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ENGINEERING DESIGN GRAPHICS JOURNAL

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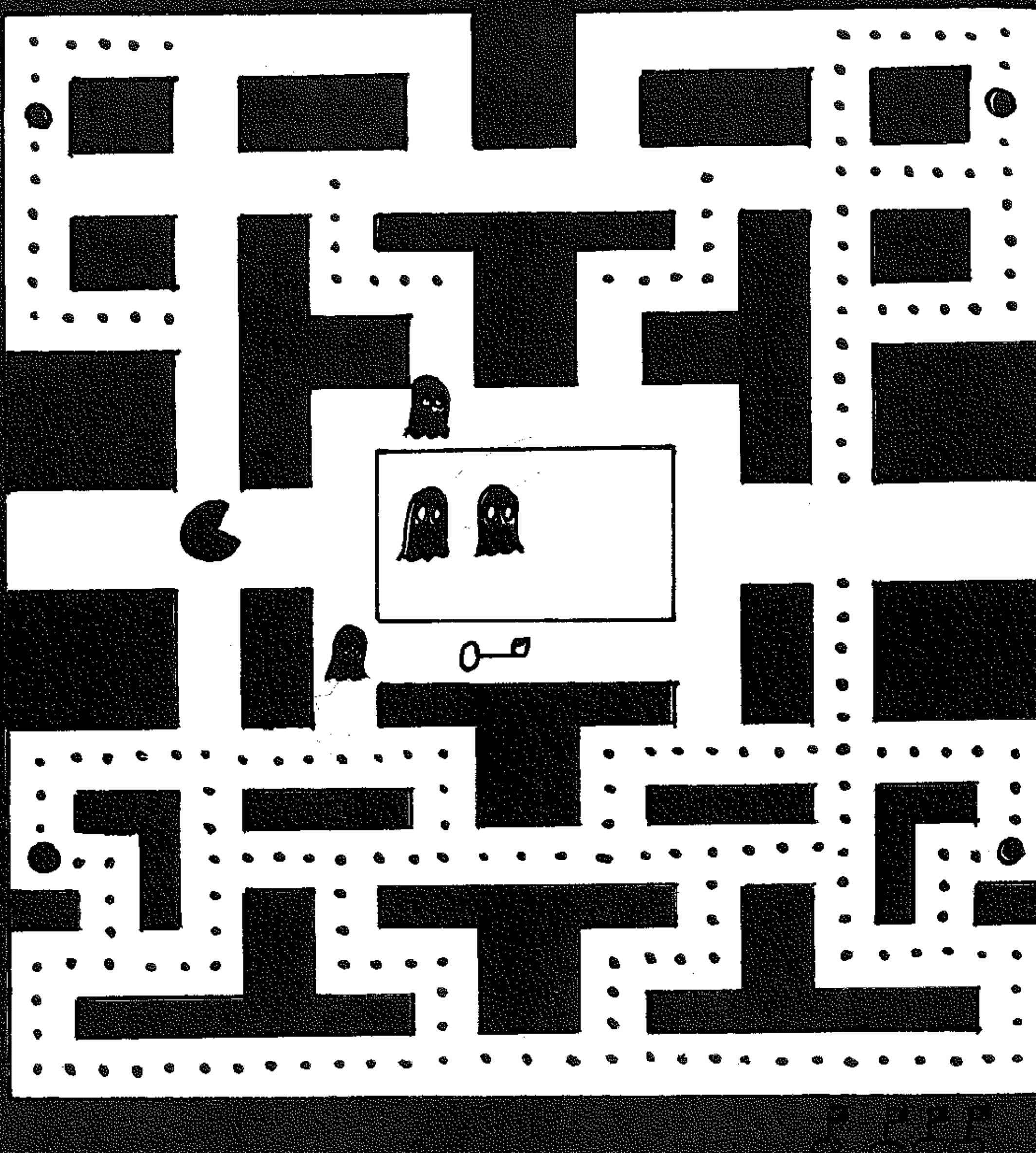

"COMPUTER GRAPHICS IS FUN" ISSUE

ENGINEERING DESIGN GRAPHICS JOURNAL

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

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

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ENGINEERING DESIGN GRAPHICS JOURNAL OBJECTIVES:

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

DEADLINES FOR AUTHORS AND ADVERTISERS

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

Fall	September 15
Winter	December 1
Spring	February 15

STYLE GUIDE FOR JOURNAL AUTHORS

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

1. All copy is to be typed, double-spaced, on one side only, on white paper, using a black ribbon.

2. All pages of the manuscript are to be consecutively numbered.

3. Two copies of each manuscript are required.

4. Refer to all graphs, diagrams, photographs, or illustrations in your text as Figure 1, Figure 2, etc. Be sure to identify all material accordingly, either on the front or back of each.
Illustrations cannot be redrawn; they are reproduced directly from submitted material and will be reduced to fit the columnar page.

Accordingly, be sure all lines are sharply drawn, all notations are legible, reproduction black is used throughout, and that everything is clean and unfolded. Do not submit illustrations larger than 198 x 280 mm. If necessary, make 198 x 280 or smaller photocopies for submission.

5. Submit a recent photograph (head to chest) showing your natural pose. Make sure your name and address is on the reverse side. Photographs, along with other submitted material cannot be returned, unless postage is prepaid.

6. Please make all changes in your manuscript prior to submitting it. Check carefully spelling, structure, and clarify to avoid ambiguity and maximize continuity of thought. Proofreading will be done by the editorial staff. Galley proofs cannot be submitted to authors for review.

7. Enclose all material unfolded in a large size envelope. Use heavy cardboard to prevent bending.

8. All articles shall be written using Metric-SI units. Common measurements are permissible only at the discretion of the editorial staff.

9. Send all material, in one mailing to:

Mary A. Jasper, Editor
P.O. Drawer HT
Miss. State University
Miss. State, MS 39762

REVIEW OF ARTICLES

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

NOTE: The editor, although responsible for copy as it is published, begs forgiveness for all typographical mistakes, mis-spelled words and any goofs in general. Typing is done mostly by non-professional word processors who either are still in high school or are not trained in professional word processing. Thank you for your patience.

CALENDAR

ASEE ANNUAL CONFERENCES

1982 - Texas A & M University
College Station, June 21 - 24

1983 - Rochester Institute of Technology
Rochester, New York

EDGD MIDYEAR CONFERENCES

1982 - California Polytechnic Univ.
Pomona, CA

EDITOR'S PAGE

It gives one a weird feeling to put out a Winter Issue of the Journal at the end of May. However, all things considered, This issue, although short, may be one of the "meatiest" issues yet.

This is the second annual Computer Graphics Issue, and the articles are both practical and informative. The Oppenheimer Award Winner from the Midyear Conference in Louisville, by Abe Rotenberg is especially practical. Readers are urged to contact Prof. Rotenberg for the BASIC program for "JOHNNY". This writer received a copy at Louisville, but the resolution was very poor, and I did not trust my rudimentary knowledge of BASIC to try to fill in the gaps.

Jenison's and Vogel's article (also from the Midyear Meeting) is a boon for those who would like to practice "grantsmanship" for computer graphics equipment. Whether "luck" or "clean living", we congratulate these colleagues at Iowa State on their fortunate windfall.

Finally, for those of you who have wondered "What happened to the Journal this year?", the answer is simple. This editor was plagued with both technical difficulties beyond her control (eg., the late publication of the Fall isssue), and personal difficulties which ranged from full faculty workload to a recurring gout-type ailment of the leg. In between all of this were local educational riots and demonstrations (the county board of education has threatened (?) to shut down the local 12 grade school) to having two graduating seniors at one time.

Oh well, as Jim Earle says, "Only one more to go!"

Mary A. Jasper

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

ENGINEERING DESIGN GRAPHICS JOURNAL

VOLUME 46 NUMBER 1 WINTER 1982

T A B L E O F C O N T E N T S

IN MEMORIUM

In the past year, several of our membership have left this earth for a higher realm. The Journal would like to take this space and this opportunity to remember them and what they have meant to the division and engineering education.--Ed.

CHARLES VIERCK
Deceased 1981

There is probably not a single person who, having been involved with education in Engineering Graphics or Mechanical Drawing, is not familiar with the name, Charles J. Vierck. Prof. Vierck was the well-known co-author of the classic texts and workbooks in these subjects, and with Thomas E. French, has set the standards for the teaching of these graphic arts not only in the United States, but around the world. Few texts have been more widely read and studied by all engineering graphics teachers than these. As an acknowledged authority, we shall all miss him. Many will feel the loss of a great friend.

PERCY H. NEAL
Deceased 1981

In the southeast United States, Dean Neal was as well-known as many others have been at the national level in engineering education. Although he never authored a text, during his years as a professor of Engineering Drawing at Mississippi State, he taught many who became outstanding in their engineering professions. Even after his retirement as Associate Dean of the College of Engineering at Mississippi State, he still made regular trips up to the third floor offices of the Graphics department to chat and visit. As an artist, his pen-and-ink drawings of campus landmarks has been sold as notecards, placemats and included in books. An avid historian, he knew more about the architecture and history of early buildings on the MSU campus than anybody. We shall miss him as a mentor, citizen and friend.

GEORGE PANKRATZ
Deceased 1982

On January 31, the Journal received word that George Pankratz had passed away from this life just three days earlier. Those of us who have been active in division affairs in recent years will feel his passing as a great loss. George had worked, even through his recent illness, with the very difficult job of Director of Zones. A gentle man, George will be missed by all of us who knew him. Few have worked as hard for national recognition of the EDGD at section meetings, and fewer still have executed their responsibilities with the same practical attitude and patience.

ENGINEERING GRAPHICS INSTRUCTION AND COMPUTER GRAPHICS -- A NECESSARY MERGER

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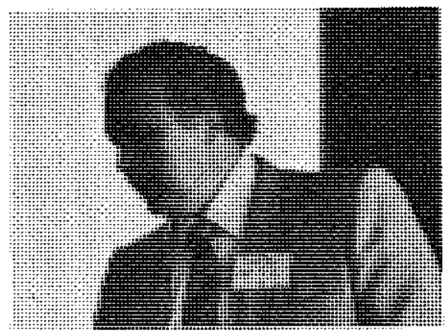

ABSTRACT

Industry is experiencing increased productivity with the utilization of computer-based information in the design and manufacturing processes. The computer graphics terminal is rapidly becoming the drawing board. This points to the need for improved graphics education for the engineering student. However, engineering graphics instruction has decreased dramatically in most curricula over the past two decades. This paper proposes that a merger of computer graphics and engineering graphics instruction is the solution to the dichotomy. The Freshman Engineering Department at Iowa State now has the potential to merge computer graphics and graphics instruction. The impact of computer graphics on the traditional methods of teaching graphics is predicted to be profound.

Some Observations

Major industries appear to be rapidly moving into the CAD/CAM business in order to increase productivity to the point that they keep or regain their competitive advantage. Industry spokesmen will quickly point out the advantages afforded by CAD/CAM techniques and, at the same time, indicate that the universities must be willing to update curricula to take full advantage of these new techniques. The operating engineer in the design/manufacturing loop is now closely aligned with the drafting, shop, and quality control processes. In addition, the number of iterations in the design process in increasing significantly and the analysis required involves much more complex geometric modeling than ever imagined previously. One industry spokesman indicated that there are enough sophisticated analysis techniques available as computer software; what is needed now is engineers who can utilize the techniques to create competitive products. These facts all point to a need for the engineering student to have a more thorough "grilling" in the fundamentals of engineering graphics. Industry is expecting the universities to equip the new engineer with the needed expertise.

Engineering curricula have undergone dramatic changes in the past two decades. One of the most significant changes has been the cutback in engineering graphics to accommodate more science and mathematics. The need for the engineer to keep abreast with rapidly expanding technology seemed to justify removal of "skills" content from the curricula. The engineer thus became a specialist, relying on draftspersons and technicians to carry out the graphical details. Today, engineering curricula, on the average contain a one semester course in graphics. In the view of Dean Karl Brenkert, as expressed at the 1979 Midyear meeting of the EDGD, graphics coverage would not be expanded but would instead face a continuing fight to remain in the engineering curricula. This view, while not necessarily representing all engineering education administrators, is not compatible with the apparent industrial expectations.

The engineering graphics teacher is caught between the conflicting viewpoints. On one hand, we see the need for more graphics in the engineering curricula and have expressed this viewpoint over and over. Mostly our efforts have fallen on deaf ears, except for our own. Professor William Rogers, in a rebuttal to the remarks of Dean Brenkert, at the 1979 midyear meeting, suggests that engineering education administrators find out

a) what should be in a present-day engineering graphics program;

b) how an adequate preparation in graphics can enhance learning in advanced courses;

c) what employers expect the new engineering graduate to know and be able to do;

d) and what constitutes functional literacy in graphics and how much time is needed to acquire the necessary knowledge and skills.

On the other hand, we have worked very hard to provide our students the necessary knowledge and skills in the face of continually decreasing time allotment. We have, perhaps, attempted to retain traditional methods and coverage in our teaching of graphics and in this lies the dilemma. We, as teachers of engineering graphics must be considered to be knowledgeable in the needs of the engineering student and capable of equipping the student with the appropriate knowledge. Industry tells us the students need better graphics preparation and engineering administrators see little need for graphics. If this dichotomy is not solved soon, not only will engineering graphics educators suffer, but a serious rift will develop between industry and education.

The authors have drawn some specific conclusions from the previously discussed observations.

