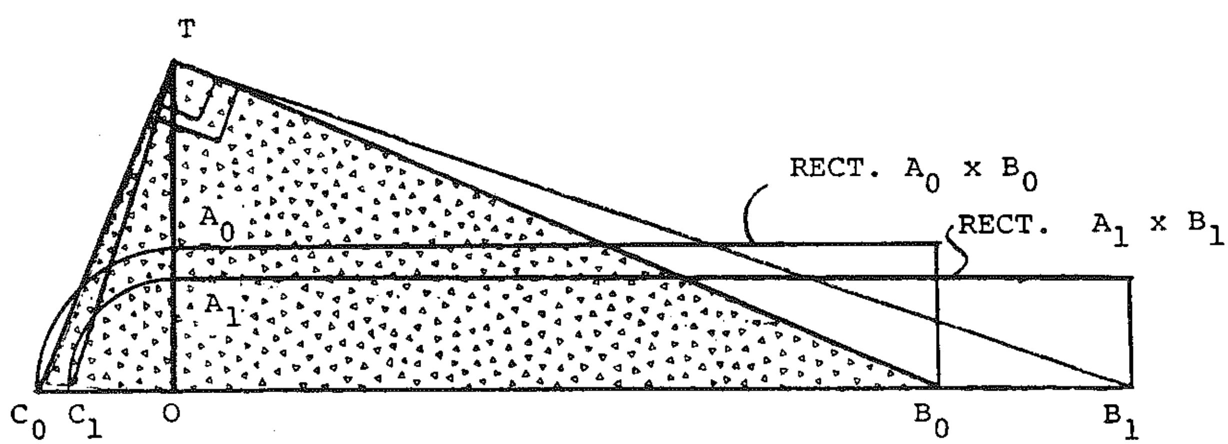


Fig. 2 Construction A: Rectangle to Rectangle Conversion

scribe an arc to intersect the base OB_0 (extended) at point C_0.

2. Using segment C_0B_0 as a base, construct a right triangle having its apex T located on line OA_0 (extended). This may be accomplished by positioning a drafter's right triangle such that the 90^o corner lies on the extended side OA_0 to form the apex of the triangle, while the adjacent edges of the triangle touch the base points C_0 and B_0. Alternately, the right triangle may be formed by (a) constructing a semi-circle having as its diameter the base C_0B_0, (b) locating point T where the semi-circle intersects side OA_0 (extended), and (c) connecting the points C_0 and B_0 to point T with straight lines. The distance OT thus found is the mean proportional of the two line segments OB_0 and OC_0 that form the base and height equivalent, respectively, of the given rectangle.

3. Once point T is found, join B_1 to T with a straight line. Then construct a perpendicular to B_1T to intersect base OB_1 (extended) at point C_1. The distance OC_1 thus found is the height equivalent of the desired rectangle.

4. Complete the rectangle $A_1 \times B_1$.

Example 1 (Fig. 3)

Given the parallelogram ABCD, where AB is parallel to CD and AD is parallel to BC, construct another parallelogram having equal area on base AG, where G is a point on AD (extended).

Solution

1. Convert the parallelogram ABCD to an equivalent rectangle. This is accomplished by constructing perpendicular lines to base AD at points A and D such that these lines intersect BC (extended) at points E and F, respectively.

2. Follow steps 1 through 4 of the procedure for Construction A to construct the rectangle ASPG

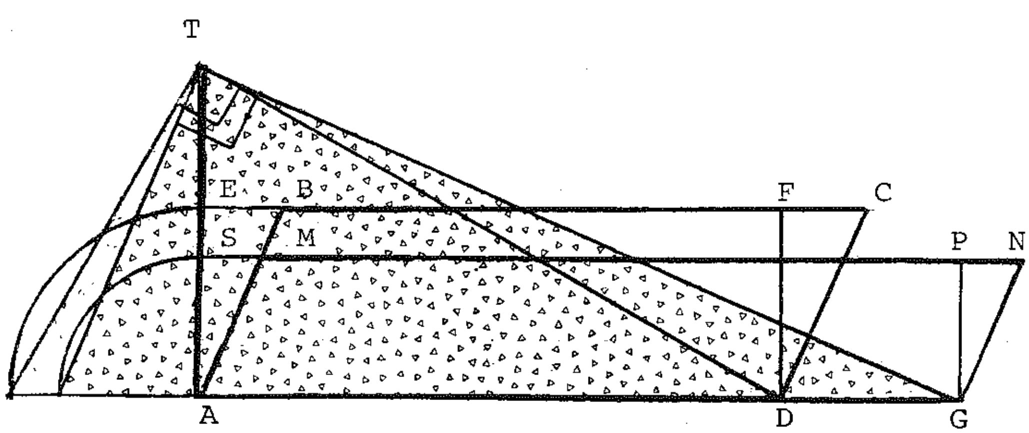


Fig. 3 Example 1

which is equal in area to rectangle AEFD.

3. Convert rectangle ASPG to a parallelogram by extending side SP to meet GN, drawn parallel to AM, at a point N. Note that M is defined as the intersection of AB and SP. The parallelogram AMNG thus formed is the required parallelogram.

Construction B: Rectangle to Square Conversion

Given the same rectangle A_0 x B_0 (Fig. 2), construct a square having an area the same as this rectangle.

Procedure (Fig. 4)

Steps 1 and 2 are identical to that of Construction A. The distance OT found in step 2, besides being the mean proportional of the triangle C_0TB_0, also represents the length of one side of the required square. Thus, the final step (step 3) is to complete the square OTRS.

Example 2 (Fig. 5)

Suppose that the square root of a number (such as 24) is desired. This number could be found by:

(a) choosing any pair of numbers (such as 6 and 4) with a product equal to the given number,
(b) constructing a straight line by joining, at some point O, two line segments, scaled to represent the chosen numbers,
(c) constructing a perpendicular through point O,
(d) constructing a right triangle, with the hypotenuse formed by the line in step b and apex located on the perpendicular in step c, (as in step 2 of Construction A), and finally,
(e) scaling the perpendicular to obtain the required square root.

The same result would be obtained if the chosen pair of numbers were 8 and 3 or 12 and 2.

Practical Applications

One practical application in

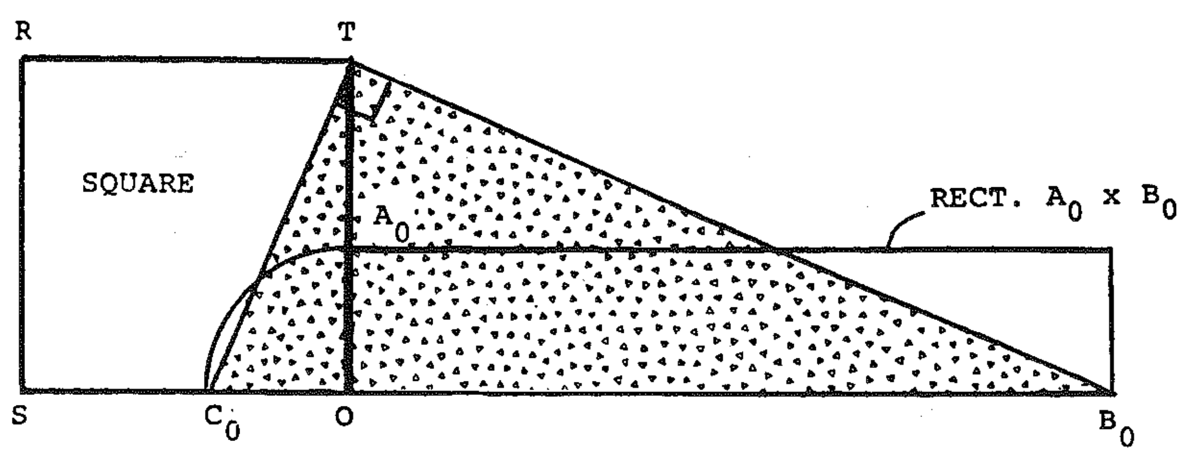


Fig. 4 Construction B: Rectangle to Square Conversion

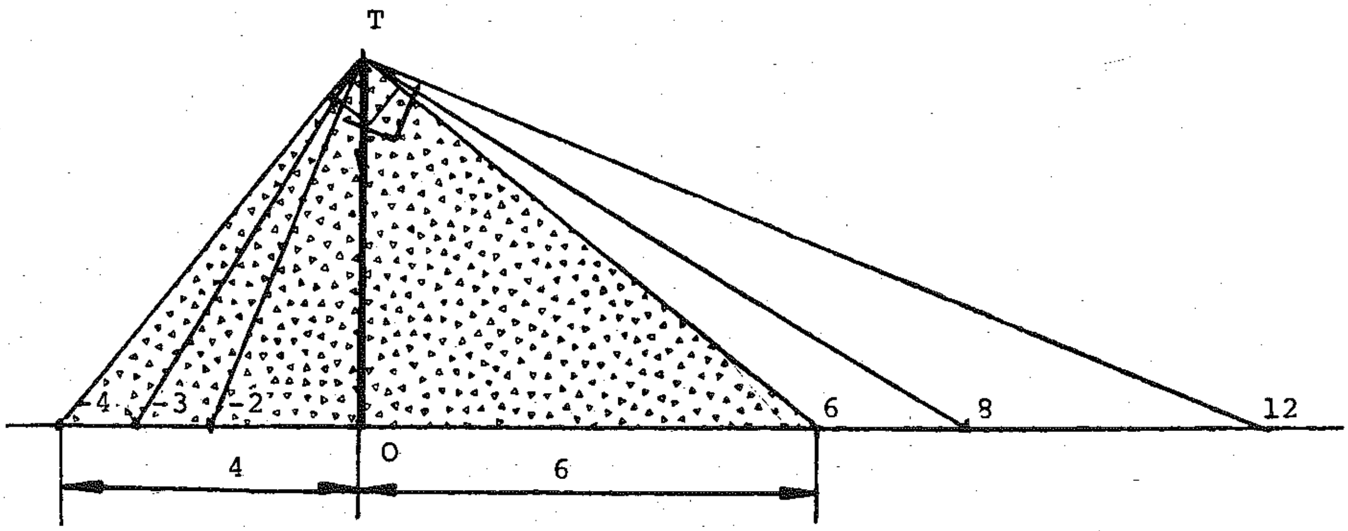


Fig. 5 Example 2

which the above constructions have been found useful is in the graphical solution of the Euler-Savary equation, commonly encountered in the study of path curvature theory for planar mechanisms[2,3]. Two forms of this equation are

