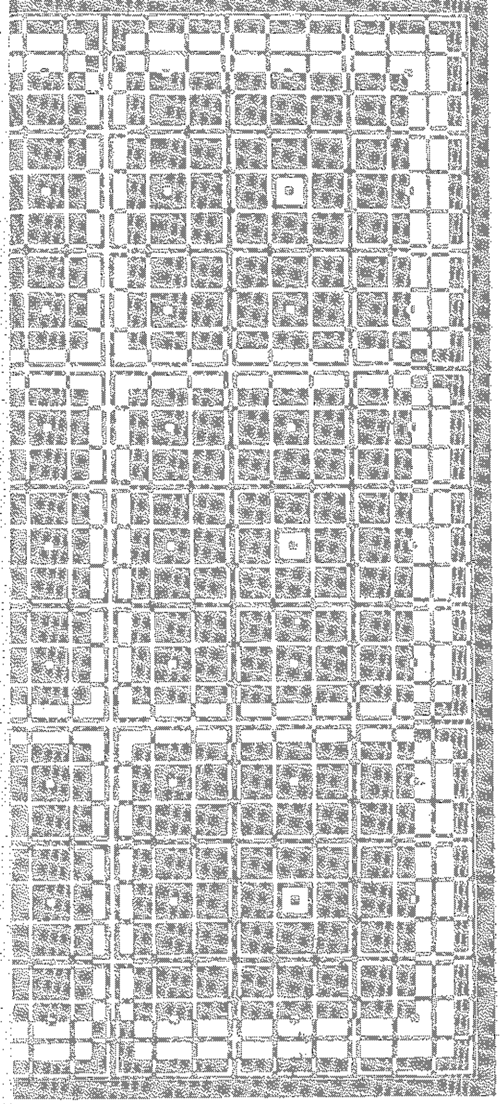
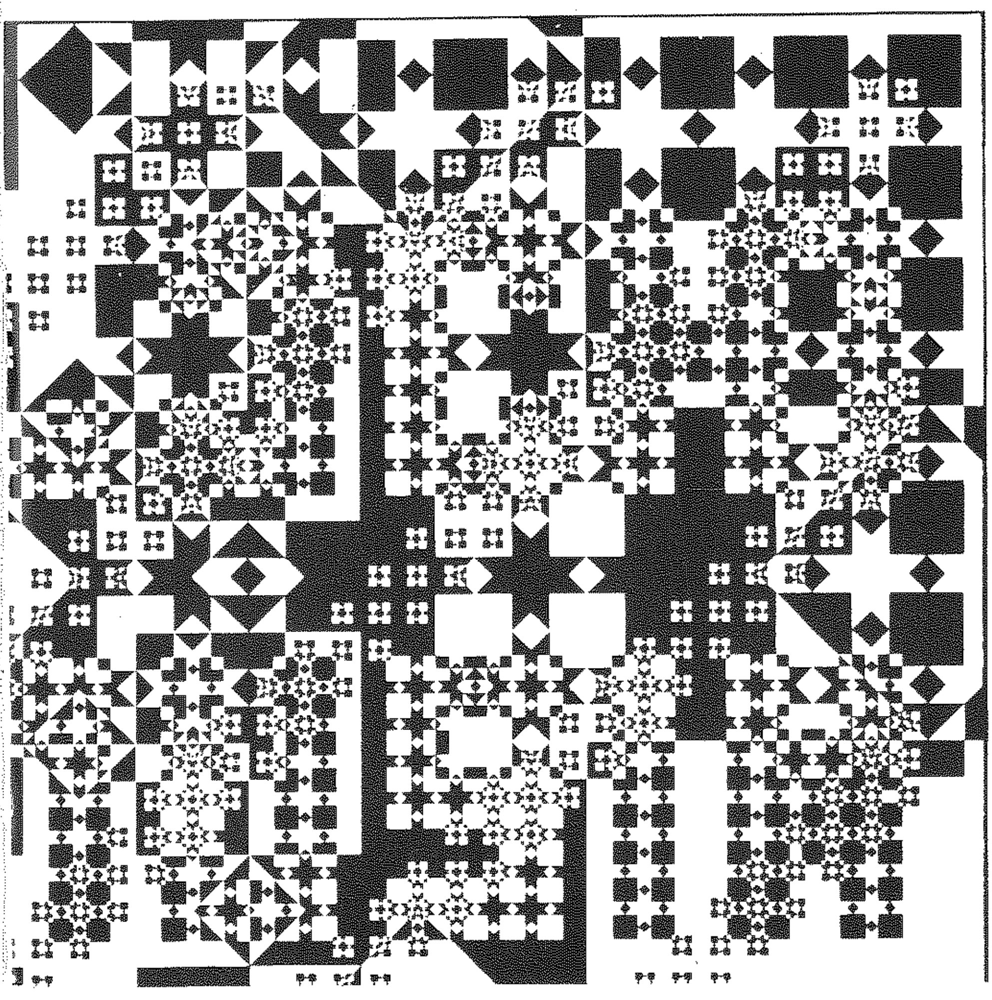
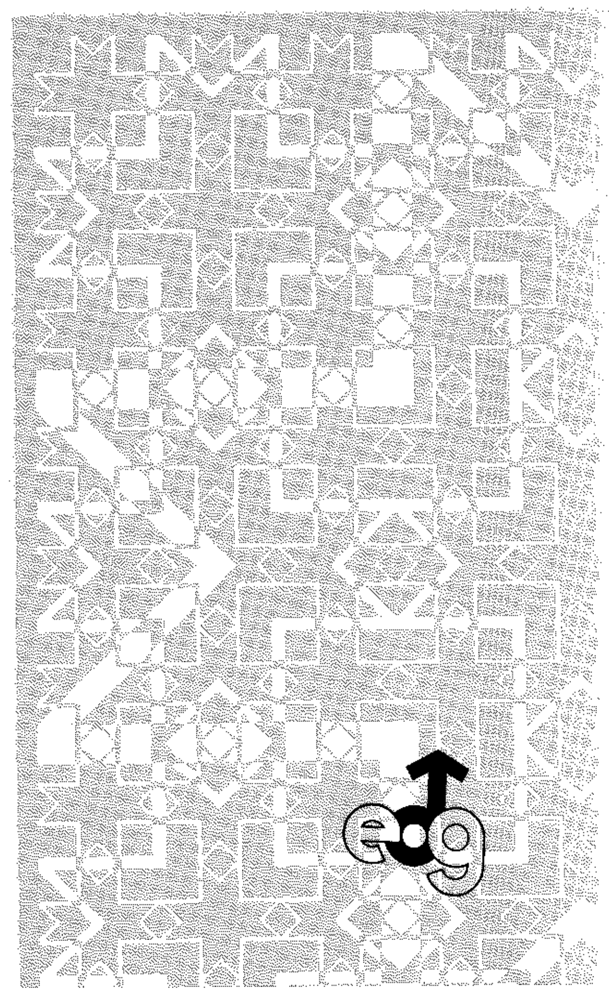