1. The expanding use of CAD/CAM has swung the pendulum once again toward engineering graphics.

2. Additional time for engineering graphics in the curricula will not be allotted.

3. Responsible actions (not words) by engineering graphics educators are needed to solve the industry-education dichotomy in graphics.

4. The solution lies in making better use of available educational time.

5. The solution requires a merger of engineering graphics instruction with computer graphics.

Why Computer Graphics?

The CAD/CAM system, in full utilization, operates from a shared data base. The engineering functions of establishing performance specs, conceptual design, final design, drafting, manufacturing, and quality control all stem from this shared data base. The key element in the data base is the geometry of the three dimensional concept. In order to efficiently use the data base for design, structural analysis, performance analysis, and manufacturing considerations, the engineer must understand how the geometry is described and how to manipulate the geometry in order to obtain desired results. This is the core of engineering graphics. An engineer cannot simply sit down at a computer terminal and expect the answer to appear on the screen. Indeed, in the design applications the engineer is also the draftsperson when interacting with a graphics terminal. The need for more thorough graphics training is obvious.

Utilization of computer graphics in the teaching of graphics fundamentals can provide the following enhancements:

1) The instructor/student pair has the capability of repetitive exercises not afforded by the classic freehand or instrument drawing techniques that consume tremendous amounts of time. Repetition is one of the most important parameters in the learning process.

2) Using drawing packages, the student can become experienced in the generation of 3-D geometries and the visualization techniques necessary to fully investigate and communicate the geometries.

3) The amount of fundamentals coverage in engineering graphics can be increased due to the speed at which the computer graphics systems can process material.

4) The dynamic capability of a computer graphics system allows the student to quickly view the form of an object and also the function of the object in an assembly. A detail drawing on paper does not always reveal clearly the function of the object unless a complete set of working drawings is available.

5) The student will gain insight necessary to take full advantage of the CAD/CAM processes in advanced level courses. Traditional coverage of graphics fundamentals precludes modern design techniques from being applied in design courses.

The introduction of computer graphics in the teaching of graphics fundamentals should not result in a decrease in material coverage. This would be sheer tragedy in a time when a more thorough job is needed. The time required to become familiar with the computer system, a necessary evil, will be more than offset by the increase in learning speed by the student. We would be remiss if we did not explore in detail the potential of computer graphics in our education process.

The Iowa State Story

For three years a committee within the Department of Freshman Engineering has been studying the potential of computer graphics in the engineering graphics, introductory design and engineering problems courses. The committee initiated a program to upgrade faculty programming skills and developed some software which was used as demonstration in some classes. It quickly became apparent that computer graphics offered the means by which engineering graphics fundamentals could be effectively taught as well as allowing for a much needed increase in topical coverage. (At Iowa State, graphics/design is a 3 semester credit course.)

Exactly one year ago, the committee drafted a proposal for an educational system utilizing interactive computer graphics. This system would accommodate a classroom holding 48 students, thus allowing 350-400 students per semester to be exposed to the system. The facility would be used in an educational format and would complement the user facility donated to the engineering college two years earlier by the John Deere Company. The proposal was first channeled through the engineering college where it received enthusiastic support but no financing. The proposal was then sent to the university central committee on computer utilization for consideration. Our departmental committee felt that a group of 3-5 terminals might be approved with additional terminals added on a yearly basis if justified by initial results. We were also prepared to submit the proposal to industries for possible funding. As fortune (or clean living!) would have it, the university decided to concentrate the small amount of funds available into computer graphics systems rather than trying to satisfy small portions of all computer equipment requests submitted. Thus, Freshman Engineering was awarded its total request. Installation of the equipment will be completed about January 15, 1982, just one year from the original proposal date. As an aside to this, the authors firmly believe that a well written, logically justified proposal is a powerful mechanism for generating interest. Simply asking the department head, engineering dean, or university president for several thousand dollars for some computer graphics equipment will not get results in this day of austere budgets.

The total system is valued at $130,000 and includes:

a) 28 GIGI terminals and BARCO monitors (25 for classroom and 3 for faculty development area);

b) 2 hardcopy units;

c) 1 Tektronix 4051 and digitizer board;

d) 2 line printers;

e) 1 color TV camera;

f) 4 26" BARCO TV monitors.

The instructional modes are as follows:

1) Live lectures using the overhead camera viewed through the large BARCO monitors at the front of the classroom.

2) Instructor-delivered computer lectures accessed from the VAX host computer and displayed through the large BARCO monitors.

3) Computer lectures and problems accessible at the student station from the VAX host computer.

4) Stand-alone graphics at the student stations.

5) Video tape lectures viewed through the large BARCO monitors.

This variety allows for instructor creativity in teaching and provides the student rapid access to a number of learning possibilities.

During the Spring (1982) semester, the facility will be used for the engineering problems course, which includes FORTRAN programming instruction, and one section of the graphics/design course. In the graphics/design course, we anticipate adding material coverage in connectors and clearances, intersection of simple curved surfaces, and perhaps a look at manufacturing processes. The design project will involve some analysis and synthesis on the computer with final results measured by a payoff factor, something that has been difficult to do with our current conceptual design projects.

The Future

Software development is an ongoing, tedious process but essential to the attainment of the goals. The authors strongly recommend that each department develpp their own software, thus tailoring the software to the engineering graphics instructional objectives. This also provides a means of evaluating instructional techuiques using computer graphics in light of the traditional methods of instruction. In addition, all faculty become involved in the development process, an obvious plus.

At Iowa State, it is the desire of Freshman Engineering to involve as many of the college's faculty as possible in developing a strong engineering graphics program. It appears that a college CAD/CAM committee will be formed to suggest policy for the utilization of CAD/CAM in the various disciplines. A college-wide CAD/CAM policy will certainly assist Freshman Engineering in establishing future directions in engineering graphics instruction.

Our computer graphics committee will continue to monitor the literature and share experiences at ASEE and other society conferences. We know that a great deal of work is going into CAD/CAM, and other aspects of computer-aided engineering at various universities. Sharing successes and failures with our fellow graphics teachers can only lead to a better educated engineer.

Conclusions

We have cited some observations from industry, engineering administration and graphics teachers. It is apparent to us that a solution to the dichotomy lies in the merger of computer graphics with engineering graphics instruction. It is most important that this merger take place in an evolutionary, not revolutionary, atmosphere. It is mandatory that the impetus for change come from the engineering graphics teachers. Industry today is very aware of the needs of engineering education and in many cases is very willing to provide financial assistance for well-defined, educational goals. Professor Rogers, in the Spring 1979 EDG Journal, states the current situation most eloquently, "unless something is done soon to rebuild this crucial cornerstone (engineering graphics) of engineering, the entire superstructure is in danger of collapsing from its own weight." The time is here for aggressive, responsible action to enhance the future of our only product, the engineering student.

Acknowledgements

The authors are indebted to several persons for input to our remarks and for assistance in developing the successful proposal for the instructional computer graphics facility now available to Freshman Engineering students at Iowa State. In addition to the authors, the Computer Applications Committee consists of Professors Robert Bernhard, Lawrence Genalo, Steve Hooper, and Gawad Nagati. Many other Freshman Engineering Faculty have contributed their graphics expertise and have provided feedback and programming assistance in the development of software.

NUCLEAR REGULATORY COMMISSION

STAFF MEMBER TO SPEAK

Dr. James Jenkins, a senior staff member in the Human Factors Branch of the office of Nuclear Regulatory Research, U.S.N.R.C., will speak at Session No. 3236, Graduate Education in Human Factors Engineering. His paper, "Human Factors in Nuclear Power Systems Design will describe typical human factors problems encountered in the nuclear power field and discuss how the needs might be met by the formal and special education provided by universities.

The importance and the degree of involvement of human factors has been pointed out by the report from the President's Commission on the Three Mile Island Accident. This report states:

> "our investigation has revealed problems with the 'system' that manufactures, operates, and regulates nuclear power plants.. ...... within the NRC ... no one was specifically concerned with human factors engineering."

Someone is concerned now, and we as engineering educators need be concerned that our graduates are prepared to solve the problems of today, and the future.

Dr. Malcolm Ritchie of the FAA and Wright State University will discuss the importance of the human factors/systems approach to engineering tasks, and tell how this is being integrated in graduate engineering programs.

Dr. Hutchingson of Texas A&M, replacing Dr. Long on the program, will discuss the extent to which human factors enters every field of engineering and its importance in engineering education. Dr. Hutchingson is the author of a well received text on Human Factors Engineering.

OPPENHEIMER AWARD WINNER

"JOHNNY" -- AN ALGORITHM FOR READING ORTHOGRAPHIC DRAWINGS

A. ROTENBERG
DEPARTMENT OF MECHANICAL ENGINEERING
UNIVERSITY OF MELBOURNE
AUSTRALIA

I. INTRODUCTION

A basic reason "Johnny can't draw" is that "Johnny can't see". (Robert H. MCKIM,"Visual Thinking and the Design Process", Engineering Education, March 1968, p.795)

Student: "I can't imagine what this new view should look like, so how can I draw it?"

Wellman: "Good! Since you have no preconceived idea, you can go ahead and draw the view without prejudice. Follow exactly the rules and the principles that you know apply here. When the view is finished, you'll see what it looks like and you'll know that it is right". (B. Leighton Wellman, Preface to :Technical Descriptive Geometry, McGraw-Hill, N.Y. 1948)

These two, apparently conflicting approaches, have prompted the author to investigate the possibility of writing an algorithm which, when followed, would result in an orthographic or axonometric view of any object in any arbitrarily selected direction. The shape of the object is to be described by a conventional orthographic drawing and the algorithm is to be used by a "Johnny" who "can't see" but has learned "the rules and the principles" of representation of points and lines on such drawings. In this paper, the category of "objects" is limited to solid polyhedı It is intended later to extend the inves· tigation to solids bounded by curved surfaces. The problem presented to Johnny may be formulated as follows:

Given: two or more orthographic views of an arbitrary polyhedron π and arbitrary line AB.

Required: an orthographic view of π in the direction AB.

Since AB is an arbitrary line, an "orthographic view in the direction AB" includes also any orthogonal axonometric view of π. Thus, an algorithm for the solution of Johnny's problem would also permit Johnny to "read" an orthographic drawing of an arbitrary polyhedron. Furthermore, if the algorithm were written in a language of any available computer with a suitable memory and graphics facility, it should be relatively easy to teach Johnny to solve his problem using this computer. And finally: if Johnny's task can be reduced to a mindless following of a set of prescribed steps, Johnny could, at least in principle, be eliminated altogether and the task of reading orthographic drawings taken over by suitable mechanical, electronic or other gadgets.

One condition for Johnny's problem to be solvable, is that the given orthographic views describe the shape of the polyhedron completely and unambiguously. Unfortunately, the existing drawing and descriptive geometry textbooks do not formulate a sufficiency criterion for a drawing of an arbitary polyhedron to be its complete and unambiguous representation. The current practice is to rely on the draftsman's experience and to regard an orthographic drawing as a complete and unambiguous representation. The current practice is to rely on the draftsman's experience and to regard an orthographic drawing as a complete

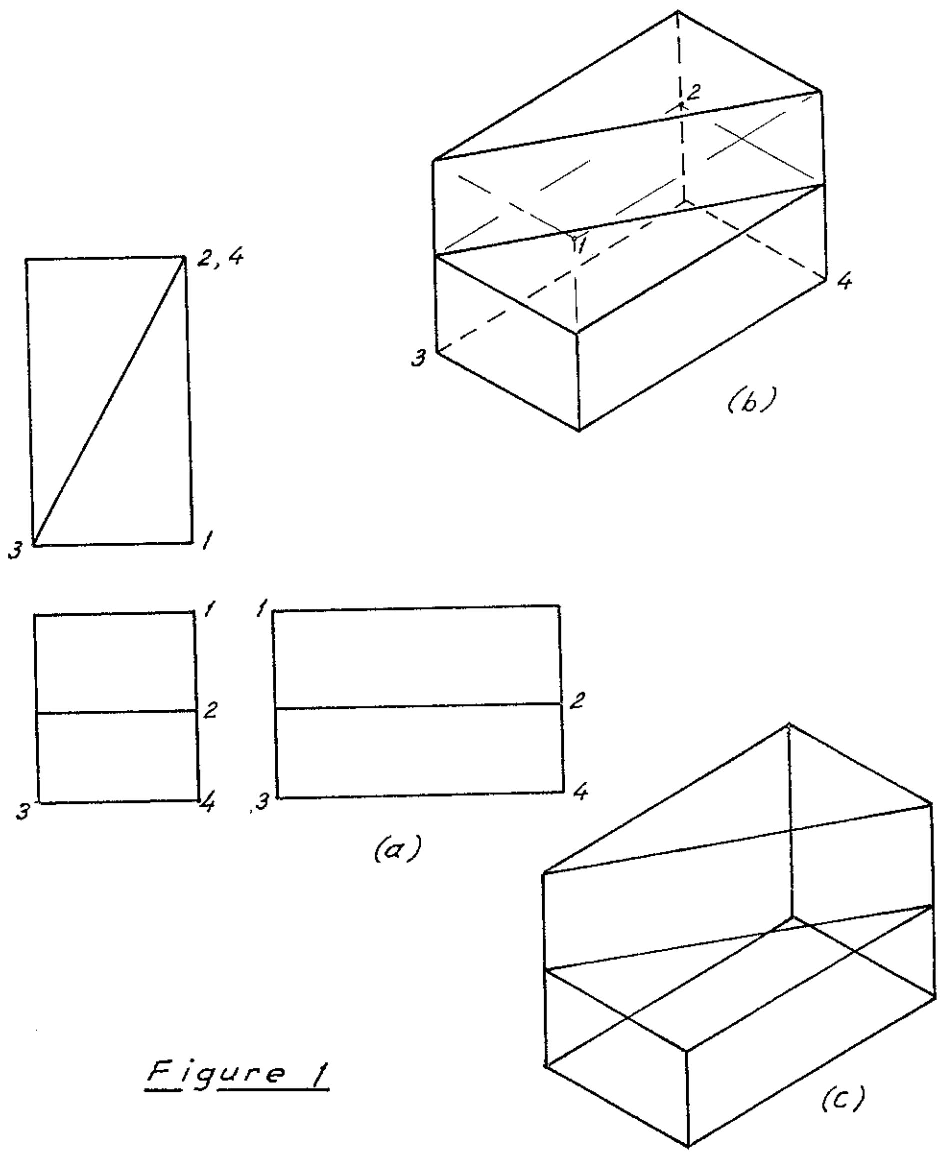

Figure 1

and unambiguous representation of an object as long as no one has or was able to produce evidence to the contrary. This paper

(i) formulates a sufficiency criterion for an orthographic drawing to be a complete and unambiguous representation of a polyhedron;

(ii) describes a procedure for retrieval of the information from the drawing satisfying the above criterion;

(iii) describes an algorithm JOHNNY for computer drafting of axonometric or additional orthographic representations of polyhedra from their orthographic drawings.