$$PA(PA_0 + PJ) = (PA_0)(PJ) \qquad (3)$$

and

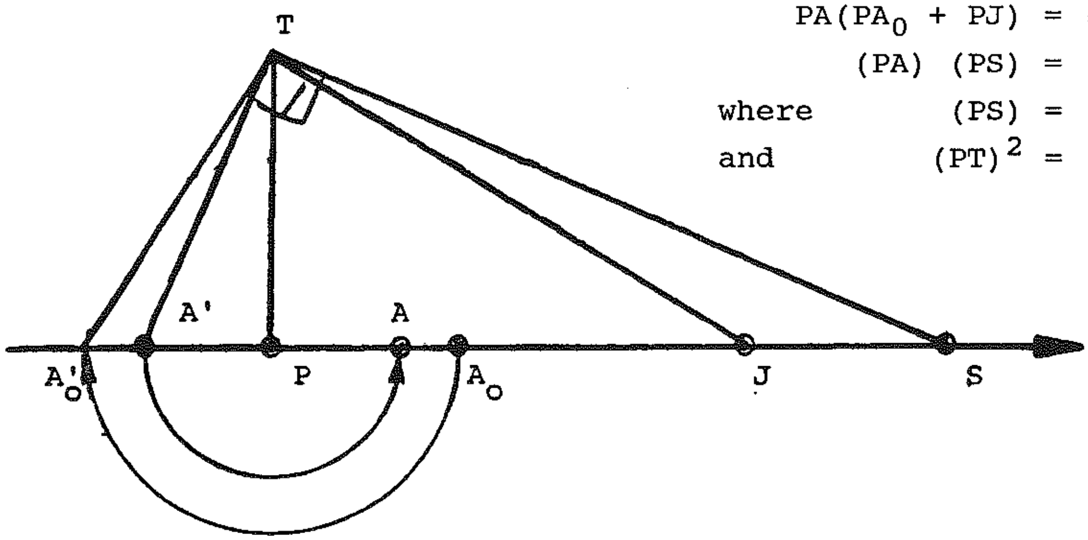
$$(AA_0)(AJ) = (PA)^2 \qquad (4)$$

where P (instant center), A (coupler point), A_0 (center of curvature) and J (inflection point) are four points on a ray, or line, such that if three of these points are known, then the fourth can be found.

In this application, Construction A (or rectangle to rectangle procedure), as required by Eqn. 3, can be very useful in determining the coupler point (A), while Construction B (or rectangle to square procedure), as required by Eqn. 4, can be very useful in determining the center of curvature (A_0) or inflection point (J). Figure 6, based on Construction A, and Fig. 7, based on Construction B, illustrate, respectively, the graphical representations of Eqns. 3 and 4. Note that all distances (e.g., PA_0 and PJ) are directed quantities, like vectors, having positive or negative signs depending on their direction from the instant center P. Another application, using Construction B, is in the development of a complete graphical acceleration analysis[4] of a linkage system, where it is required to determine graphically the normal accelerations of certain points in the linkage having known velocities. By noting the identity between this acceleration relationship, i.e.,

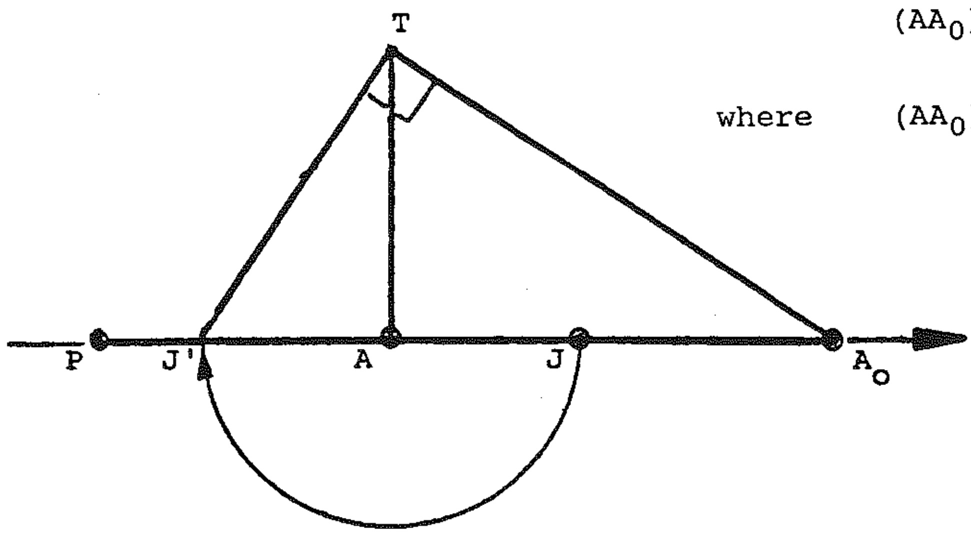
$$(BA)A^N = V^2 \qquad (5)$$

and Eqn. 4, the required task may then be accomplished (Fig. 8) when the following substitutions are made:



$$PA(PA_0 + PJ) = (PA_0)\ (PJ)$$
$$(PA)\ (PS) = (PT)^2$$
where $$(PS) = (PA_0 + PJ)$$
and $$(PT)^2 = (PA_0)\ (PJ)$$

Fig. 6 Geometric Representation of Equation 3



$$(AA_0)\ (AJ) = (PA)^2$$
$$(AT) = (PA)$$
where $$(AA_0)\ (AJ) = (AT)^2$$

Fig. 7 Geometric Representation of Equation 4

BA (radius of rotating point)
... for AA_0

A^N (normal acceleration)
... for AJ, and

V (velocity of point A)
... for PA.

Finally, another application for Construction A is in the development of the pressure-volume diagram used for a graphical analysis of an engine's performance. This important case is related to the isothermal expansion of gas in the engine's cylinder and is governed by the expression

$$PV = \text{constant} \qquad (6)$$

or

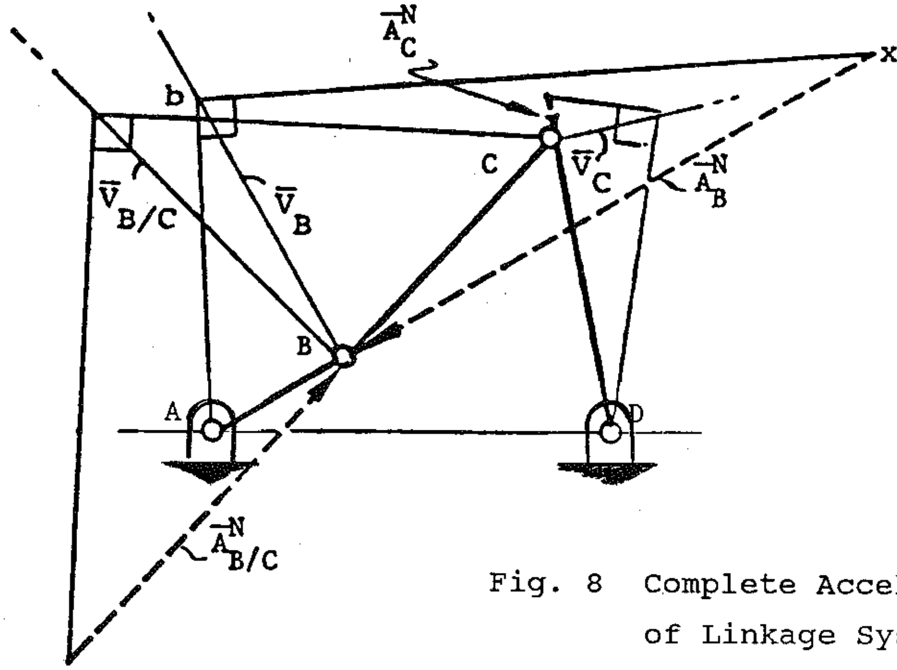


Fig. 8 Complete Acceleration Analysis of Linkage System

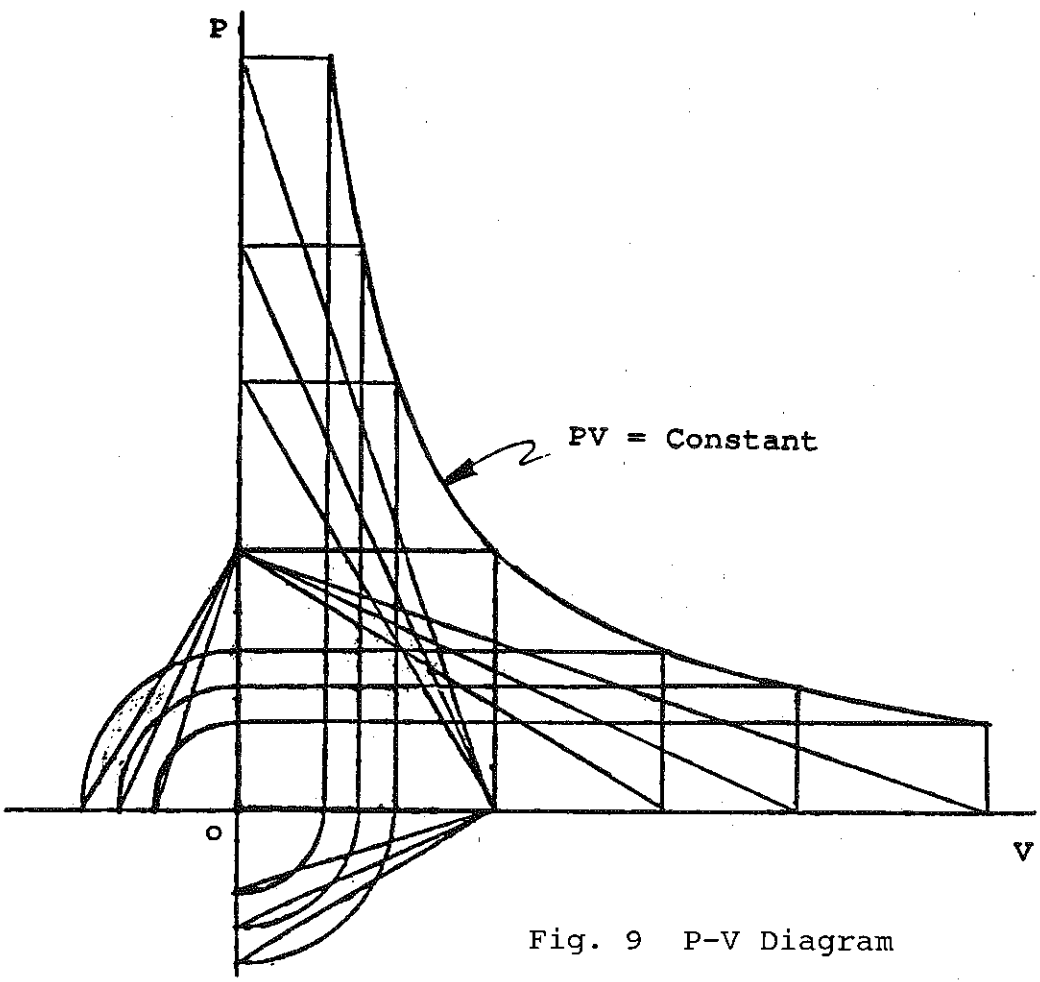


Fig. 9 P-V Diagram

$$P_1 \times V_1 = P_2 \times V_2 \qquad (7)$$

where P and V denote pressure and volume, respectively, and subscripts 1 and 2 indicate the positions in the piston stroke. Again, by noting the identity in form between this relationship and Eqn. 3, the required task may be greatly simplified (Fig. 9).