In contrast to many (all?) existing programs, JOHNNY does not require the user to have a "mental picture" of the object to be represented.

II. DEFINITIONS

An aligned drawing of a figure is a set of orthographic views of this figure arranged in accordance with the first or third angle projection convention. For example, figures 1(a) and 2(a) are aligned drawings of the three-dimensional figures whose axonometric projections are shown in figures 1(b) and 2(b) respectively.

An aligned drawing of a figure is said to be complete if all figures represented by this drawing are similar (i.e., a complete aligned drawing of a figure is an unambiguous linearly scaled representation of this figure).

A wireform of a polyhedron π is the set of all the vertices and all the edges of π. For example, figure 1(c) is an axonometric projection of a wireform of the figure represented in 1(b).

A false (vertex-edge) of a polyhedron π (or its wireform W) represented by an aligned drawing is a (point-line) which is not a (vertex-edge) of π (or W) and whose projections in all the views of the drawing coincide with two or more (vertices-edges) of π (or W). For example, in Figure 1(a), points 1 and 2 are false vertices and the line 3-4 is a false edge of the polyhedron whose axonometric projection is shown in figure 1(c).

A simple closed polygon is a plane polygon which is a simple closed curve.

A false face of a polyhedron π is a simple closed polygon formed by the edges of π and which is not a boundary of any face of π. For example, in figure 2(a), the simple closed polygon 1-2-3-4 is a false face of the polyhedron whose axonometric projection is shown in figure 2(b).

An outer boundary of a (real) face of a polyhedron is a simple closed polygon formed by the edges of this face and such that all points of the face are inside or on it. For example, in figure 3, the polygon KLMN is the outer boundary of the face KLMN.

A hole of a face of a polyhedron is a simple closed polygon formed by the edges of the face and such that no points of the face are inside it. For example, in figure 3, both, ABCD and EFGH are holes of the face KLMN.

III. SOME PROPERTIES OF POLYHEDRA.

Every edge of a polyhedron π is a side of exactly two faces of π.

Every simple closed polygon formed by the edges of a polyhedron π is either a false face or a boundary of a real face of π.

Every real face of a polyhedron is bounded by an outer boundary and n holes (n=0 or n is an integer).

IV. A CRITERION OF COMPLETENESS OF WIREFORM DRAWINGS.

Since (i) any wireform is uniquely defined by the lengths and the relative positions of all its edges, and

(ii) any pair of corresponding lines in any pair of adjacent views in an aligned drawing of a wireform W defines the length and the position of either real or a false edge of W,

An aligned drawing of a wireform W consisting of two or more orthographic views of W is complete if it permits to identify all false edges of W.

V. A CRITERION OF COMPLETENESS OF DRAWINGS OF POLYHEDRA

The shape of any polyhedron can be uniquely defined by specifying the shapes and the relative positions of all its faces. Every such face is bounded by one or more simple closed

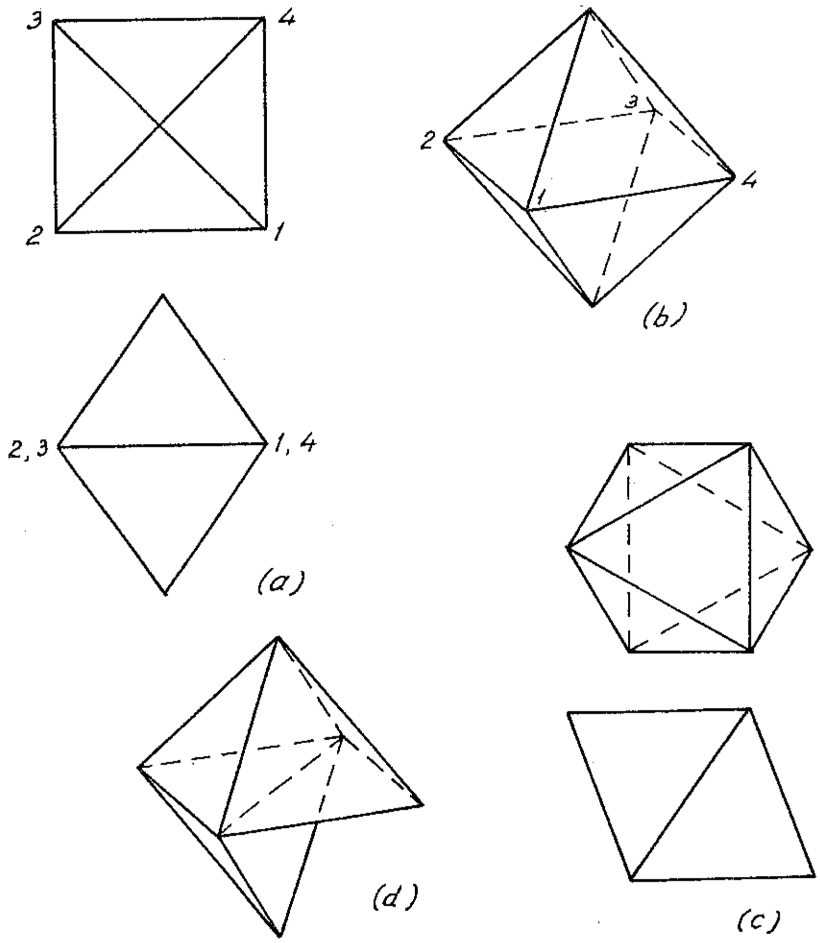

Figure 2

polygons. A complete drawing of a wireform of a polyhedron π permits identification of all simple closed polygons formed by the edges of π. Since each of these polygons defines either a false face or a boundary of a real face, a complete drawing of the wireform W of π is also a complete drawing of π if the drawing of W includes some means of distinguishing the false faces from the real ones. Thus,

> an aligned drawing of a wireform W of a polyhedron π consisting of two or more views of W is also a complete drawing of π if it permits to identify all false faces of π .

The criteria formulated in IV and V are only sufficiency conditions of completeness of orthographic drawings of wireforms and polyhedra. They have been selected from other possible criteria and stated here because they can be usefully employed in the algorithm described below.

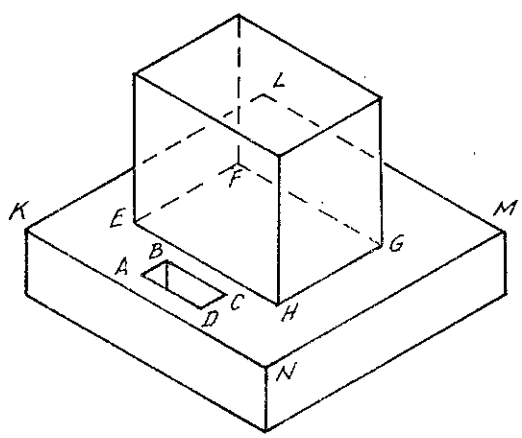

Figure 3

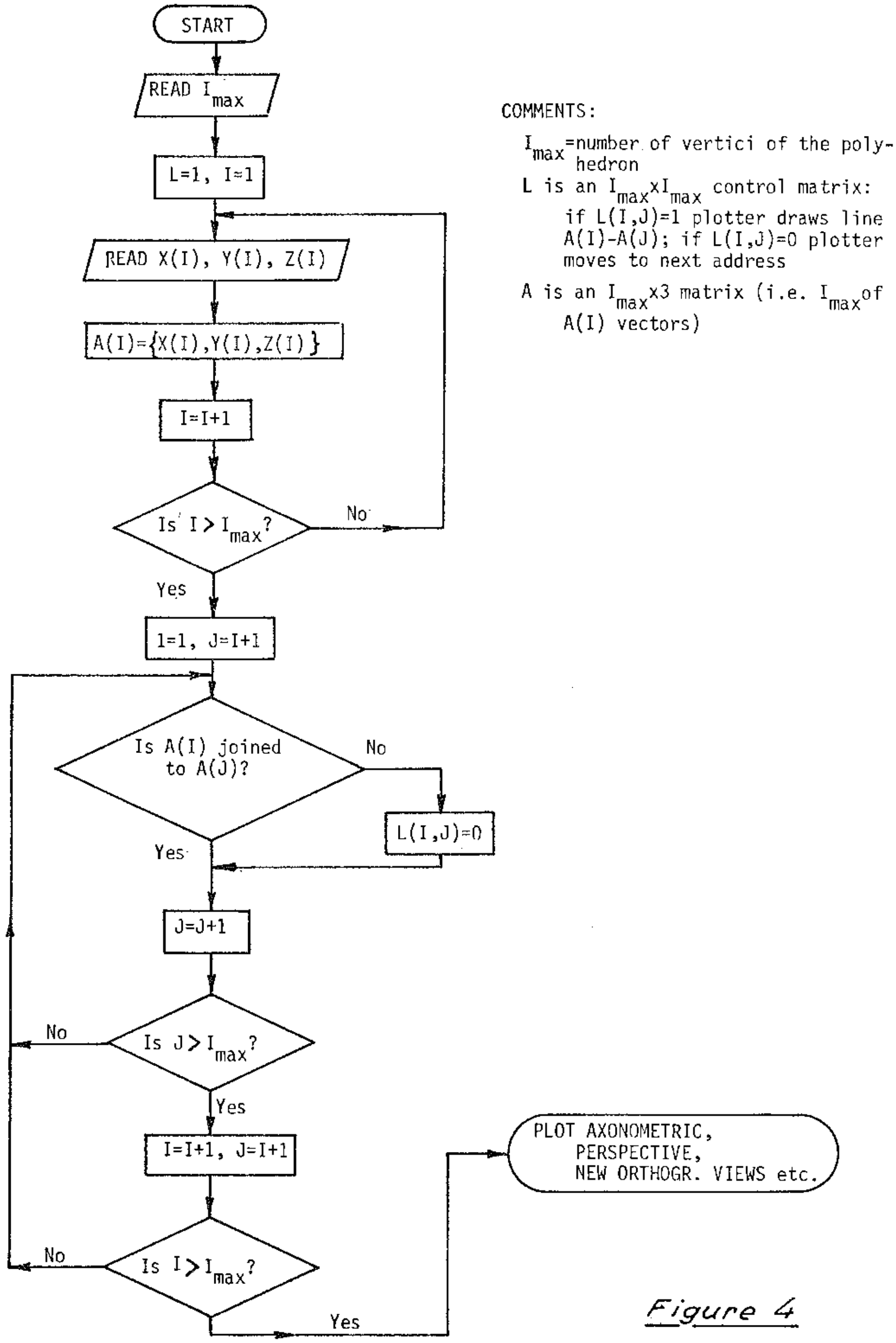

Figure 4

VI. THE ALGORITHM.

The algorithm JOHNNY is desribed in Figure 4. The operator is presented with a conventional orthographic drawing of a polyhedron consisting of two or more views which either are selected so that there are no false edges or, if there are any, they must be specified on the drawing. For

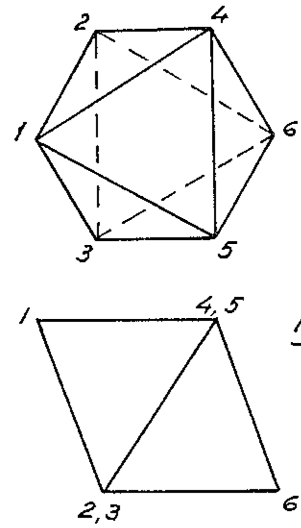

Figure 5

example, both, Figures 2(a) and 2(c) are aligned two-view drawings of the same regular octahedron represented in Figure 2(b). It should be noted that, while Figure 2(c) contains no false edges and is a complete representation of the polyhedron, Figure 2(a) must be accompanied by an appropriate statement that 1-3 and 2-4 are false edges. Without such statement, Figure 2(a) is ambiguous: it can represent at least two different polyhedra, say those shown in Figures 2(a) and 2(d). The operator then assigns sequential numbers to all vertices (e.g., v. Figure 5) and notes all those vertices which are not joined by a line in at least one of the given views. For example, in Figure 5, 1-6, 2-5 and 3-4 are not joined in at least one of the two views. The drawing is then placed on a digitizing table and the program started. All the instructions to the operator appear on the screen and, if followed faithfully, the selected wireform view of the given polyhedron is computer-plotted on the screen or on paper depending on the type of the output selected. JOHNNY will also produce views of the given polyhedron with all hidden edges shown "dotted" if the appropriate information is entered by the operator. This information may again be obtained by following step by step a procedure which does not require the operator to have a "mental picture" of the polyhedron. The reader may be puzzled by an apparent contradiction; the term "reading" of a drawing of an object is commonly used to mean "creating a mental picture" of this object, yet, the paper refers to reading of drawings without creating mental pictures. It should be noted that no precise definition of the term "mental picture" exists and, rather than attempt such <u>definition</u>, the author decided to use a <u>test</u>: "being able to read a drawing of an object" here means "being able to produce a view of the object in any given direction".