Conclusion

The constructions presented have demonstrated only some of the many applications in which the mean proportional can or has been employed to solve engineering problems graphically. Also, as most other graphical solutions, they not only serve to enhance the theory, but also provide useful insight into some problem solutions that can be otherwise difficult to visualize.

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Faster Ellipse Drawing Algorithms

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Improvements to the midpoint scan-conversion algorithms used to draw ellipses are described. The two methods described are each made more efficient. The first algorithm is a minimal pixel algorithm that requires more operations for selecting each pixel. The second algorithm requires fewer operations per pixel, but plots more pixels. The extra time for the added pixels often overbalances the time saved in computing their positions. Each of these disadvantages is lessened to make these algorithms more efficient.

Introduction

Accurate and efficient ellipse drawing algorithms are important in graphics due to their occurrence when circles are rotated and when aspect ratios make adjustment of circles necessary. Consider a CAD display of a part with one or more circular holes. When these holes are viewed other than straight-on, they become ellipses. Also, consider a screen with a non-unit aspect ratio. A circle drawing algorithm on such a screen will produce an ellipse. Therefore, the major or minor axis radius must be adjusted. Then the use of an ellipse algorithm will produce a circle.

Improvements to two popular ellipse algorithms are presented. The first is a minimal pixel minimum error algorithm that uses 8-way-stepping (8WS)[1,2]. That is, it will move vertically, horizontally, or diagonally. The second method requires significantly fewer operations per pixel but will plot more pixels[2]. This method uses 4-way-stepping (4WS) which results in a slightly larger bounded error. Only vertical or horizontal moves are made with this method. If not for the extra time to plot the additional pixels, the computational savings with the 4WS algorithm would be more than worth the additional error.

The improvements presented will reduce the time required by each of these algorithms to render an ellipse. The first algorithm will be improved by saving an operation as compared to the presentation made in Refs. 1 and 2. The second algorithm will be modified to plot only a minimum number of pixels.

The Current Algorithms

The two algorithms to be described each construct an ellipse defined by the nonparametric equation

$$f(x,y) = b^2x^2 + a^2y^2 - a^2b^2 = 0$$

This represents an ellipse centered at the origin, having major and minor axes horizontal and vertical, respectively (Fig. 1). Each algorithm will start at (a,0) and compute the pixels up to (0,b).

The first algorithm is the 8WS midpoint algorithm[1,2]. This algorithm evaluates f(x,y) at a midpoint between either two horizontally adjacent or vertically adjacent pixels. The two candidate pixels are dependent upon the tangent to the ellipse. This tangent divides the computed part of the ellipse into two regions (Fig. 2). Figure 3 illustrates the candidate pixels for each of these regions.

While in region 1, y is increased by 1 and the function is evaluated at (x - 1/2,y + 1), a point midway between the two horizontally adjacent candidate pixels. The sign of f(x - 1/2,y + 1) determines which pixel is closest to the actual elliptical curve. That is, if f(x - 1/2,y + 1) is less than zero, indicating the midpoint is inside the curve, choose (x,y + 1). Otherwise choose (x - 1,y + 1) (Fig. 4).

While in region 2, x is decremented and the sign of f(x - 1,y + 1/2) determines whether pixel

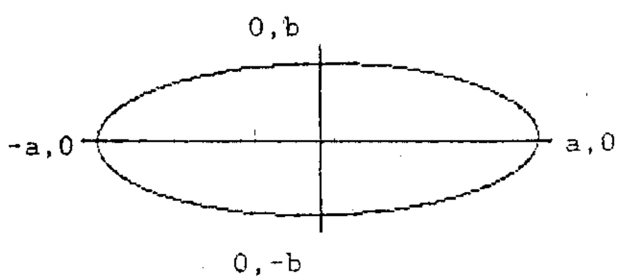


Fig. 1 The ellipse

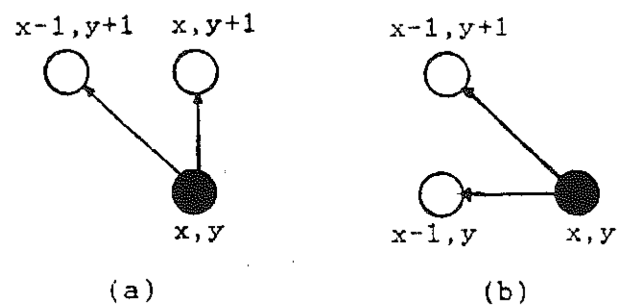


Fig. 3 Midpoint candidate pixels for tangent a) < -1 and b) > -1

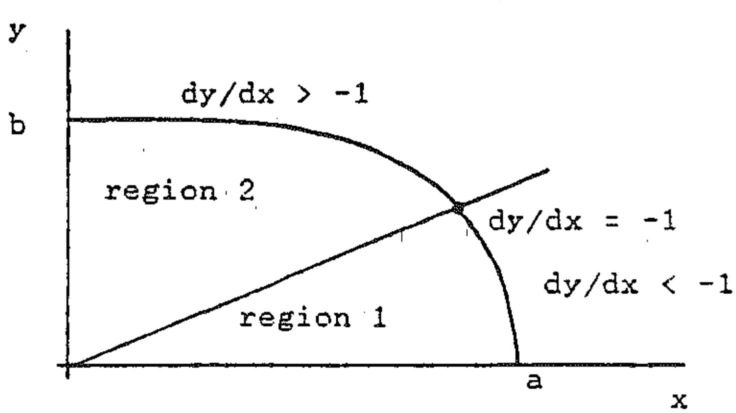


Fig. 2 Two regions for midpoint algorithm

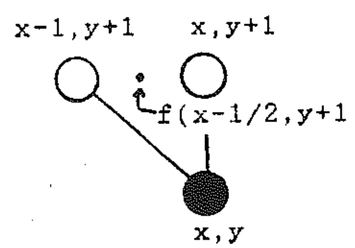


Fig. 4 Decision variable in midpoint algorithm when tangent is < -1

(x - 1,y + 1) or (x - 1,y) is selected.

The following are derivatives of recursive decision variables for each region.

When the tangent is less than -1, the decision variable is:

$$d1 = 2f(x - 1/2, y + 1)$$

$$= 2b^2(x - 1/2)^2 + 2a^2(y + 1)^2 - 2a^2b^2$$

$$= b^2(2x^2 - 2x + 1/2) + a^2(2y^2 + 4y + 2) - 2a^2b^2$$

The selection is based upon the sign of the variable. That is:

d1 < 0 implies (x - 1/2,y + 1) is inside the curve. Choose (x, y + 1) as the next pixel.

d1 ≥ 0 implies (x - 1/2,y + 1) is outside the curve. Choose (x - 1,y + 1) as the next pixel.

For efficiency, a recursive expression for d1 is needed. Two possibilities for a new d1 exist.

1. d1 < 0 implies x = x and y = y + 1

$$d1 = b^2(2x^2 - 2x + 1/2) + a^2[2(y + 1)^2 + 4(y + 1) + 2] - 2a^2b^2$$

$$d1 = b^2(2x^2 - 2x + 1/2) + a^2(2y^2 + 4y + 2) - 2a^2b^2 + a^2[4(y + 1) + 2]$$

or recursively,

$$d1 = d1 + a^2[4(y + 1) + 2]$$

But, using the updated y yields

$$d1 = d1 + 4a^2y + 2a^2$$

2. d1 ≥ 0 implies x = x - 1 and y = y + 1

$$d1 = b^2[2(x - 1)^2 - 2(x - 1) + 1/2] + a^2[2(y + 1)^2 + 4(y + 1) + 2] - 2a^2b^2$$

$$d1 = b^2(2x^2 - 2x + 1/2) + a^2(2y^2 + 4y + 2) - 2a^2b^2 - 4b^2(x - 1) + 4a^2(y + 1) + 2a^2$$

Recursively,

$$d1 = d1 - 4b^2(x - 1) + 4a^2(y + 1) + 2a^2$$

Again, using the updated x and y values yields

$$d1 = d1 - 4b^2x + 4a^2y + 2a^2$$

Similarly, when the tangent is greater than -1

$$d2 = 2f(x - 1, y + 1/2)$$

$$= 2b^2(x - 1)^2 + 2a^2(y + 1/2)^2 - 2a^2b^2$$

$$= b^2(2x^2 - 4x + 2) + a^2(2y^2 + 2y + 1/2) - 2a^2b^2$$

The recursive expressions for d2 are:

d2 < 0 implies x = x - 1 and y = y + 1

$$d2 = d2 - 4b^2x + 2b^2 + 4a^2y$$

d2 ≥ 0 implies x = x - 1 and y = y

$$d2 = d2 - 4b^2x + 2b^2$$

The variable d2 is used for selecting the pixel to choose in the second region. It also serves to indicate that the slope has changed and the second region has been entered. Therefore, both d1 and d2 are monitored while the curve has a tangent less than -1. When d2 becomes negative, (x - 1,y + 1/2) is outside the curve. Thereafter, the algorithm only needs to monitor d2.

Figure 5 is an efficient form of this algorithm, as implemented in Ref. 1, written in C and using integer additions and subtractions.

The second algorithm also chooses between one of two pixels. But, the difference is that it does not matter what the tangent is. The two candidate pixels are always the same. This approach decreases the number of computations required for each pixel.