VII. VISIBILITY OF EDGES.

In a general case, to decide the visibility of the edges of a polyhedron, it is necessary to define its faces. This may be achieved by incorporating in the program a test to check the coplanarity of all the vertices of every simple closed polygon ("SCP"). Such test may lead to the following results:

(i) the vertices are not coplanar and, therefore, the SCP is not a representation of a face.

(ii) the vertices of only one SCP are coplanar and, therefore, the SCP is a representation of a real or of a false face. If the drawing permits to identify the false faces (as stipulated in the criterion in V), the decision is straightforward.

(iii) the vertices of more than one SCP are coplanar. After elimination of the false faces, several cases are possible of which the basic ones are summed up in Figure 6.

In the general case, the time required for a complete analysis of visibility may become prohibitive. In practice, it is usually possible to decide visibility of all the edges by examining only some of the SCP. In many cases, visibility may be reduced to an examination of the points of intersection of lines which are not the representations of vertices of the polygon. Every such point indicates that at least one part of at least one of the two intersecting lines is hidden and the decision which one may become apparent after examining the adjacent views.

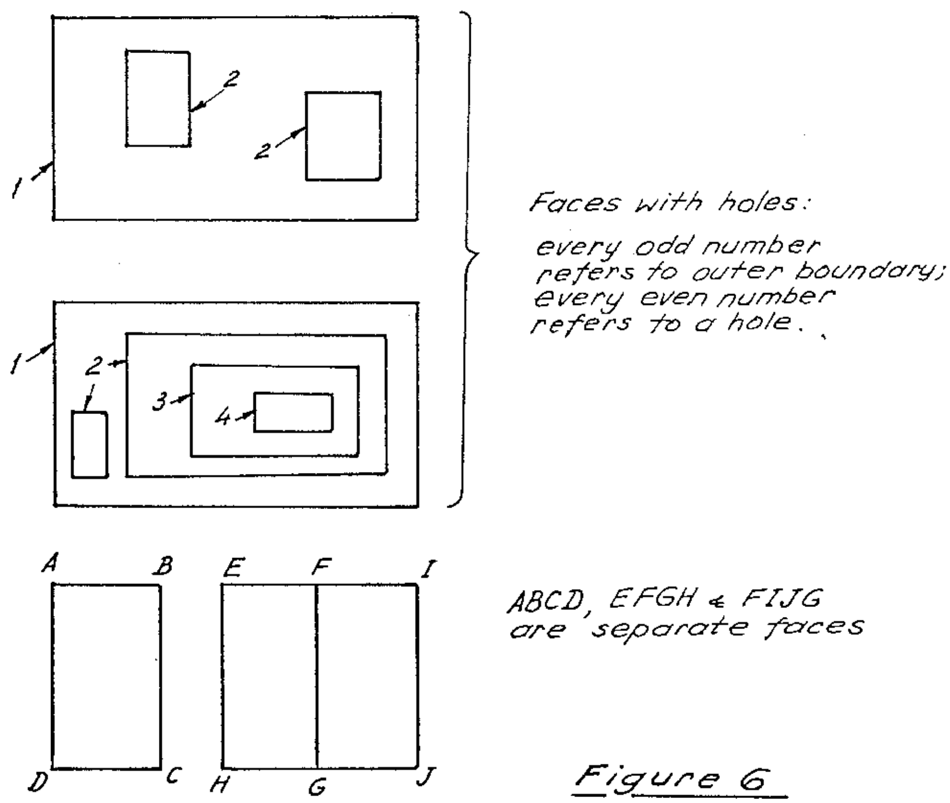

Figure 6

VIII. FUTURE DEVELOPMENTS.

It has been demonstrated that the reading of unambiguous drawings of polyhedra may be reduced to a set of rules and, therefore, is amenable to computerization. Future work in this area suggested by the author:

(i) an extension of the analysis described to objects bounded by curved surfaces.

(ii) development of a device which would scan the drawing and supply to the computer all the information needed for "reading" without human participation.

It is expected that such work would involve a revision of the current drawing practices and of the existing procedures for retrieval of information from drawings. The author believes that attempts in the suggested direction will be worthwhile and rewarding even in the case of failure to achieve the target.

EDITOR'S NOTE: Copies of the BASIC program for Prof. Rotenberg's paper are available, and may obtained by writing either the JOURNAL, or Prof. Rotenberg at the above address. Please Enclose with your request a stamped, self-addressed envelope. Otherwise, the JOURNAL will not be able to respond to your request. Send your request to:

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HIDDEN LINES ELIMINATION FOR PARAMETERIZED SURFACES

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A new algorithm is described for perspective representations, with visibility of part of a surface given by the parametric equations:

$$\left.\begin{array}{l} r(u,v)=(x_1(u,v),\ x_2(u,v),\ x_3(u,v) \\ \qquad \text{defined in the domain} \\ D = [u_o,u_n] \times [v_o,v_n] \end{array}\right\} \quad (1)$$

in an orthonormal frame $\{e_1, e_2, e_3\}$ of $\mathbb{R}^3$.

The representation is obtained by plotting a family A of curves contained in the surface.

Let B be a continuous one-parameter family of curves on the surface, for instance, the coordinate lines

$$u = \text{constant}.$$

The algorithm determines the visible line segments and the hidden line segments of a finite set B' of lines of the family B.

If A is not equal to B', the visibility of a member $\underline{a}$ of A is found by testing whether or not the intersection of $\underline{a}$ with each curve of B' is on a visible line segment.

1. Visibility of a Point on the Surface.

Let σ be the piece of surface given by (1), and S is not on σ and that σ is contained in an appropriate cone of vision with vertex S.

Let σ be the piece of surface given by (1), and S be an observer. It is assumed that S is not on σ and that σ is contained in an appropriate cone of vision with vertex S.

A point P of σ is <u>visible</u> if the intersection of the open segment (P,S) with σ does not contain any isolated point; in the other case, P is <u>hidden</u>. A function <u>vis</u> over σ is obtained by defining <u>vis</u> (P) = 0 if P is visible, and <u>vis</u>(P) = 1 otherwise.

The <u>complete evaluation</u>, denoted by EVCOMP, is the subroutine which computes <u>all</u> the isolated intersection points of (P,S) with σ.

Consider the unit vector

$$d = PS/\ \|PS\| .$$

Every vector m of the straight line through P and S can be expressed as

$$m = P + \lambda d$$

with λ variable. The required intersection points are the solutions of the system

$$r(u,v) = P + \lambda d \qquad (2)$$

With three equations and three unknowns u, v and λ, in the domain D x I(P), where

$$D = [u_o, u_n] \times [v_o, v_n]$$

and I(P) is the open interval $(0, \|PS\|)$. Eliminating λ from (2) gives a simpler solution: D is not parallel to two of the three basic vectors $\{e_1, e_2, e_3\}$ say e_1 and e_2. The straight line through P and S is the intersection of the two planes generated by $\{d, e_1\}$ and $\{d, e_2\}$, with the equations $[d, e_1, m - P] = 0$ and $[d, e_2, m - P] = 0$, respectively, (where $[a, b, c]$ denotes the mixed product of a, b, c.) The given straight line intersects σ at the solutions of

$$\left.\begin{array}{l} d, e_1, r(u,v) - P = 0 := \phi(u,v) \\ d, e_2, r(u,v) - P = 0 := \psi(u,v) \end{array}\right\} (3)$$

with the unknowns u and v. If $(\bar{u},\bar{v})$ is a solution of (3) in D, the corresponding value of $\bar{\lambda}$ is obtained from one equation of (2); $(\bar{u},\bar{v},\bar{\lambda})$ is an admissable solution of (2) if

$$\bar{\lambda} \in I(P).$$

The subroutine EVCOMP will give all the solutions of (2) if there is an effective algorithm to compute the solutions of (3) in D.. It would be best to have a means to know only if there exist solutions of (3) in D. Without having this means available, the following approximate method is proposed: let (u_i,v_j) be a gridded subdivision of D and assume that (u_i,v_j) is an approximate solution of (3). In that case, an iterative Newton-like algorithm (as described for instance by Brown in [1], with (u_i,v_j) as a starting guess) will converge quickly to a solution $(\bar{u}_i,\bar{v}_j)$. On the other hand, if the assumption on (u_i,v_j) is false, after a few iterations either $|\phi|$ and $|\psi|$ will be close to zero, or $|\phi|$ and $|\psi|$ will not sufficiently diminish, or the divergence of the process will become apparent from the high value of one of these two numbers. Thus we can decide whether or not to pursue the iterations.

By doing so, starting from each (u_i,v_j), a set of solutions of (3) is finally obtained which may be empty; the solutions not in D and those corresponding to P itself must be eliminated, and thus the solutions in proximity to each other obtained by starting from different points of the grid could be identified.

In the case of a surface periodical in u or in v, the periods must be accounted for in order to bring back into D those solutions which were possibly not included in the initial iterations.

Henceforth, a zero of P will be any isolated solution of (2) contained in D x I(P), i.e. every isolated intersection point of the open segment (P,S) with σ; vis(P) = 0 if and only if P has no zero.

In the method described, the following numerical bounds have proven to be satisfactory in most cases for a grid of 20 points, regular but slightly displaced: at least 3 iterations -- at most 7 -- in addition to the tests of divergence; and the break before 7 (if the values of ϕ and ψ are sufficiently small). If the grid is too fine the same solution will often be obtained, which will increase the sorting operations and the total number of iterations; if the grid is too coarse, the risk of missing solutions becomes greater.

2. Visibility of a Curve on the Surface.

Consider, for example, a line of coordinates u = constant = c:

$$\gamma(v) = (x_1(c,v),\ x_2(c,v),\ x_3(c,v)\ \ v \in [v_0,v_n].$$

Since plotting curves is the main concern, we subdivide $\gamma(v)$ into N-1 segments by a regular or irregular partition (as dictated by the case) of the interval $[v_0,v_n]$. Thus we obtain N points $P_i = \gamma(v_i)$ on γ, in order to determine the visibility vis(P_i).

Clearly, the use of EVCOMP (n.1) N times is too costly: it is much simpler to take the continuity of γ (and of σ) into account, even if γ must be assumed to be of class C.

The subroutine which computes the zeros of P, starting from the zeros of a point P' near P shall be called partial evaluation and denoted by EVPAR.

If P and P' are two neighboring points on σ, the segments (P,S) and (P',S) are neighboring segments, and so also are the zeros of P and the zeros of P'. Thus, in order to compute the solutions of the system (2) for P, it is no longer necessary to use the grid as was the case for the complete evaluation, since the known zeros of P' are already good approximations for the desired solutions. The Newton-Brown method will at once converge to them, or will diverge at once (taking, at most, 3 iterations.)

The solutions, however, must be sorted: two different zeros of P' may have coalesced (this happens if (P,S) becomes tangent to a "fold curve" of σ); a zero of P' may lead to P itself (if P goes through a "fold curve"). We have thus obtained the zeros of P; therefore, by EVPAR vis(P') = 0 clearly implies vis(P) = 0.

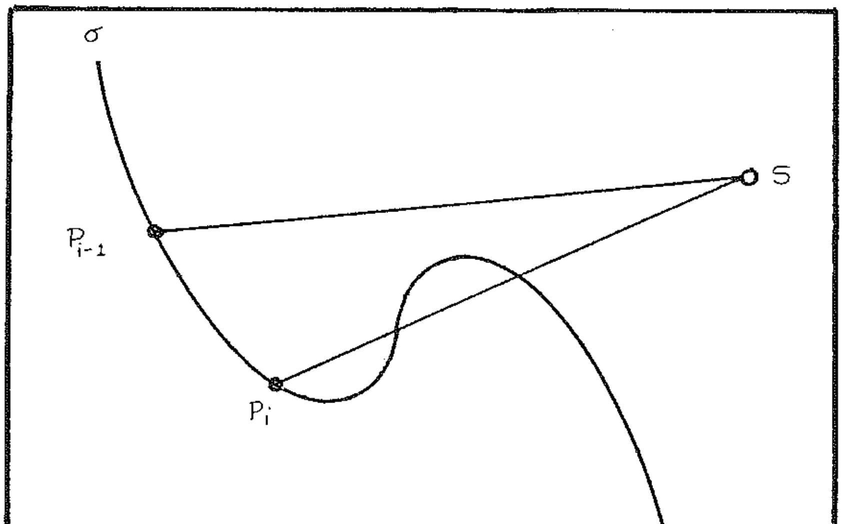

Figure 1.

Hence, to determine the zeros of each of the N points of γ, the zeros of P_1 are computed first with EVCOMP, then the zeros of P_i by EVPAR, starting from those zeros of P_{i-1}.