This algorithm uses a midpoint on the diagonal from the current pixel as the decision variable. Thus, it will be referred to as the mid-diagonal algorithm here-

```
      /****************************************/
      /*  Midpoint algorithm for an ellipse    */
      /****************************************/
void Ellipse(r1,r2)
   int r1,r2;
     {  int x,y;
        long d1,d2,rsq1,rsq2,t1,t2,t3,t4,t,tt;
        void plot();        /*   the plotting function  */
        x = r1; y = 0;                     /* start point */
        rsq1 =r1*r1;  rsq2 = r2*r2;
        t1 = 4*rsq1;  t2 = 4*rsq2;             /*  let's add  */
        t3 = 2*rsq2;  t4 = 2*rsq1;
        d1 = (long)(t4 -t3*x + rsq2/2);        /* two decision variables */
        d2 = (long)(rsq1/2 - t2*x + t3);       /* close enough */
        t = t2*x;
        tt = 0;
     /***  compute points in 1/4 of ellipse  ***/
        while ( d2 < 0 )            /* tangent less than -1 */
          {   plot(x,y);
              if ( d1 < 0 )
                   {  y++;
                      tt = tt +t1;
                      d1 = d1 + tt +t4;  /* d1 = d1 + 4*y*rsq1 + 2*rsq1; */
                      d2 = d2 + tt;      /* d2 = d2 + 4*rsq1*y; */
                   }
              else
                   {  x--; y++;
                      tt = tt + t1;
                      t = t - t2;
                      d1 = d1 + tt - t + t4;
                                /* d1 = d1 - 4*x*rsq2 + 4*rsq1*y + 2*rsq1  */
                      d2 = d2 + tt - t + t3;
                                /* d2 = d2 - 4*rsq2*x + 2*rsq2 + 4*rsq1*y */
                   }
          }
        while (x > 0)          /* tangent greater than -1 */
           {  plot(x,y);
               if (d2 < 0)
                    {   x--;  y++;
                        tt = tt + t1;
                        t = t - t2;
                        d2 = d2 + tt - t + t3;
                              /* d2 = d2 - 4*rsq2*x + 2*rsq2 + 4*rsq1*y */
                    }
                 else
                    {   x--;
                        t = t - t2;
                        d2 = d2 - t + t3;  /* d2 = d2 - 4*rsq2*x + 2*rsq2 */
                      }
             }
          plot(x,y);          /* the last point */
     }
```

Fig. 5 C code for implementation of midpoint algorithm after. The mid-diagonal algorithm starts at the same place, (a,0). The selection is between the pixel at (x - 1,y) or the pixel at (x,y + 1). The function is evaluated at (x - 1/2,y + 1/2) and the diagonal pixel is never selected. If f(x - 1/2,y + 1/2) is negative, that is (x - 1/2,y + 1/2) is inside the curve, then pixel (x,y + 1) is chosen. If f(x - 1/2,y + 1/2) is positive, then pixel (x - 1,y) is chosen (Fig. 6). The algorithm continues its selection between the two candidate pixels until x becomes zero. The decision variable requires fewer computations than the decision variables used in the midpoint algorithm. Also, there is no need to check whether the tangent is greater than -1. The lack of a computation for the switch in slope reduces the number of computations even more significantly.

The following is a derivation of the decision variable for this algorithm. There is no such derivation in Ref. 2.

The decision variable is:

$$d = f(x - 1/2, y + 1/2)$$

$$= b^2(x - 1/2)^2 + a^2(y + 1/2)^2 - a^2b^2$$

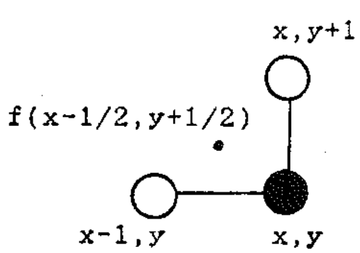


Fig. 6 Mid-diagonal algorithm candidate pixels and decision variable

$$= b^2(x^2 - x + 1/4) + a^2(y^2 + y + 1/4) - a^2b^2$$

The sign of d determines the next pixel as follows:

$d < 0$ implies $(x - 1/2, y + 1/2)$ is inside the curve. Choose $(x, y + 1)$ as the next pixel.

$d \geq 0$ implies $(x - 1/2, y + 1/2)$ is outside the curve. Choose $(x - 1, y)$ as the next pixel.

The recursive decision variable is as follows:

$d < 0$ implies $x = x$ and $y = y + 1$

$$d = b^2(x^2 - x + 1/4) + a^2[(y + 1)^2 + (y + 1) + 1/4] - a^2b^2$$

$$d = b^2(x^2 - x + 1/4) + a^2(y^2 + y + 1/4) - a^2b^2 + 2a^2(y + 1)$$

Recursively,

$$d = d + 2a^2(y + 1)$$

Using the updated y yields

$$d = d + 2a^2y$$

Similarly,

$d \geq 0$ implies $x = x - 1$ and $y = y$

$$d = b^2[(x - 1)^2 - (x - 1) + 1/4] + a^2(y^2 + y + 1/4) - a^2b^2$$

$$d = b^2(x^2 - x + 1/4) + a^2(y^2 + y + 1/4) - a^2b^2 - 2b^2(x - 1)$$

Recursively,

$$d = d - 2b^2(x - 1)$$

Using the updated x value,

$$d = d - 2b^2x$$

The initial values of x = a and y = 0 give

$$d_0 = 1/4a^2 + 1/4b^2 - ab^2$$

An efficient form of this algorithm, in C, is illustrated in Fig. 7.

Improvements

The midpoint algorithm as presented in Refs. 1 and 2 has an inefficiency which, if eliminated, can save one additional step in three of the four cases (Table I).

The major advantage of the mid-diagonal algorithm is that it has only three additions/subtractions per pixel as compared to the improved implementation of the midpoint algorithm with a minimum of three to a maximum of nine (dependent on region and condition). The disadvantage is that the mid-diagonal algorithm plots more points and thus the computational advantage may be overbalanced by the extra time for these additional pixels.

By considering the pixels two at a time, plotting of the corner pixels may be avoided when horizontal and vertical moves alternate. That is, if a vertical or horizontal move is followed by a diagonal move, only the diagonal pixel is plotted (Fig. 8).

The adapted mid-diagonal implementation, shown in Fig. 9, demonstrates the use of the two variables "vert" and "hor" to track alternate vertical and horizontal moves that will eliminate plotting one of the two pixels.

```
      /**********************************************/
      /*     Mid-diagonal algorithm for an ellipse   */
      /**********************************************/
void Ellipse(r1,r2)
   int r1,r2;
     {  int x,y;
        long d,rsq1,rsq2,t1,t2,t,tt;
        void plot();             /*   the plotting function  */
        x = r1;  y = 0;                /* start point */
        rsq1 =r1*r1;   rsq2 = r2*r2;               /* initial d  */
        d =  (long)((rsq1 + rsq2)/4 - r1*rsq2);  /* close enough */
        t1 = 2*rsq1;    t2 = 2*rsq2;               /* let's add */
        t = t2*x;
        tt = 0;
      /***  compute points in 1/4 of ellipse  ***/
        while ( x > 0 )
          {   plot(x,y);      /* plot the points */
              if ( d < 0 )
                   {  y++;
                      tt = tt + t1;
                      d = d + tt;          /* d = d + 2*y*rsq1; */
                   }
              else
                   {  x--;
                      t = t - t2;
                      d = d - t;            /* d = d - 2*x*rsq2; */
                   }
          }
        plot(x,y);              /* plot the last point */
     }
```

Fig. 7 C code for the mid-diagonal algorithm

old	new
t = t2 * x;	t = t2 * x - t3; t4t3 = t4 - t3;
d1 = d1 + tt - t + t4; d2 = d2 + tt - t + t3;	d1 = d1 + tt - t + t4t3; d2 = d2 + tt - t;
d2 = d2 + tt - t + t3;	d2 = d2 + tt - t;
d2 = d2 - t + t3;	d2 = d2 + t;

Table I

The additional computations are one add per pixel and one "if" test for each pair of pixels. The assignments are also added, but these are very fast compared to additions.

Error

The 8WS midpoint algorithm has a maximum error of half the distance between vertically and horizontally adjacent pixels. The 4WS mid-diagonal algorithm has a slightly larger maximum error of half the distance between diagonally adjacent pixels. If the vertical and horizontal distances are defined to be equal to a unit step, the 8WS error is bounded by 1/2 and the 4WS error is bounded at $\sqrt{2}/2$.

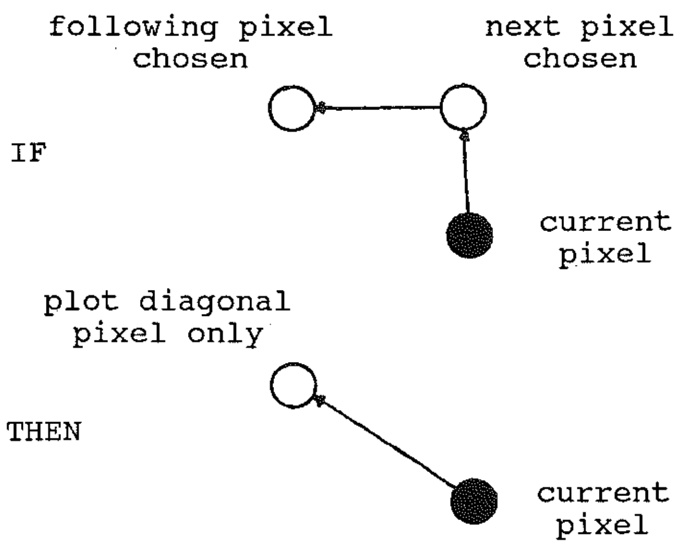


Fig. 8 Minimizing pixels

Performance Change

The mid-diagonal method produces more pixels with fewer computations. The increased robustness occurs closest to the slope of the ellipse. This fullness can enhance the edge, especially useful as systems are produced with smaller and smaller pixels.