Examining figure 1, which represents a cross-section of σ, it is observed that an inconvenience may occur: new zeros of P_i may appear, which cannot be deduced from the zeros of P_{i-1}. To remedy this drawback, an integer K is selected which divides N (eg., N = 40 and K = 10 is fairly appropriate in practice) and, when i is a multiple of K, after having deduced the zeros of P_i from those of P_{i-1}, if any, the zeros of P_i are computed again by EVCOMP; if new zeros appear, new zeros of P_{i-1} are obtained by boing back with EVPAR and so on, until a P_j ($j \geq 1$) is reached where there is nothing new to add. This process is called retrocorrection and the subroutine which executes it, CORIG. We use the retrocorrection starting from a P_i, (= multiple of K), if necessary, even if $\underline{vis}(P_{i-1}) = 1$, because a maximum of zeros must be preserved for further use.

In summary, the collection of the operations of complete evaluation, partial evaluation and retrocorrection producing the set of zeros and $\underline{vis}(P_i)$ for each of the N points P_i of γ will be called complete visibility of the curve γ ; VISCOMP will denote the corresponding subroutine. VISCOMP uses K + 1 times EVCOMP, at most K times CORIG, and at least N - 1 times EVPAR. Furthermore, the case illustrated by figure 2 shows that VISCOMP may leave fully visible a close wave of σ (an obvious remedy would be to displace $[v_o, v_n]$).

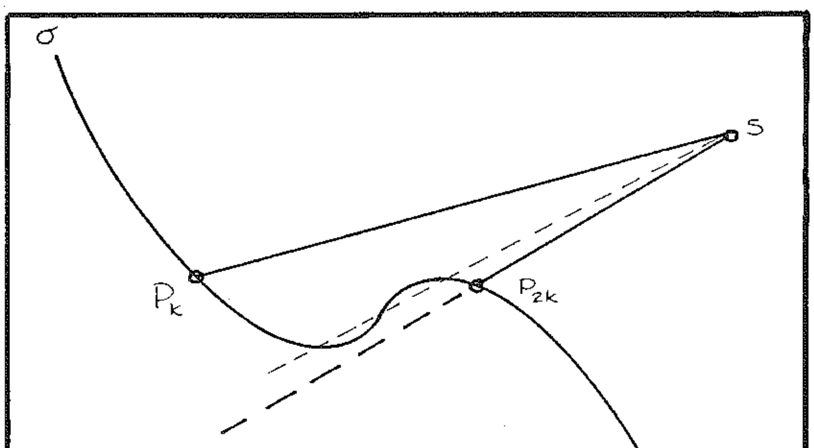

Figure 2.

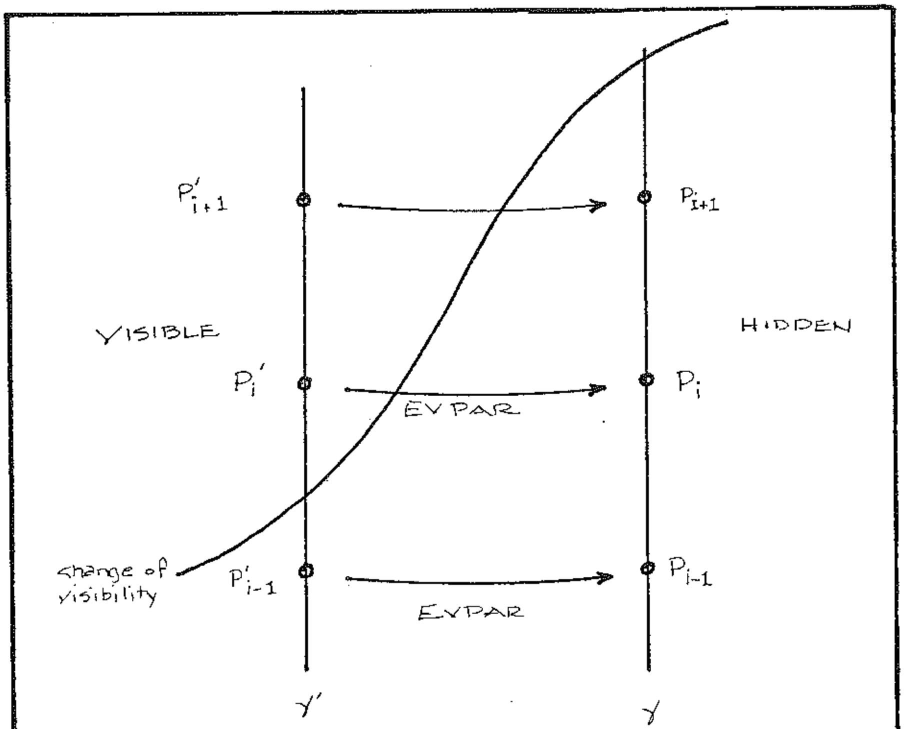

Figure 3.

Between a visible P_i and a hidden P_{i+1}, experience shows that it is not advantageous to compute the exact point of γ at which visibility changes.

3. <u>Visibility of a Family of Curves</u>.

Consider now a continuous one-parameter family B of curves on σ, say the coordinate-lines u = constant. Let γ and γ' be two <u>neighboring curves</u> of the family B, partitioned respectively by the points P_i and P_i', $1 \leqslant i \leqslant N$, according to the same subdivision of $[v_0, v_n]$.

Suppose that the set of zeros of each P_i' on γ' is available. For the same reason of continuity which was the basis for partial evaluation, the set of zeros of each P_i on γ may be computed <u>without ever having to use EVCOMP</u>: the zeros of P_1 are obtained by starting from those of P_1' using EVPAR. The zeros of P_2 may be obtained with EVPAR in two ways -- by starting from P_2' or from P_1. In order to avoid the drawbacks mentioned in n.2, which would lead to retrocorrection, it is better to start from the zeros of P_2'. The zeros of each P_i are thus sorted from those of P_i' using EVPAR.

As shown in figure 3, the change of visibility for γ' (from visible to hidden) may occur between P'_{i-1} and P_i', whereas it occurs, say, between P_{i+1} and P_{i+2} for γ : thus, whenever <u>vis</u>$(P_i') = 0$, while <u>vis</u>$(P_{i-1}) = 1$, EVPAR must be used starting from the zeros of P_{i-1}.

This method of computing the visibility of γ from that of γ' is called <u>partial visibility</u> and the corresponding subroutine is denoted by VISPAR.

In summary, M curves γ_j of the family B being given, VISCOMP may be used to obtain the visibility of γ_1, then VISPAR to deduce the visibility of γ_j from that of γ_{j-1}.

Inconveniences may, however, occur as was the case for EVPAR; eg., if B is formed by the rectilinear generatrices of the cylinder (figure 4), then γ_j is entirely visible, while it is not the case for γ_{j+1}, since γ_{j+1} is behind the fold curve. As before, the process of <u>retrocorrection for curves</u> is applied. Let L be a divisor of M (L = 8 for a multiple M of (L + 1)8 is usual practice). Having computed the visibility of γ_j, with j a multiple of

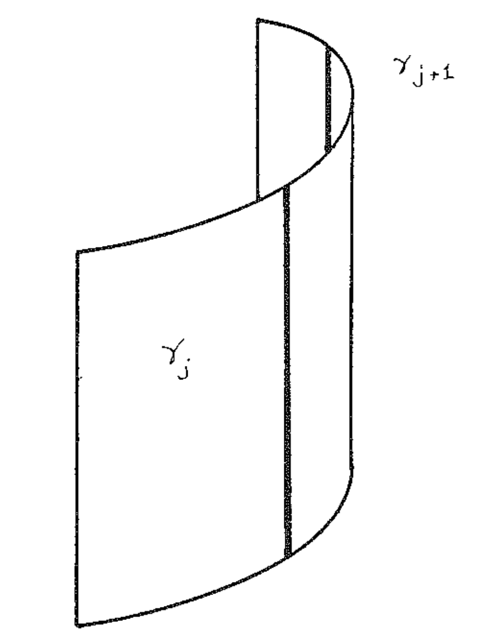

Figure 4.

L, by means of VISPAR, this visibility is computed again with VISCOMP. If at a point P_i of γ_j a non-empty set of zeros of P_i is found while VISPAR had predicted $\underline{vis}(P_i) = 0$, the subroutine EVPAR will rectify the visibility of the corresponding points on the preceeding curves, inasmuch as their visibility is not already equal to 1: this is the task of the subroutine CORIGC.

The combined use of VISCOMP, VISPAR, and CORIGC as described above produces the complete visibility of σ in the form of a M x N matrix, having as the (i,j)th-entry the value of 0 or 1 of $\underline{vis}(P_{ij})$ where P_{ij} is the ith point of the jth curve.

As was shown in n.2, the visibility of σ may be false in the case of a narrow wave of weak amplitude.

4. Utilization of the Algorithm.

Data. In a subroutine which, as a rule, does not need to be modified further (except in very special cases of surfaces), the values are fixed for:

- The density of the grid used in EVCOMP (n.1); the parameters which limit the maximum and minimum number of iterations, as well as the limiting values of $|\phi|$ and $|\psi|$, beyond which the iterations will not be pursued (n.1); the limits for the identification of two zeros (n.1); the maximum number NZ of zeros for one point (n.1).

- The number N of points on a curve; the regularity of the subdivision of $[v_o, v_n]$ into N-1 parts; the number K (of which N must be a multiple) determining the step for the use of EVCOMP (n.2).

- The number L which determines the step for the use of VISCOMP (n.3).

In a subroutine SURF(u,v), we give the parametric equations of the surface: $x_1(u,v)$, $x_2(u,v)$, $x_3(u,v)$, together with their partial derivatives, if EVCOMP does not make use of finite differences.

The data necessary for the execution are the limits u_o, u_n, v_o, v_n which define the domain D, the number M of curves to deal with, and the periods in u and in v (0 if there are none), and the observer.

Memory.

If γ' is the curve previously studied, the set of zeros of each point must be in the memory, that is, at most NZ · N triples (u, v, λ); if γ is the curve presently studied, the zeros of the points of γ' are replaced successively by those of the points of γ. At the end of the execution the M x N matrix with the values of 0 or 1 for the $\underline{vis}(P_{ij})$ will be formed.

Execution.

The execution time is a function of the number of zeros to be iterated for each point, and essentially a function of the number of calls to the routine EVCOMP. The number of zeros depends on the number of overlapped parts of the surface in the projection, and also of the computing precision in EVCOMP and of the interval for the identification of two zeros. The basic part of the algo rithm is the subroutine EVCOMP for which the research time for solutions and the precision of the results must be equalized. For that, it must be remembered that if the results at P are insufficient or inconclusive, they can be better at the following point, and the retro-correction attribute of this analysis is utilized gratefully. In all the cases discussed thus far, the execution time has always been between 15 and 45 seconds (Fortran program, with the values mentioned above, on a CDC Cyber 7328).

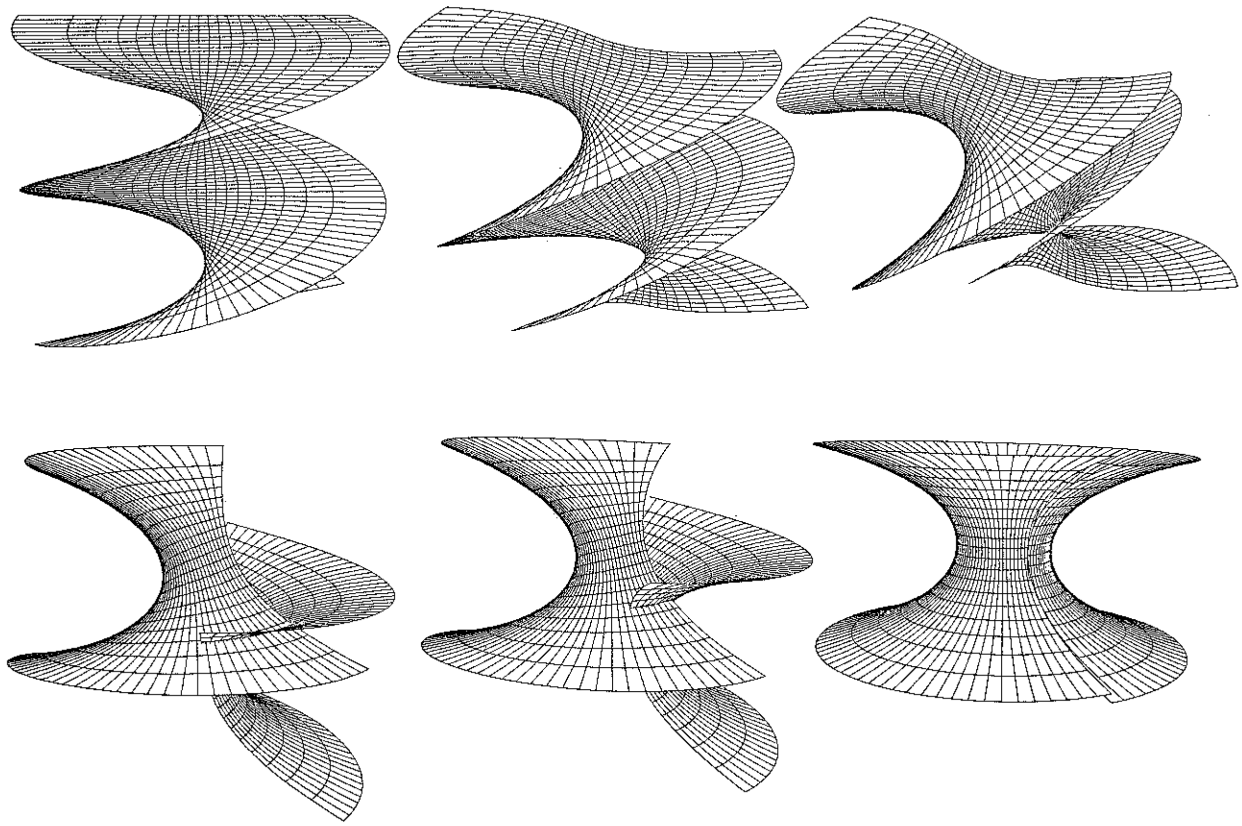

Figure 5.