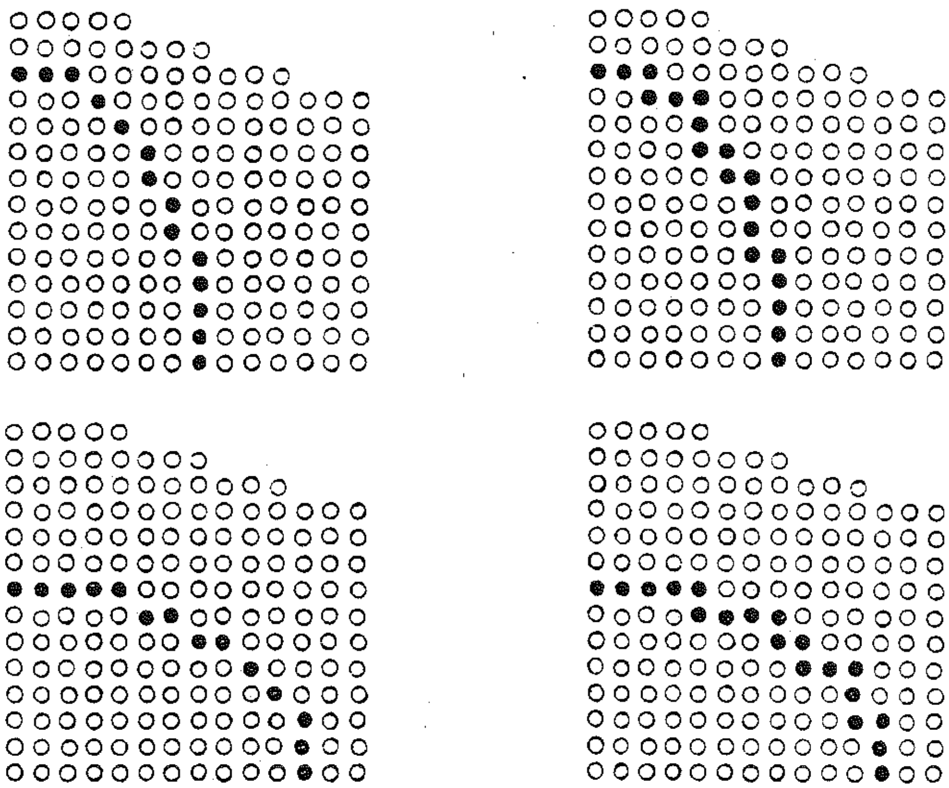
While the mid-diagonal algorithm chooses more pixels, it requires fewer computations. Table II compares the number of pixels and the number of integer additions/subtractions for various ellipse sizes. In general, there is a more than thirty percent reduction in computations with about a thirty percent increase in pixels using the mid-diagonal method. Figure 10 compares the

```
        /****************************************************/
        /*  Improved mid-diagonal algorithm for an ellipse   */
        /****************************************************/

void Ellipse(r1,r2)
   int r1,r2;
     {  short vert, hor;
        int x,y,xx,yy,cnt;
        long p,rsq1,rsq2,t1,t2,t,tt;
        void plot_points();          /*   the plotting function  */
        x = r1;  y = 0;                   /* start point */
        rsq1 =r1*r1;   rsq2 = r2*r2;
        d =  (long)((rsq1 + rsq2)/4 - r1*rsq2);   /* close enough */
        t1 = 2*rsq1;    t2 = 2*rsq2;              /* let's add */
        t = t2*x;
        tt = 0;
        vert = 0;  hor = 0;            /* keep track of pixel pairs */

           /***  compute points in 1/4 of circle  ***/
        while ( x > 0 )
          {   plot_points(x,y);    /* plot points */
              if ( d < 0 )
                  {  y++;  vert++;
                     tt = tt + t1;
                     d = d + tt;          /* d = d + 2*y*rsq1; */
                  }
              else
                  {  x--;   hor++;
                     t = t - t2;
                     d = d - t;           /* d = d - 2*x*rsq2; */
                  }
                  /**  second point of set  **/
              if ( d < 0 )
                  {  yy = y + 1;  xx = x;
                     vert++;
                     tt = tt + t1;
                     d = d + tt;          /* d = d + 2*y*rsq1; */
                  }
              else
                  {  xx = x -1;   yy = y;
                     hor++;
                     t = t - t2;
                     d = d - t;           /* d = d - 2*x*rsq2; */
                  }
             if (vert != hor)
                 plot_points(x,y);       /*  plot both points */
             x = xx;  y = yy;
             vert = 0;   hor = 0;
           }
        plot_points(x,y);      /* plot the last point */
     }
```

Fig. 9 C code for improved mid-diagonal method

Ellipse size	No. of pixels MP	MD	No. of computations MP	MD
7 x 11	14	19	88	54
11 x 7	14	19	78	54
40 x 50	65	91	415	270
50 x 40	65	91	393	270

Table II Comparing the algorithms (1/4 ellipse)



(a) (b)

Fig. 10 Comparison of pixel selection for 7x11 and ellipses using a) the midpoint algorithm and b) the mid-diagonal algorithm

Ellipse size	No. of pixels MP	MD	No. of computations MP	MD
7 x 11	14	14	81	72
11 x 7	14	14	67	72
40 x 50	65	65	375	360
50 x 40	65	65	343	360

Table III Improved algorithms (1/4 ellipse)

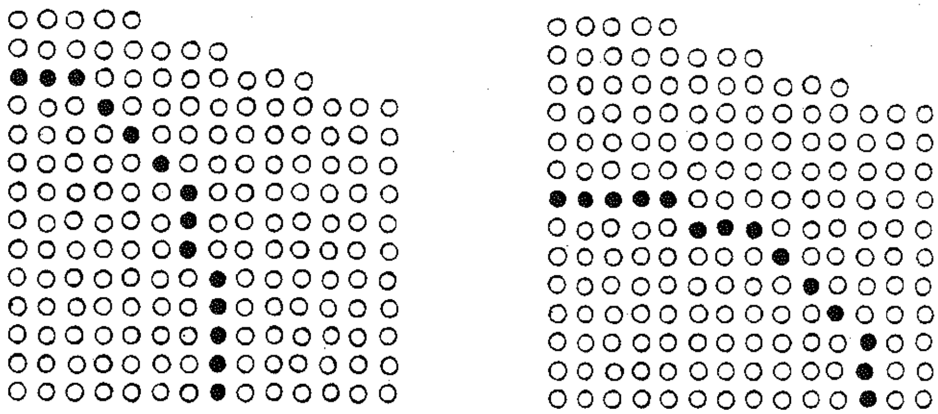


Fig. 11 Pixel selection for 7x11 and 11x7 ellipses using the improved mid-diagonal algorithm

midpoint pixel selection with the mid-diagonal pixel selection for both a horizontal and vertical ellipse.

The improved algorithms are compared in Table III. The number of operations for the improved midpoint algorithm has been reduced as expected. Now the improved mid-diagonal algorithm produces the same number of pixels as the midpoint algorithm. The computational saving for the midpoint algorithm now causes ellipses with a larger major axis to be drawn more efficiently than the mid-diagonal method. This indicates that perhaps the selection of drawing algorithm should be made dependent on the major and minor axes.

Figure 11 illustrates the mid-diagonal pixel selections for the same two ellipses as shown in Fig. 10. There is one pixel selection using the mid-diagonal algorithm that differs from the midpoint algorithm. For other ellipses more differences could be expected since the error for these two algorithms is not the same. As the resolution of CRTs improves, the minor differences in the pixel selections will have less and less meaning.

References

[1]VanAken, J. R., "An Efficient Ellipse-Drawing Algorithm", *Computer Graphics and Applications*, Vol. 4, No. 9, Sept., 1984, pp. 24-35.

[2]VanAken, J. R. and Novak, M., "Curve Drawing Algorithms for Raster Displays", *ACM Transactions on Graphics*, Vol. 4, No. 2, April, 1985, pp. 148-169.

UPDATE OUR RECORDS

In order to provide you with uninterrupted mailing of the *Engineering Design Graphics Journal* and other services provided by the Engineering Design Graphics Division of ASEE, we would like to know of any changes in your mailing address, phone number, and FAX number. If changes need to be made, please copy this form, complete all sections, and mail to:

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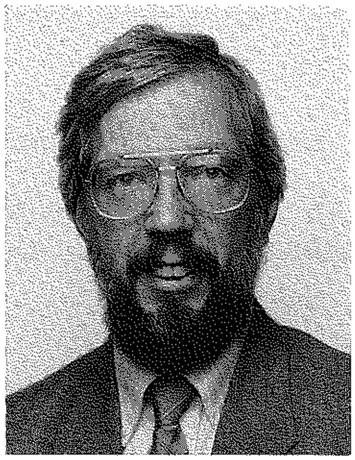
Chairman's Message

by
Jon Jensen



Shakespeare once said that "all of life is a stage upon which we play out our lives". I'm not entirely sure that this is true, but it sounds good to me. Fred Pryor, a nationally known business and management consultant, states that as we play out our lives we can represent three different roles; we can be an "Understudy", a "Primadonna", a "Performer", or perhaps more appropriately, a "Director". Interestingly enough, I find that these concepts have a rather profound significance to me as I attempt to formulate a sense of the direction that engineering graphics programs and coursework are now taking. An Understudy is a person who is just a shadow of the existence that he could be, and a Primadonna is always trying to overshadow everyone else's existence. But if we are a Director, we're directing our light and being a source of light, not only to ourselves, but also to those around us.

For those who had the good fortune to be able to attend the Mid-year Conference in Tempe, Arizona, we were treated to wonderful weather, great conference arrangements, and a slate of paper presentations that exemplify the term "Direction". Many of the presentations involved new materials and techniques, new concepts of teaching the content, altogether new concepts, and research. It appears to me, of late, that the "Directors" are taking command (but not necessarily control) of the program. This is an encouragement to me. However, it would appear we also need to be more involved with something that Karl Smith at the University of Minnesota coined, "Structured Controversy". That is, we need to develop formal times to discuss important issues before our Division and profession in an unrestricted fashion. A time when we can engage each other and/or express opposing viewpoints. Some say that doing this can be risky. However, there is a risk in undertaking any course of action. For instance, if we choose not to take a risk, we are taking the risk of staying the same. So - What risk do you prefer?

I would now like to take this opportunity to thank the membership of the Division for their guiding support during my tenure as Chairman of the EDG Division. I am looking forward to the Annual Conference in New Orleans and hope to see all of you there. If you have never been to this extraordinary city, it is worth the effort. See you all in Cajun country.