Errors.

Errors in the visibility arise from a lack of zeros not computed by EVCOMP (eg., this happens frequently near a regression curve); errors also result from changes in the visibility between two calls of EVCOMP; in the latter case, $[v_0, v_n]$ must be divided so that "many points lie near the changes of visibility and few where nothing happens". The domain D may also be displaced, the number of curves increased, etc. In any case, the usual practice shows that several views of a surface must be produced to be able to see and to understand how it is shaped and to get a readable representation.

This algorithm has been widely used in the development of an animation film "L'Hélice et l'hélicoïde" [2] , where it was necessary to produce 200 pictures representing the continuous isometric deformation of an helicoid into a catenoid (fig. 5). It has als been used for a number of illustrations in a course on differential geometry [3] .

In conclusion, the author submits that this algorithm is very effective in determining visibility in perspective projections of families of curves.

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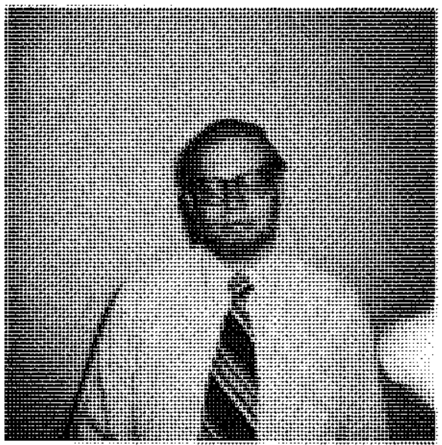
A COMPUTER GRAPHICS PROGRAM TO AID IN TEACHING OF CAM DESIGN



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Abstract

A computer graphics program to aid in the teaching of cam design and cam profiles is presented. The program requires the inputting of a of a displacement curve, the desired follower configuration, and the follower offset. Three types of follwers are permitted: (1) knife edge followers, (2) roller followers, and (3) flat-faced followers. The program calculates the cam profile using standard graphical techniques and then displays the profile with the designated follower, offset, and displacement curve.

Introduction

A cam provides a convenient means of transforming rotary motion into reciprocating motion. Since the cam can be of a wide variety of shapes and have a number of various followers, many different types of motion can be secured. In most cases, the construction of the cam profile does not present a difficult problem, except for the tedious work required in tracing the actual profiles once the pitch curve has been calculated and drawn.

There have been many attempts to graphically describe cam motion, among them Doughtie and James (1), Burton Paul (2), Bernard, Waters, and Phelps (3), and Mabie and Ockvirt (4). These methods are well accepted, but still require the drawing and/or plotting of the cam profiles. This drawing and/or plotting of the profiles is for the most part unacceptable for the classroom situation. The time and effort that the instructor must put into developing a cam profile is excessive and usually results in a lack or loss of interest by the student. The mathematical approach is also unacceptable for the same reasons. The computer graphics program presented here quickly and accurately calculates and then displays the appropriate cam profile. The capability of storing the profiles, as well as the curves on tape adds an added dimension to the classroom atmosphere.

Program Description

The program offers the user the capability of dividing the displacement-angle diagram into as many as seven segments. Along with each segment the angles θ_1 and θ_2, representing the initial and final angles of rotation, are also input. Each of the segments are represented by an equation of the form

$$s = f(\theta).$$

In order to give the user maximum freedom of choice, any function or functions may be input to represent the follower displacement; however, the motion tables from Mabie and Ockvirk (4) are included in the user's manual to assist in the choice of the desired equations. These tables not only give the mathematical equation, but also show characteristic displacement, velocity, and acceleration curves for simple harmonic, cycloidal, and eighth power polynomial motions. The program next divides the displacement curve into 360 equal segments, each segment representing one degree of cam rotation. The user is then requested through a tel prompt to identify the type of follower (knifeedge, roller, flat) and offset that is desired. The mathematical calculations used in the program are based on calculations derived in the text by Burton Paul (2). For the flat-faced follower, the follower is first depicted with a length R, which is equal to the radius of the base circle. The base circle is then drawn and divided into 360 equal sections. On each of the 360 rays an XA and YA coordinate is located (see Fig. 1.). The distance of each point (XA, YA) to the cam center is equivalent to the sum of the radius of the base circle and the corresponding displacement. In the graphical construction of the cam the procedure is to draw a perpendicular to the rays at the point (XA,YA) and then draw the cam as a smooth curve which is everywhere tangent to the family of straight lines represented by the follower face (See Fig. 2). The program uses a different technique.

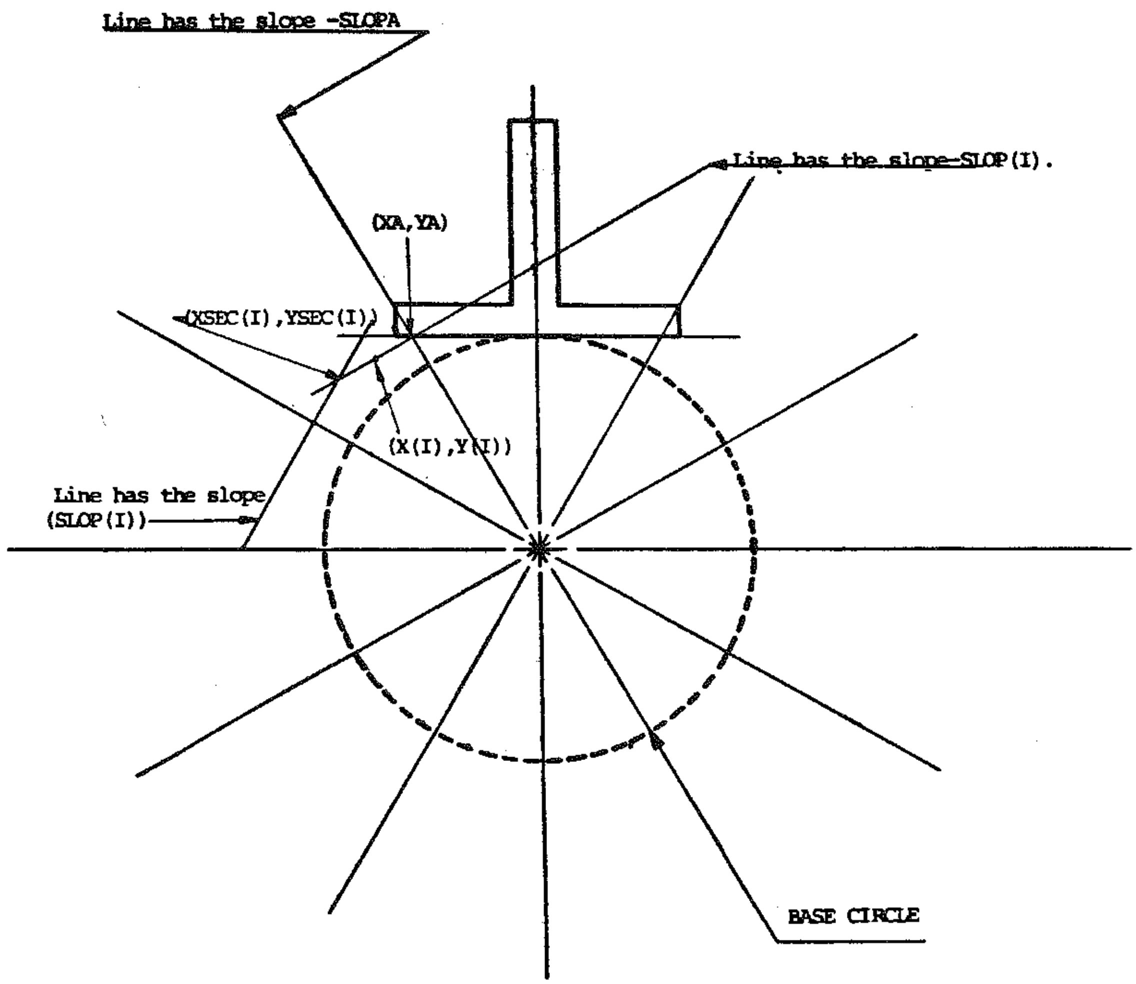

Figure 1 - Construction of Cam Profile for a Flat-Faced Follower

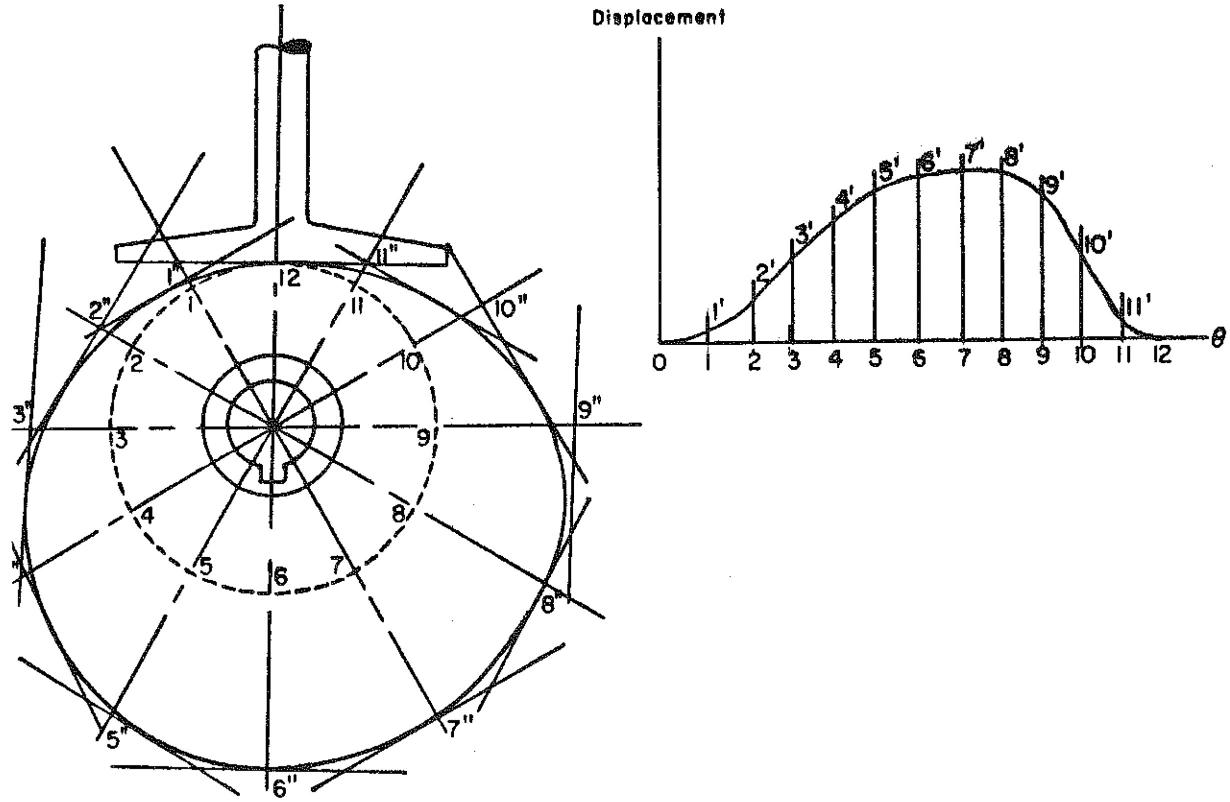

Figure 2 - Graphical Construction of Cam Profile for a Flat-Faced Follower

The intersection of the two adjacent rays is calculated (XSEC(I),YSEC(I)) and the line (XSEC(I)-X(A), YSEC(I)-Y(A)) is then divided in half, locating the point X(I), Y(I) (See Fig. 1). After this procedure has been carried out for each ray, the points X(I), Y(I) are joined to determine the cam profile. Although the concept of tangency is not included in the method, the accuracy of the cam profile is acceptable due to the large number (360) of divisions.

The construction of a cam with roller follower is depicted in Fig. 3. The program first draws the cam center with the keyway. If no offset is desired, the base circle is drawn and again subdivided into 360 sections. On each ray the point (X(I),Y(I)) is located at a distance equal to the sum of the circle and the appropriate displacement. The points are then connected to describe the cam profile. If an offset is desired the procedure differs in that an offset circle is first constructed. This circle is next subdivided into 360 sections. At the intersection of each ray with the offset circle a tangent line is drawn with a slope of SLOP2 (See Fig. 4). The program then moves a distance, DOS, which is determined by the user, along the first ray to locate the center of the follower. This distance plus the appropriate displacement locates the center of the roller follower on the remaining rays. Since we are dealing with roller followers, a line is extended from the center of the roller to the center of the offset circle. This is necessary to locate the contact point between the follower and the cam. Moving toward the offset circle center a distance equal to the radius of the roller follower locates this point (X(I),Y(I)). The program again connects the 360 points to determine the cam profile.