Calendar of Events

by
Bill Ross

1991 ASEE Annual Conference
June 16-20, 1991
New Orleans, Louisiana
Theme: Challenges of a Changing World
Program Chair: Bill Ross
Purdue University
Ph. (317) 494-8069
FAX (317) 494-0486
Facilities Chair: Mary Jasper
Mississippi State Univ.
Ph. (601) 325-3922
FAX (601) 325-8573

1991-92 EDGD Mid-year Conference
November 3-5, 1991
Norfolk, Virginia
Host: Old Dominion Univ.
Gen. Chair: Moustafa Moustafa
Old Dominion Univ.
Ph. (804) 683-3767
FAX (804) 683-4898
Prog. Chair: Barry Crittenden
VPI&SU
Ph. (703) 231-6555
FAX (703) 231-6903

1992 ASEE Annual Conference
June 21-25, 1992
Toledo, OH

1992 5th International Conference on Engineering and Descriptive Geometry
August 17-21, 1992
Melbourne, Australia
(See announcement - page 56)

1992-93 EDGD Mid-year Conference
San Francisco, CA (tentative)

1993 ASEE Annual Conference
June 20-24, 1993
Urbana, IL

International Computer Graphics Calendar

by
Vera Anand

May 13 - 16, 1991
ICSE 13, 13th Int'l Conf. on Software Engineering, Austin, TX. Contact: David Barstow, Schlumberger Lab for Computer Science, PO Box 200015, Austin, TX 78720-0015

May 15 - 17, 1991
CCW 91, Third IEEE Conf. on Computer Workstations, Cape Cod, MA. Contact: Keith Marzullo, Computer Science Dept., Upson Hall, Cornell University, Ithaca, NY 14853.

Jun 5 - 7, 1991
2nd Eurographics Workshop on Object Oriented Graphics, The Netherlands. Contact: Marja Hegt, O-O Graphics Workshop, CWI, Kruislaan 413, 1098 SJ Amsterdam, The Netherlands. Ph. (+31)20-592-4058; FAX (+31)20-592-4199.

Jun 5 - 7, 1991
ACM Solid Modeling Sym., Austin, TX. Contact: Mary Johnson, CII7015, RPI, Troy, NY 12180-3590. FAX (518) 276-2701.

Jun 10 - 12, 1991
7th Annual Sym. on Computational Geom., North Conway, NH. Contact: Scot Drysdale, Math. and Computer Sci., Dartmouth College, Hanover, NH 03755. Ph. (603) 646-2101.

Jun 22 - 28, 1991
Computer Graphics Int'l '91, Cambridge, MA. Contact: N. M. Patrikalakis, MIT Rm. 5-428, 77

Massachusetts Ave., Cambridge, MA 02139. Ph. (617) 253-4555; FAX (617) 253-8125.

Jun 22 - 28, 1991
Computer Graphics International '91, Cambridge, MA. Contact: N. M. Patrikalakis, MIT Rm. 5-428, 77 Massachusetts Ave., Cambridge, MA 02139. Ph. (617) 253-4555; FAX (617) 253-8125.

Jun 25 - 27, 1991
First Int'l. Conf. on Artificial Intelligence and Design, Royal Museum of Scotland, Edinburgh, UK. Contact: John Gero, Dept. of Arch. and Design Science, Univ. of Sydney NSW 2006, Australia. Ph. 61-2-6922328.

Jul 29 - Aug 2, 1991
SIGGRAPH 1991, Las Vegas, NV. Contact: Michael Bailey. Ph. (619) 534-5142.

Aug 7 - 10, 1991
12th Annual Conf. of the European Assoc. for Computer Graphics, Vienna, Austria. Contact: Interconvention, Austria Center Vienna, 1450 Vienna Austria.
Ph. +43/222/23 69/2643
FAX +43/222/23 69/648

Aug 13 - 15, 1991
ASE '91 - 2nd Int'l. Conf. on Applications of Supercomputers in Engrg., Boston, MA. Contact: Liz Newman, Computational Mechanics Institute, Ashurst Lodge, Ashurst, Southampton, S042AA, England. Ph. +44 (0) 703 293223.

Aug 13 - 16, 1991
7th Scandinavian Conf. on Image Analysis, Aalborg Univ., Denmark. Contact: Prof. Erik Granum, 7th SCIA Conf. Chair, Lab. of Image Analysis, Institute of Electronic Systems, Aalborg Univ., Badehusvej 23, DK-9000, Aalborg, Denmark.

Aug 27 - 30, 1991
CADDM'91, Third Int'l. Conf. on Computer Aided Drafting, Design and Manufacturing Tech., Beijing, China. Contact: Prof. Chen Jiannan, P. O. Box 85, Beijing, China. Telex 22036 BIAAT CN.

Sep 2 - 6, 1991
Eurographics '91, 12th Annual Conf. of the European Assoc. for Computer Graphics, Hofburg, Vienna, Austria. Contact: Interconvention, Austria Center Vienna, 1450 Vienna, Austria. Ph. +43/222/23 69/2643.

Sep 11 - 13, 1991
6th Int'l Forum on CAD, Hilton Hotel, East Midlands Airport, UK. Contact: Carolyn Hall, Euroteam, Univ. of Leicester, LE1 7RH, U.K. Ph. (44) 533-522408; FAX (44) 533-522200.

Sep 16 - 20, 1991
COMPUGRAPHICS 91 - First Int'l Conf. on Computational Graphics and Visualization Techniques, Sesimbra, Portugal. Contact: Harold Santo, Dept. of Civil Engrg, Institute of Engrg, Tech. Univ. of Lisbon, 1096 Lisboa Codex, Portugal.
Ph. +351-1-801579/802045 x 1638
FAX +351-1-897650/899242
e-mail d1663@eta.ist.rccn.pt.
(See full page ad - page 2)

For further information, contact Vera Anand, 302 Lowry Hall, Clemson Univ., Clemson, SC 29631. (803) 656-5755

N.B. Discount rates will apply to ASEE & EDGD members

5th International Conference on Engineering Computer Graphics and Descriptive Geometry

August 17-21, 1992
Hilton International Hotel, Melbourne, Australia

FIRST ANNOUNCEMENT AND CALL FOR PAPERS

Sponsored by: Engineering Design Graphics Division, American Society for Engineering Education (ASEE).

Co-sponsored by: Association for Computer Aided Design, Victoria (ACADS).

Hosted by: Royal Melbourne Institute of Technology, Melbourne, Australia.

The Fifth International Conference on Engineering Computer Graphics and Descriptive Geometry will be a continuation of the International conferences in this series held in Vancouver in 1978, Beijing in 1984, Vienna in 1988 and Florida in 1990.

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Papers dealing with the following topics are solicited:

1. Theoretical Graphics
   Descriptive Geometry
   Kinematic Geometry and other Applications of Geometry
2. Engineering Computer Graphics
   Computer Aided Design
   Computer Aided Geometric Design
   Computerised Descriptive Geometry
3. Graphics Oriented Expert Systems
   Scientific and Technical Visualisation
   Engineering Animation
   Image Processing and Remote Sensing
4. Graphics Teaching
   Graphics Exercises
   Computers in Engineering Graphics Education
5. Other topics of interest will be considered.

Deadlines

- Submission of the pre-registration forms:
  May 1, 1991
- Deadline for submitting a 250 word abstract:
  September 16, 1991
- Notification about preliminary acceptance by:
  December 2, 1991
- Deadline for submitting full papers ready for photo-offset:
  March 2, 1992
- Notification about acceptance by:
  May 15, 1992

For further information contact:

In Australia : *Mr. V. O. (Tom) Thomas,*
Mechanical Engineering,
Department of Manufacturing and Process Engineering,
Royal Melbourne Institute of Technology,
Melbourne, Victoria 3001, Australia.
Ph. +61 3 660 2166, 660 2523, Fax No: +61 3 663 7873

In USA : *Prof. Larry D. Goss,*
University of Southern Indiana, 8600 University Boulevard, Evansville, Indiana 47712, USA.
Ph. (812) 464 1892, Fax No: (812) 464 1960

Call for Papers

EDGD 1991-92 Mid-year Conference
November 3-5, 1991
Old Dominion University
Norfolk, Virginia

A Potpurri of Engineering Design Graphics

Topics are limited to various aspects of engineering design graphics. If the response to the Call for Papers is suitable, a "poster session" may be initiated.

Abstracts to 250 words are due not later than July 1, 1991. Submit to:

Barry Crittenden
Program Chairman, EDGD Mid-year Conference
EF, VPI&SU
Blacksburg, VA 24061-0218

Ph. (703) 231-6555

FAX (703) 231-6903

Notice of acceptance will be mailed by July 31, 1991. Completed papers will be due not later than September 15, 1991.

Reorganization at Iowa State

by
Rollie Jenison

The College of Engineering at Iowa State University completed the last phase of its reorganization when the new Division of Engineering Fundamentals and Multidisciplinary Design (EFMD) was recently approved by the University and Board of Regents. The core faculty group for the Division will be the faculty formerly associated with the Department of Freshman Engineering which was eliminated in the reorganization. The faculty will carry titles of Professor of Engineering, Associate Professor of Engineering, etc.

EFMD will continue to provide lower-division instruction in graphics and problem solving and will maintain computer laboratories for use in common-knowledge-base subjects and multidisciplinary activities. New opportunities are available for faculty to participate in team efforts to improve engineering education with new methodologies and new technologies. EFMD faculty are being encouraged to work with departmental faculty in an effort to make the total engineering education experience more coherent, meaningful and exciting for the student. A new high-tech classroom and the NSF synthesis coalition, of which Iowa State is a member, will help support new undergraduate initiatives in the Division and across the college.

Rollie Jenison, who for the past two years has served as Interim Department Executive Officer for Freshman Engineering, will continue in that capacity for EFMD until a new chairperson takes over on July 1, 1991. More information may be obtained on this new organization by contacting:

Rollie Jenison
EFMD
Iowa State University
212 Marston Hall
Ames, IA 50011
(515) 294-1614

Comments on the Transition to New Technologies

by
Ed Knoblock
January 30, 1991

Years ago it was clear that the transition to CADD would be difficult. In addition to very limited budgets, the lack of communication between the computer programmers and designers resulted in awkward CAD programs and lousy documentation practices. Most of these problems were resolved during the past decade, resulting in relatively inexpensive, stable, and useful software. However, during this period it has become obvious that other fundamental problems persist. I had failed to recognize that so many 2-D thinkers existed in the world of engineering graphics. This accounts for more problems than first realized. More recently we have people who seem to believe that futures are enhanced by scorning the present and past.

The main reason for this letter is to take issue with the current jabber by a few that we can forget the past [whether or not we understand it] because we will be saved by a future of "virtual", "hyper-", and "cyber-" computer jive.

I will begin with several general observations, then follow with specific remarks on items in recent issues of the *Journal*.

1. One of the first things that is taught in semantics is that words do not mean; people have meanings for words. Meanings given to words change, from environment to environment, and with time.

2. New technologies are rarely developed without a relationship to prior technologies. History is a vital element of understanding any technology. New technologies often increase, rather than reduce, the set of available tools.

3. The human interface is always more important than the technology itself. I still hear that 33-40% of CAD installations are failures, i.e., not cost effective.

I had several reactions to Pat Kelso's, "A Comment", Spring, 1990[1]. Pat should not dismiss ideas that visualization can be taught just because they don't fit his need. As we note in the Winter 1991 issue some people think he is obsolete to suggest that descriptive geometry is valuable, let alone usable in 3-D modeling. It is interesting that Pat's comments on visualization are almost identical to those made by a LSU faculty member about 20 years ago on the teaching of creativity in the context of design. I would like to hear more about his concept that learning and skill enhancement are different things. Educators should understand that learning, not teaching, is the most important process. Hopefully, instructors are aware of what is being learned under their directions, and what may be learned in spite of their directions.

No publication will contain the mix of articles that exactly suits our individual needs. But any attempt to find a better understanding of how people visualize is most germane to graphics. By testing students, and listening to comments of former students, I know that visualization skills are learned, and are valuable to them. Of course, they must learn how to analyze images by classifying and defining geometric elements and primitives. They must also learn both the differences and similarities between the images of models and actual spatial relationships [i.e., lines that appear perpendicular or parallel but are not, etc.] It is true that one course does not allow enough time to do all the things we would like to do, but that's life in most engineering programs. Many technology programs have a much better shot at the task. Never-the-less, ideas begin with mental imaging, not computer imaging.

While I appreciate Pat's call for more movement to 3-D modeling, a fairly recent article[2] with his name on it illustrated using CADKEY[3] as a 2-D tool. My real concern is that the authors did not attempt to optimize its use. Nor did they explore variations of strategies. Their solution used folding lines and a backstop line that serve no purpose except to create more work. The solution is simplified by moving and rotating only four lines, [3 frontal, and the oblique] to the auxiliary position before placing projection lines. In addition, only one line needs to be drawn parallel to the datum [front or back surface]. The rest of the auxiliary view can be created using the TRiM/EXTend function.

Pat, it seems we disagree on the meaning of both the terms meatier and "Kentucky windage". Move to CADD? definitely! But not without questioning every step of the way.

I have many more serious disagreements with the ideas expressed by D. Juricic and R. Barr in the article "Geometry vs. Descriptive Geometry .....", Winter, 1991[4]. First, I am as disappointed as anyone to see CADD software misused. Faculty should know the power of their system and not just imitate manual methods. It is especially sad when people use a 3-D system and are not aware of its potential.

Second, my comments are not meant to question the importance or value of solids modeling.

However, Profs. Juricic and Barr begin by saying that developers of computer graphics systems had communications problems, and then base much of their premise on the "hype" coming from the same arena. In attempting to discredit the future of prevailing practices, they use outmoded definitions. Please note that they present no definitions for the terms, or details of methods used in their version of the future.

Let the defense of descriptive geometry be left to those who believe it has a future. Those who believe otherwise can prove their point by delineating their methods for our enlightenment. On to the defense of "descript".

In the simplest of terms, a model is <u>any</u> representation of the real thing. Beyond that, authors and dictionaries do not agree. They also do not attempt to explain the often subtle differences between iconic, analog and symbolic types. One problem is that what is symbolic to one person may look like the real thing [iconic] to another person. An example from anthropology shows a rough drawing that most of us would see as an elephant skin laid flat. The same drawing was seen by aborigines as an elephant jumping up and down.

Much of the discussion of models by the futurists is a "red herring". A 2-D drawing has as much right to be called a model as does a computer database. A multi-view drawing may logically be considered iconic by a trained observer. At this point in time all CADD images are displayed on 2-D screens, regardless of the architecture of the database. The image generated from the database follows rules of projection, upon command of an operator. When 3-D displays [holograms or others] will be cost effective for the average user is a guess. It is doubtful that it will occur in this decade.

"Descriptive geometry - the application of graphical methods to the solution of three-dimensional space problems."[5] Note that at least one dictionary presents a definition that is not tied to specific tools, media, or even techniques. Since Monge first codified Descriptive Geometry [he did not invent most of the methods used], the tools, media, and the methods have all changed. When the methods changed drastically earlier in this century it was still called descriptive geometry. In like manner, as the methods change with forms of "solids modeling", they will most likely be called descriptive geometry.

There is no such thing as 2-D descriptive geometry. It is implemented in both 2-D and 3-D modes. It includes one, two, and multi-view methods. It encompasses definitions, required conditions and techniques used to construct, not just analyze the attributes of true size, true angles, intersections, tangencies, etc., for spatial problems using orthogonal, spherical, stereographic, or other projection standards. Solids modeling does automate some of these tasks [such as intersections], but does not handle many design tasks without highly structured instructions from a person. In a graphics mode, using revolution, cutting planes, construction planes, inclined and oblique views is in fact using elements of descriptive geometry. Knowing what is required to create [not just measure] true [length, size, angles] entities and/or views of entities under many types of constraints is knowing descriptive geometry. We can now construct or find an oblique view directly without first establishing an inclined view. But knowing when to use either or both such views is knowing descriptive geometry.

Engineers and technologists will continue to work with a variety of tools [pencil, mouse, etc.] to create a useful images [drawings, CRT displays, etc.] To imply that the thinking and action processes must be named by new terms because the tools change is erroneous. This type of puffery is only used to hide the real issues.

If I create an image of a line, surface, or solid figure by pointing to endpoints, or items on a menu, I am drawing just as certainly as when using a pencil on paper. My success or failure is first evaluated by examining the image produced, not the database, or the mathematics used to execute the program. When the opportunity exists to create actual 3-D images that can be walked around, I may wish to call it sculpting. But even then I will need to use and understand "descript".

Also remember, many jurisdictions do not yet accept magnetic copies as licit documents. This is only one reason why CADD has not decreased, paper consumption. As one sage has said, "The paperless factory is as real as the paperless bathroom". In the suggestion that drawings may be needed for "another decade, or so", the "or so" may be better defined as infinity. Why do many academics insist that all engineers and technologists only work with state of the art technologies?

If I am wrong, Profs. Juricic, and Barr, and others will rebut my hypothesis. They will be able to delineate methods of the virtual, hyper-, cyber- world that accomplish tasks equivalent to those given below without any knowledge of descriptive geometry!

1. Establish the location of the optimal [constraints of your choice] tunnel between two existing skew tunnels.

2. Create a hole that passes through a known point on one surface that makes specified angles with two adjacent surfaces.

3. Design an "Ames Box" of any size, but with at least a 2.5:1 distortion ratio, to illustrate this well known 3-D visual illusion.

Generating a solid model of a given simplistic part is not design. Nor is it a justification for the demise of descriptive geometry.

A final cautionary comment. When moving on to any new academic future be sure that you clearly define an acceptable academic discipline. Also be sure that it doesn't already belong to someone else. Otherwise historians may observe that "He was hoist by his own petard!"

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[4]Juricic, D. and Barr, R. E., "Geometry vs. Descriptive Geometry and Graphics vs. 3D Modeling - In Search of Correct Terminology", *Engineering Design Graphics Journal*, Vol. 55, No. 1, Winter, 1991.

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Comments on Ed Knoblock's Letter

by
Pat Kelso
March 4, 1991

I wish to thank Edward Knoblock for copying me with his letter so I may respond in the same issue. I join him in encouraging dialogues through the Journal.

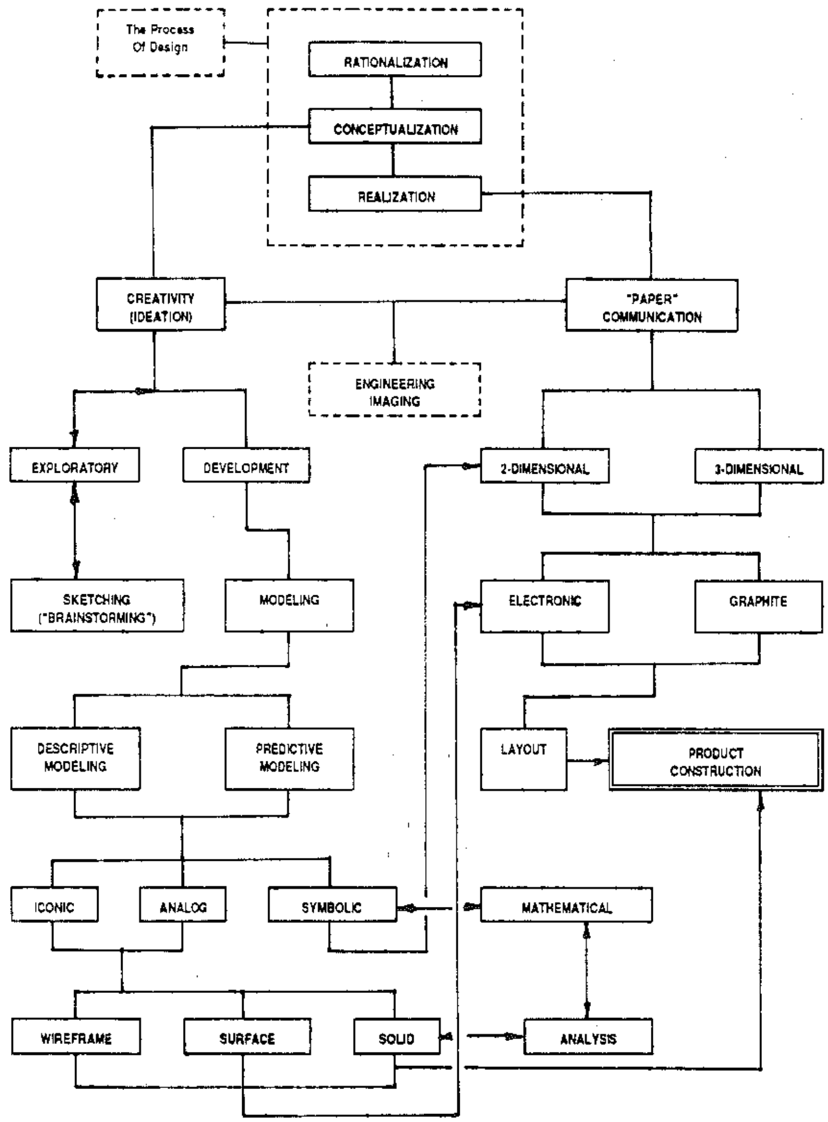
Before I address Ed's specifics, permit me to address what I believe may be the source of his frustration.