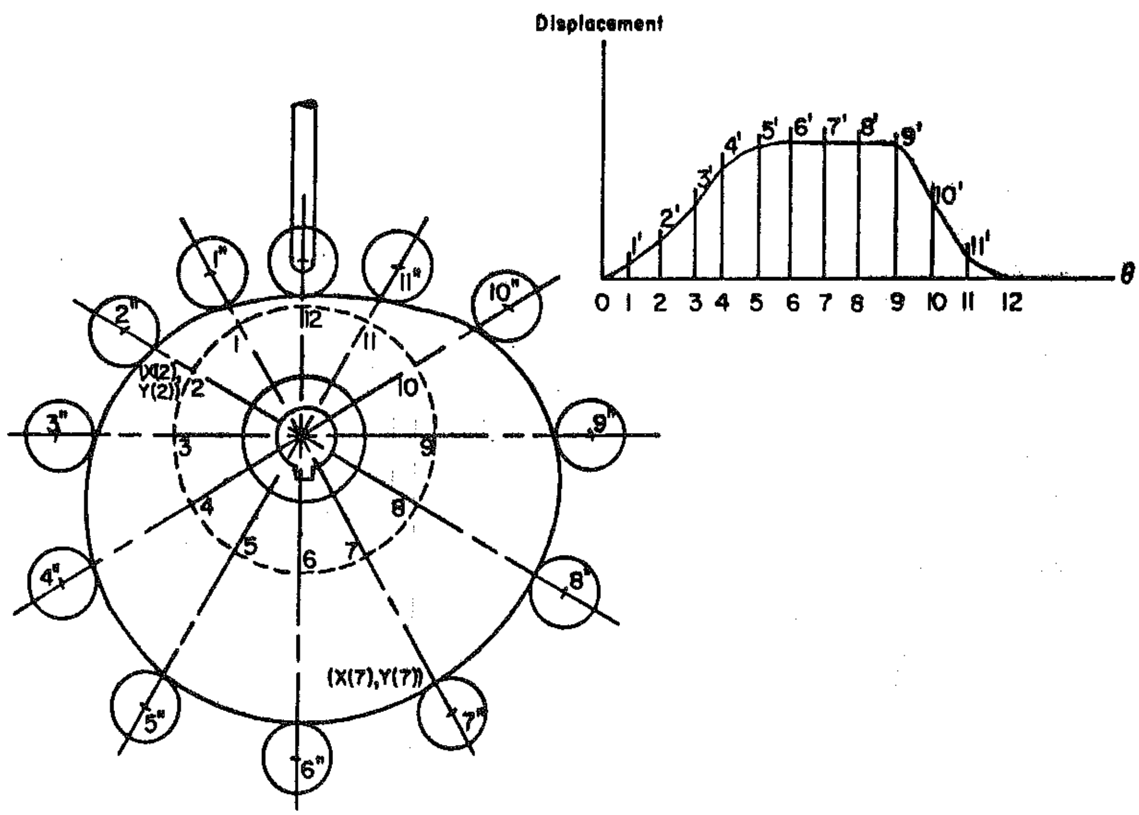

Figure 3 - Construction of Cam Profile for a Roller Follower

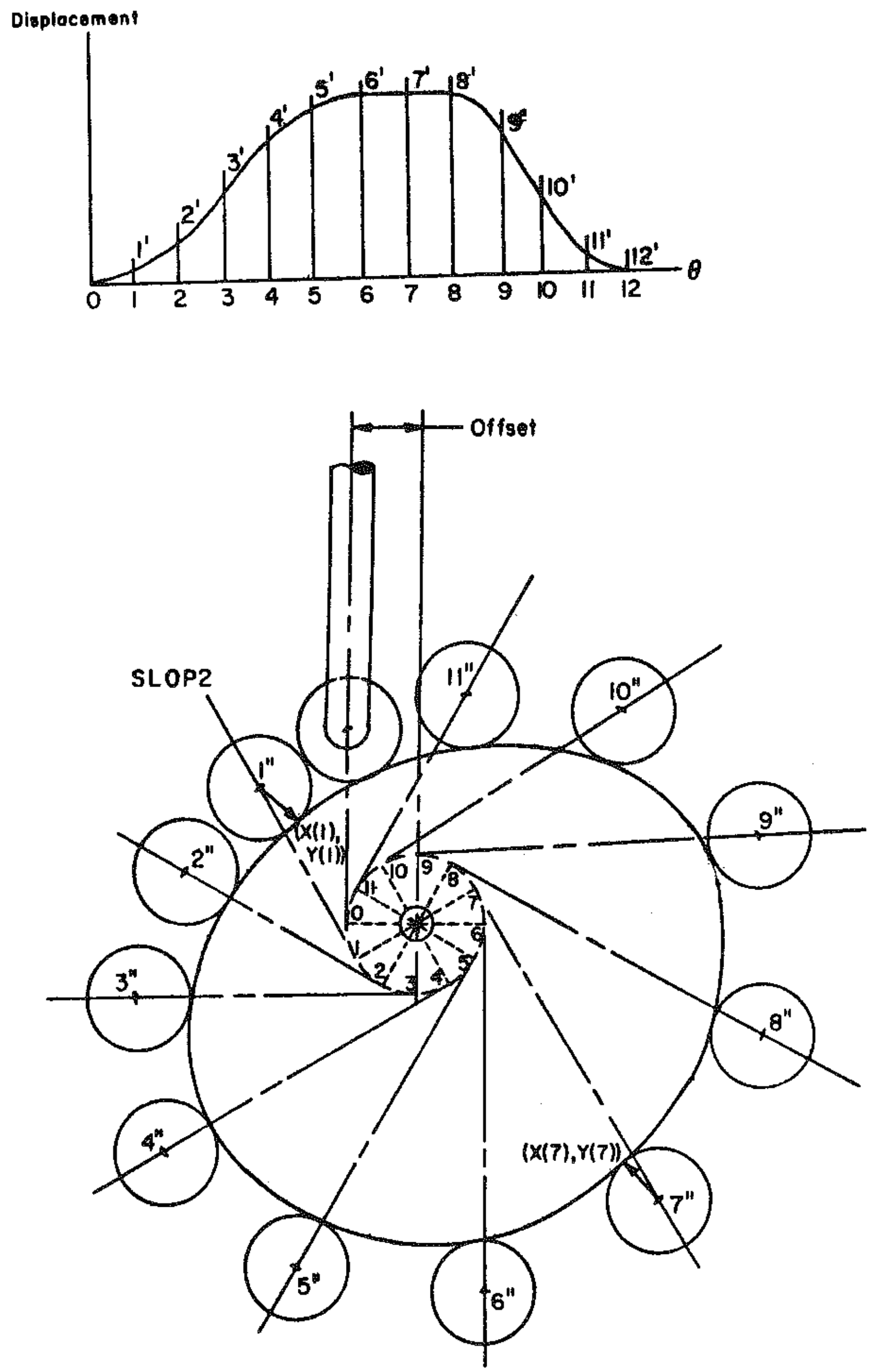

Figure 4 - Construction of Cam Profile for an Offset Roller Follower

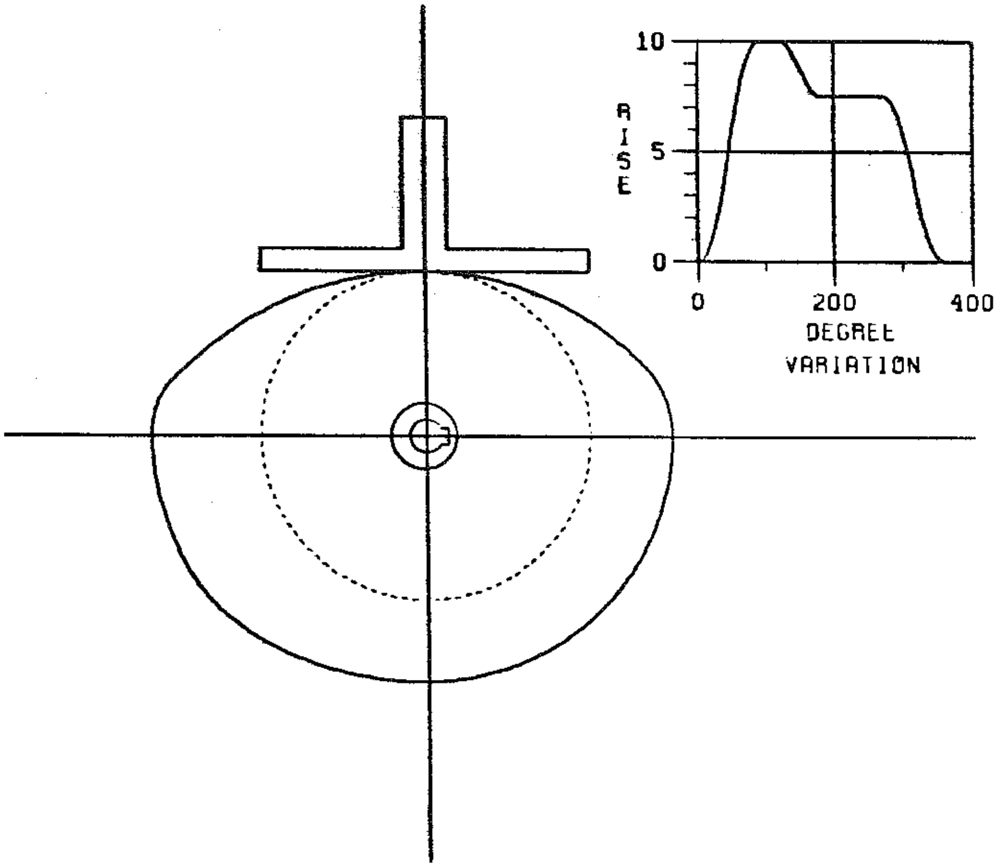

Figure 5 - Cam Profile for a Flat-Faced Follower

(Displacement Curve No. 1)

The cam profile of the knife edge follwer with no offset is determined in a manner identical to that of the roller follower with no offset. If an offset is desired the method differs in that the appropriate distance moved along the tangent line SLOP2 determines the the point of contact (X(I),Y(I)). These points are then connected to form the cam profile. Figures 5 through 9 give examples of the classroom value of the program. The five cam profiles all result in the same displacement curve. Figures 5, 6 and 8 demonstrate the cam profiles that result from the various followers. Figures 6 and 7 illustrate the concept of the offset

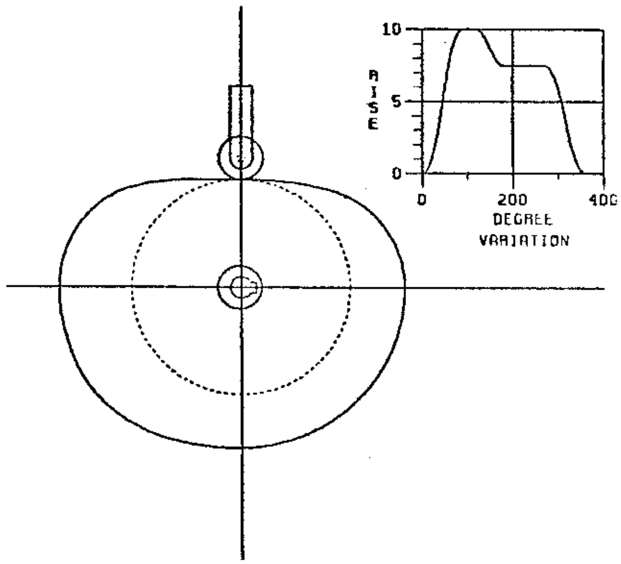

Figure 6 – Cam Profile for a Roller Follower

(Displacement Curve No. 1)

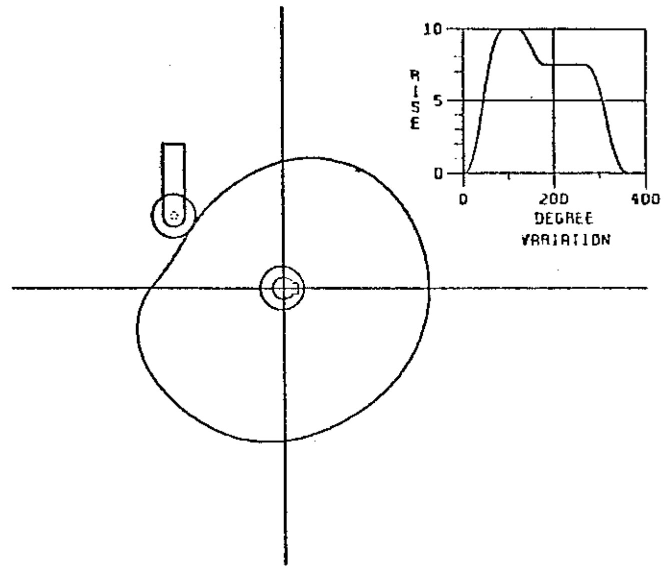

Figure 7 – Cam Profile for an Offset Roller Follower

(Displacement Curve No. 1)

roller follower while Figures 8 and 9 illustrate this concept for a knife-edge follower. The value of this program can be visualized as the aforementioned effects can be conveyed to the students in a quick and efficient manner.

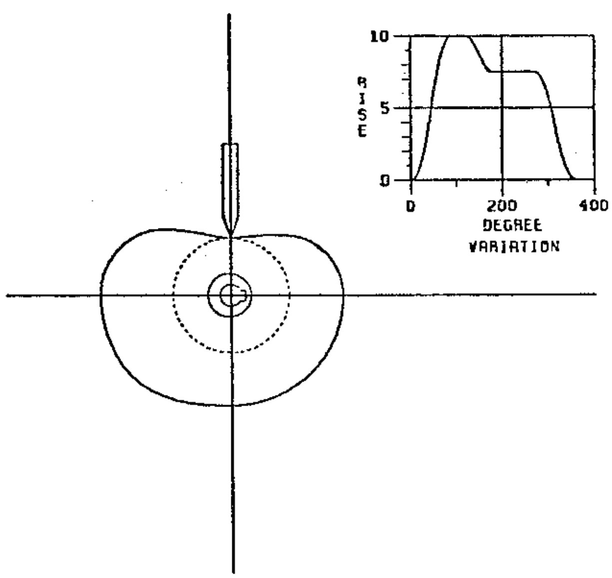

Figure 8 – Cam Profile for a Knife-Edge Follower

(Displacement Curve No. 1)

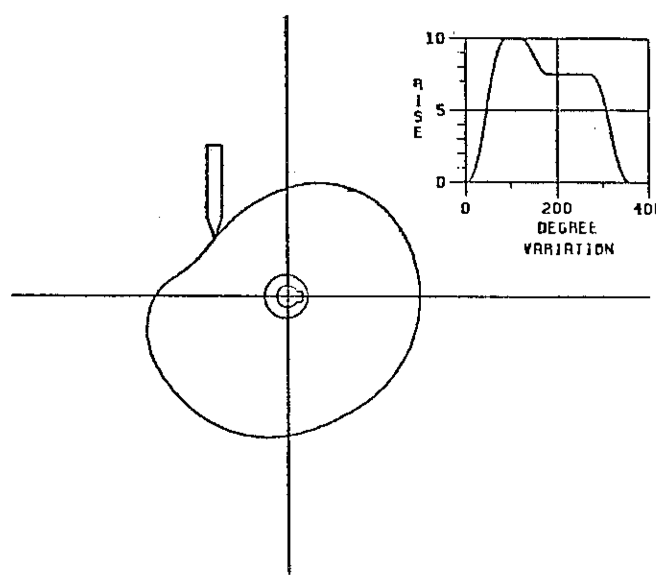

Figure 9 – Cam Profile for an Offset Knife-Edge Follower

(Displacement Curve No. 1)

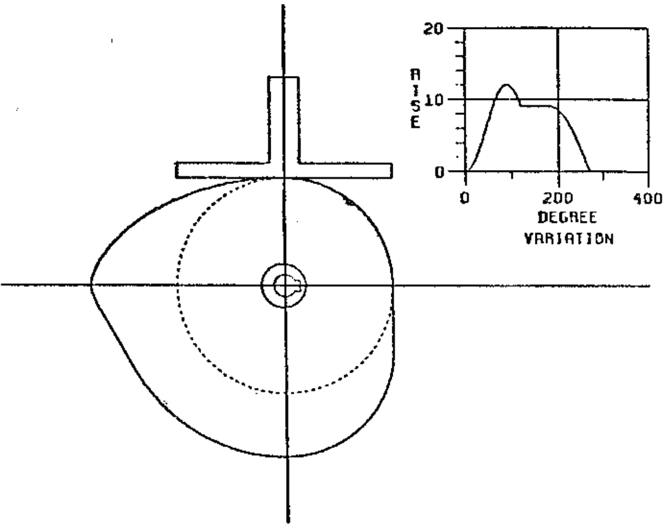

Figure 10 - Cam Profile for a Flat-Faced Follower (Displacement Curve No. 2)

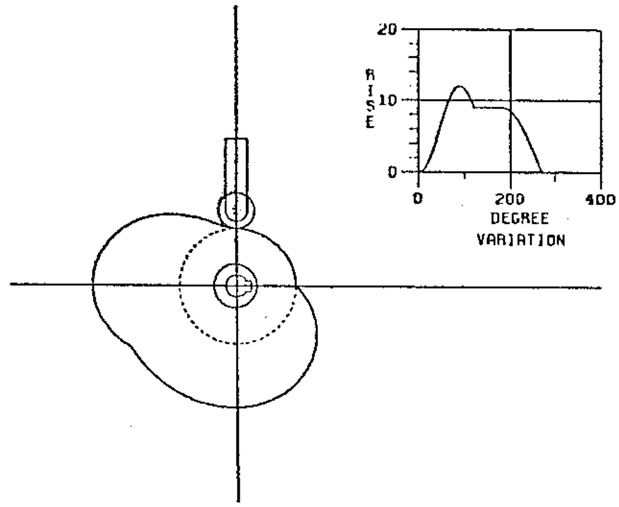

Figure 11 - Cam Profile for a Roller Follower (Displacement Curve No. 2)

Figures 10 through 14 illustrate the same concepts as the previous examples, with the exception that a different displacement curve results. These figures also illustrate the severity of the effect of a dwell on the cam profile. Again, this effect can be readily and quickly conveyed to the student.

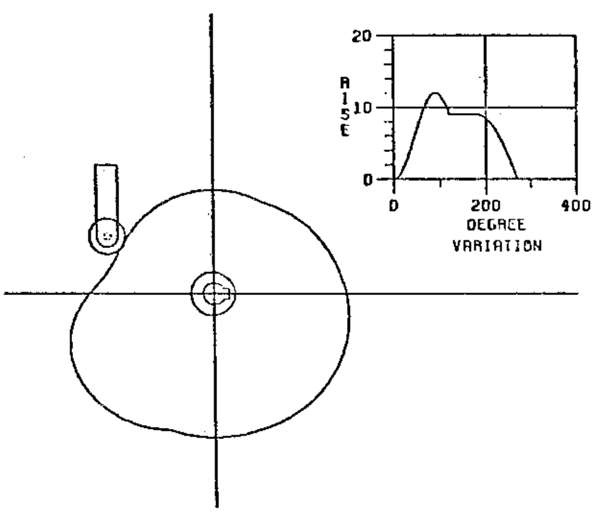

Figure 12 - Cam Profile for an Offset Roller Follower (Displacement Curve No. 2)

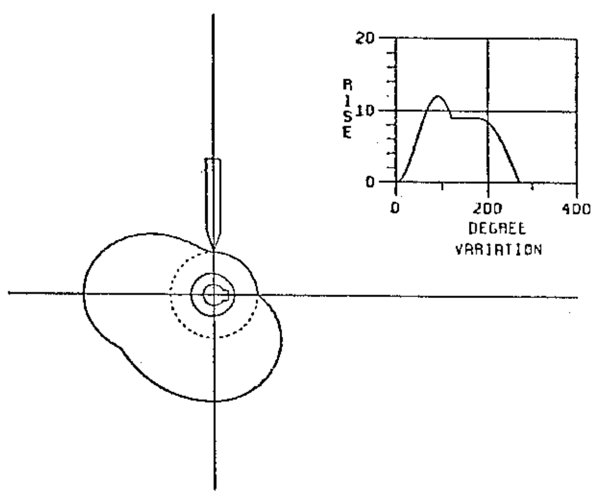

Figure 13 - Cam Profile for a Knife-Edge Follower (Displacement Curve No. 2)

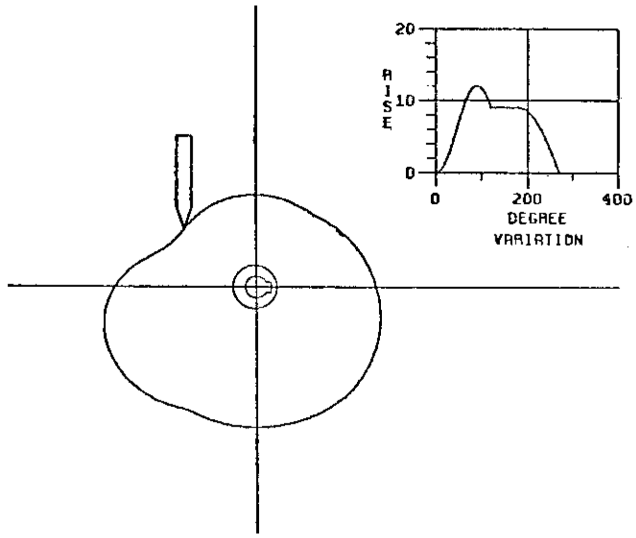

Figure 14 – Cam Profile for an Offset Knife-Edge Follower
(Displacement Curve No. 2)

Summary

A program to aid in the teaching and/or designing of cams is presented. The input of the displacement curve, cam follower, and follower offset is required of the user. The program then calculates and draws the cam profile, follower, and desired displacement diagram. Since this is accomplished in a very short period of time and with a minimum of effort, the program lends itself quite readily to the classroom situation. The user will also be able to quickly and accurately compare the effects of changing the follower, follower offset, or base circle radii on the cam profile, or the effect a change of the cam profile will have on the follower displacement.

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3. Berard, Samuel S., Waters, Everett O., and Phelps, Charles W., "Principals of Machine Design," The Ronald Press Co., 1955.

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from the midyear conference

PHOTOGRAPH CAPTION CONTEST

EXAMPLE:

"PAT"KELSO AND ABE ROTENBERG "SQUARE OFF" AND HAVE TO BE RESTRAINED BY SECONDS BILL ROGERS (CENTER) AND JACK BROWN (FAR RIGHT).

YOUR CAPTION:

____

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____

____

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EXAMPLE:

MARY COPELAND (FAR LEFT) READS DUELLING RULES TO KELSO (LEFT) AND ROTENBERG (RIGHT) WHILE KELSO CHECKS HIS INSURANCE CARD FOR POSSIBLE COVERAGE.

YOUR CAPTION:

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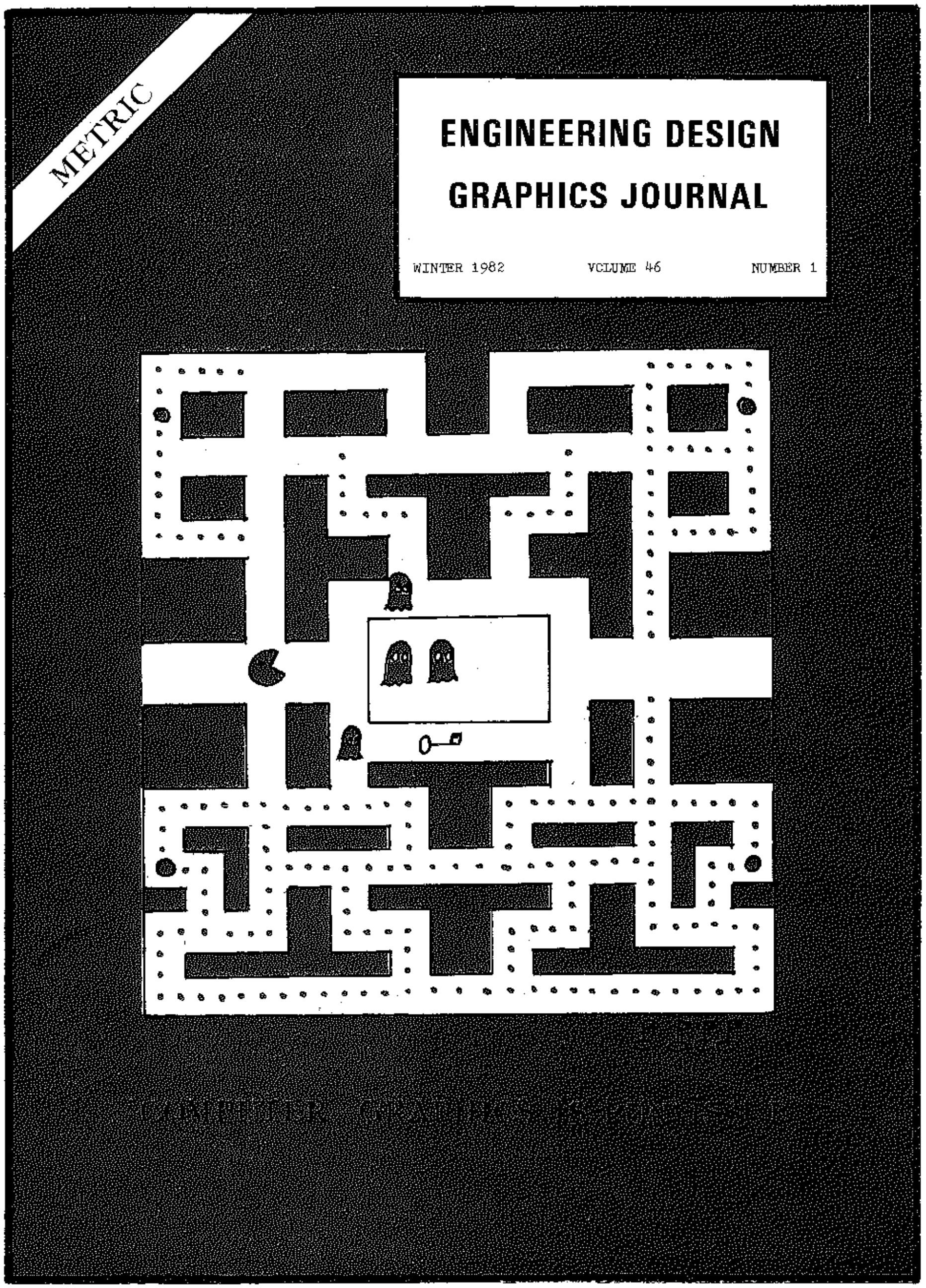

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