Monge discovered how to create virtual space on a plane surface. The computer creates virtual space behind the computer monitor screen. The character of the virtual space behind the screen is more nearly like our everyday real life space, hence, is superior to Monge's virtual space for purposes of designing three-dimensional objects, i.e., other than circuits, shims, gaskets, etc. Because a designer is still (in the main) obliged to **communicate** using paper sheets, Monge's virtual space is the only virtual space available for communication, hence, it is indispensable at this time. (Also the computer (operator) may generate Mongean virtual space, i.e., draw a multiview on the screen surface and then plot it out on a paper sheet.) *But the computer will automatically now create a multiview directly from a computer model.* Because both types of virtual space may be generated from the virtual space of the computer, but not both types from Mongean virtual space, the virtual space of the computer becomes the logical method of choice. For whatever benefit, I am enclosing a draft of a flow chart (see next page) of where computer modeling and engineering graphics/design fit within engineering design. (The double direction arrows signify possible situations of reverse engineering, i.e., synthesis. Note the incorporation of Juricic's work.)

To address Ed's points as they relate to me:

I believe the ability to visualize is an aptitude - a talent. Like any talent I believe it is enhanced by practice. However I do not believe a talent can be taught. My own talent for music is negligible. If I practice the piano all day everyday for the rest of my life I am sure I will improve but I will never be as good as a person of much greater talent and who practices just once a week. A great pianist can explain to me what I must do to become a great pianist but unless I am musically gifted then that explanation serves only to frustrate and bewilder. A better approach, I suggest, is to teach me the mechanics of how to make certain sounds on a piano in the hope that in making those sounds whatever talent I have will surface. The point: teach the theory and mechanics of engineering graphics and modeling, and a student's ability to visualize will take care of itself - to the extent it can be. This is especially true with computer geometric modeling because an isometric view is continually available as a designer creates a model. But it you tell me that you taught someone to visualize, I will tell you he would have learned it in any event.

With regard to my, and others, differences with the distin-



ENGINEERING IMAGING FLOW CHART

guished Davor Juricic, et. at., regarding the need of Descriptive Geometry within the discipline of computer geometric modeling, I believe the differences may be largely definitional. I recently came to the opinion that by Descriptive Geometry, Monge means simply, the process he devised to create virtual space on a flat surface: orthographic-orthodirectional projection. In the past, I defined Descriptive Geometry as the direction, mentally determined, to view a particular geometry, e.g., the true angle between a line and a plane, in its most descriptive fashion, i.e., the angle in True Size. I now relegate this process to a combined application of plane and solid geometry and which has no single name designation. (Note that **creating** the auxiliary (solution) view determined by this process falls within Orthographic-Orthodirectional Projection.) Unfortunately, I believe today's use of the term *Descriptive Geometry* in the literature implies the latter (incorrect) definition. I submit that Descriptive Geometry, as defined in this incorrect way, is required within the discipline of computer geometric modeling. For example, suppose that you model an irregular tetrahedron and need the size of the angle between one of its lines (of intersection) and a plane of the tetrahedron. Perhaps the most obvious solution, not using rotation, is to construct a line which is both (1) perpendicular to the given line, and (2) parallel to the given plane, and then to computer generate a Point New-View of the construction line. To determine the direction in which to draw the construction line is an exercise in Descriptive Geometry (i.e., plane/solid geometry) and seems to me fundamental for engineering students.

The "fairly recent article", *A Technique for Drawing Auxiliary Views Using 2-D CAD (CADKEY)*, was written in 1986, only one year after CADKEY released true geometric modeling for the PC. Prior to this paper, much was written about using trigonometric functions to produce the auxiliary views. The article attempted to demonstrate a geometric treatment. I now consider using the computer as a drawing tool for engineers as somewhat superfluous, if not trivial, and, therefore, must similarly characterize the 1986 paper.

Kentucky windage is a tongue-in-check term from a by-gone era referring to the amount to aim in front of a bird to allow for the wind when shooting at it on the wing. I used the term only in the context that I believe students four years hence, i.e., seniors, will primarily model, rather than draw, their designs and that to anticipate this we should begin teaching modeling now.

This letter supports Ed Knoblock's of February 20, 1991 to the Journal in which he attempts to promote a dialogue among the membership. Recall my dismay some years ago when the Journal rejected my papers because, it seemed to me, some reviewers were not current on the technology. As a result, I proposed that refereeing be suspended and that authors take their lumps through letters to the editor and such. This would allow authors to rebut in the same issue. That the membership is at a disadvantage because of a lack of a past dialogue is evident from the Austin Symposium where many presenters simply talked past each other. It's further evidenced by the rancor that followed and, at this late date, a recourse to basic definitions - even those found in dictionaries (!). (Using dictionaries for graphics definition misses an important point: the membership defines the discipline to the dictionaries, not vice versa.) Ed's idea of taking a written position on controversial topics and simultaneously copying the antagonists permits an exchange within the same issue. I encourage the Journal to structure a way to keep this going.

Election Results

by
John Demel

As a result of the recent balloting, Vera Anand of Clemson University has been elected to the position of Vice-Chairman, Jim Leach of the University of Louisville has been selected as Secretary-Treasurer, and Mary Sadowski of Purdue has been chosen as Director: Publications (*Journal* editor). Duties will begin upon adjournment of the Business Meeting of the Division at the ASEE Annual Conference in New Orleans. Our congratulations to these new officers and our thanks to all those who agreed to run for office.

Editor's Comments

by
Barry Crittenden

This issue of the *Journal* marks the end of my tenure as editor. Mary Sadowski of Purdue will assume the duties of Director: Publications in June.

My thanks to the Division membership for your support and kind remarks over the past three years. I pass the responsibilities of *Journal* editor to Mary with both sadness and exhilaration. I shall truly miss the constant contact with so many of you, which is a requirement of organizing each issue. I shall miss the feeling of accomplishment with the mailing of each issue. And I shall miss the opportunity of reading some outstanding papers before anyone else has the chance to read them.

I must admit, however, it will be a relief not having to worry about deadlines for publication. But don't let that remark discourage any of you from accepting the nomination for Director: Publications in the future. It is, without a doubt, the best position of leadership in the Division. However, assuming the editorship of the *Journal* for three years is enough. It's time for a new breath of life to be infused into the publications area. Please give Mary your full support.

Without the assistance of numerous persons, publishing the *Journal* would be impossible. The *Journal* staff and Board of Review have done a fine job. I would particularly like to thank George Lux of VPI&SU for handling the task of Technical Editor. Having papers reviewed in a timely manner is no easy task, but one which I could always count on being done most efficiently. Clyde Kearns of Ohio State, the Circulation Manager, has been a source of constant support and encouragement. Without his personally generated mailing labels, recent issues of the *Journal* might have arrived in your hands anywhere from several weeks to several months later than they did. Clyde's efforts in maintaining accurate subscription records has assured timely delivery. Jerry Smith and Dennis Short, both of Purdue University, have done yeoman service as Advertising Managers. As a result of their efforts, about one-third of *Journal* costs are now being subsidized by advertising.

There have been several disappointing aspects of being *Journal* editor. I have been unable to convince individuals to write quarterly columns - columns dealing with graphics "puzzles", book or software reviews, etc. If Mary Sadowski is inclined to include such sections, consider helping her. In addition, I have often worried whether some individuals have submitted papers for review because of their desire to convey meaningful information to the Division membership or because of their desire to list another publication on their resume. And finally, letters to the editor have been few and far between. I have published every one received. It seems for a group such as ours, more letters concerning numerous topics would be forthcoming. A colleague once asked, "Does anyone ever read that journal?" I must admit, I sometimes wonder!

I have had the pleasure of receiving numerous papers for possible publication during the past three years. A few have been truly outstanding, many have been quite good, and more than you might imagine have been rejected for publication. Why were papers rejected? Some had content not of interest to the Division membership, some attempted to present poorly conducted research, but many were rejected simply because they were so poorly written that ideas were not clearly conveyed to the reviewers. The content of the paper may have been adequate, but the presentation was so weak as to obscure those ideas.

The friendly debate (or controversy) on the future of descriptive geometry which has surfaced since the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum is, in my opinion, an example of poor communications. I have heard arguments from many persons and I am convinced that the two sides (if there are only two sides) are not as far apart some may think. I believe we are just not communicating very well. Possibly, we will improve in our ability to communicate clearly, concisely, and accurately as we realize the potential harm we could do to our profession by failing to do so.

Once again, thank you for allowing me to serve you. It has been a pleasure.

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Scope

This journal is devoted to the advancement of engineering design graphics, computer graphics, and subjects related to engineering design graphics in an effort to (1) encourage research, development, and refinement of theory and applications of engineering design graphics for understanding and practice, (2) encourage teachers of engineering design graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses, and (3) stimulate the preparation of articles and papers on topics of interest to the membership. Acceptance of submitted papers will depend upon the results of a review process and upon the judgement of the editors as to the importance of the papers to the membership. Papers must be written in a style appropriate for archival purposes.

Submission of Papers and Articles

Submit complete papers, including an abstract of no more than 200 words, as well as figures, tables, etc. in quadruplicate (original plus three copies) with a covering letter to J. B. Crittenden, Editor, Engineering Design Graphics Journal, EF - VPI&SU, Blacksburg, VA 24061-0218. All copy must be in English, typed double-spaced on one side of each page. Use standard 8 1/2 x 11 inch paper only, with pages numbered consecutively. Clearly identify all figures, graphs, tables, etc. All figures, graphs, tables, etc. must be accompanied by a caption. Illustrations will not be redrawn. Therefore, ensure that all line work is black and sharply drawn and that all text is large enough to be legible if reduced to single or double column size. High quality photocopies of sharply drawn illustrations are acceptable. The editorial staff may edit manuscripts for publication after return from the Board of Review. Galley proofs may not be returned for author approval. Authors are therefore encouraged to seek editorial comments from their colleagues before submission of papers.

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