ENGINEERING DESIGN GRAPHICS JOURNAL

WINTER 1975 VOL. 39, NO. 1, SERIES 116





THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

ENGINEERING DESIGN GRAPHICS JOURNAL

WINTER 1975 VOLUME 39 NUMBER 1 SERIES 116

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Applications, and Up-To-Date Education and Industry...

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Since its initial publication, Technical Drawing has been used by more than two and a half million students. The Sixth Edition retains the features that have made previous editions so successful while incorporating changes necessary to bring it completely up-to-date with the latest trends in engineering education and the newest developments in industry.

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ENGINEERING DESIGN GRAPHICS JOURNAL OBJECTIVES:

The objectives of the JOURNAL are:

1. To publish articles of interest to teachers of Engineering Graphics, Computer Graphics and allied subjects.
2. To stimulate the preparation of articles and papers on the following topics (but not limited to them):
3. To encourage teachers of Graphics to innovate on, experiment with, and test appropriate techniques and topics to further improve quality of and modernize instruction and courses.

CALENDAR OF MID-YEAR MEETINGS

1975-76:Arizona State University

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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 Engineering Design Graphics Journal. In order to save time, expedite the mechanics of publication, and avoid confusion, please adhere to these guidelines.

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CALENDAR OF ASEE MEETINGS

1975 -- Colorado State University
1976 -- University of Tennessee

EDITOR'S PAGE

The Engineering Design Graphics Division has made many contributions to engineering education throughout the years, but one of its most significant contributions is that of publications. Few disciplines have such a reservoir of course materials provided for their students and the instructors.

Essentially all textbooks have been written in a clear manner to truly simplify and explain the many varied theories, conventions, and principles of engineering graphics, descriptive geometry, and graphical design. All have been extensively illustrated to compliment the text material. The earlier books, since they were the pioneers of field, were less adept at content presentation than the latest books on the market.

After the first pioneering textbooks, a number of classics were authored and used universally across the nation. These books were expertly written and illustrated, covering practically all aspects of the traditional course of graphics. These books were so well done that they tended to discourage prospective authors. The drawings alone would require several man-years to prepare.

The more recent authors have attempted to use textbooks as a means of introducing and outlining new course directions other than the traditional approach. These have included the introduction of the design, computer graphics, and even self-instruction techniques.

The graphics student is also provided with the most up-to-date problems, printed in the form of problem books that enable him to complete at least fifty per cent more material than when working without printed problems. These problem books have been written by a number of teachers of graphics and by groups of teachers. They are available to emphasize the practical, the theortical, the creative and variations in between. It is to the credit of the teachers of the engineering design graphics courses that these materials are so extensively used in their classes.

The writing and using of course materials--textbooks, problem books, texts--examplifies an important characteristic so necessary to effective instruction. This is organization. The graphics teacher of today is presented with some of the most highly organized material that is known.

This organization is not structured to restrict the teacher, but instead, many of these materials actually assist the teacher and the student in approaching the course material in a creative manner. A teacher can choose the text and problem materials that he prefers, either traditional or futuristic, and introduce this approach to his classes in a highly organized manner, since these materials have been organized for him by various authors through classroom experience.

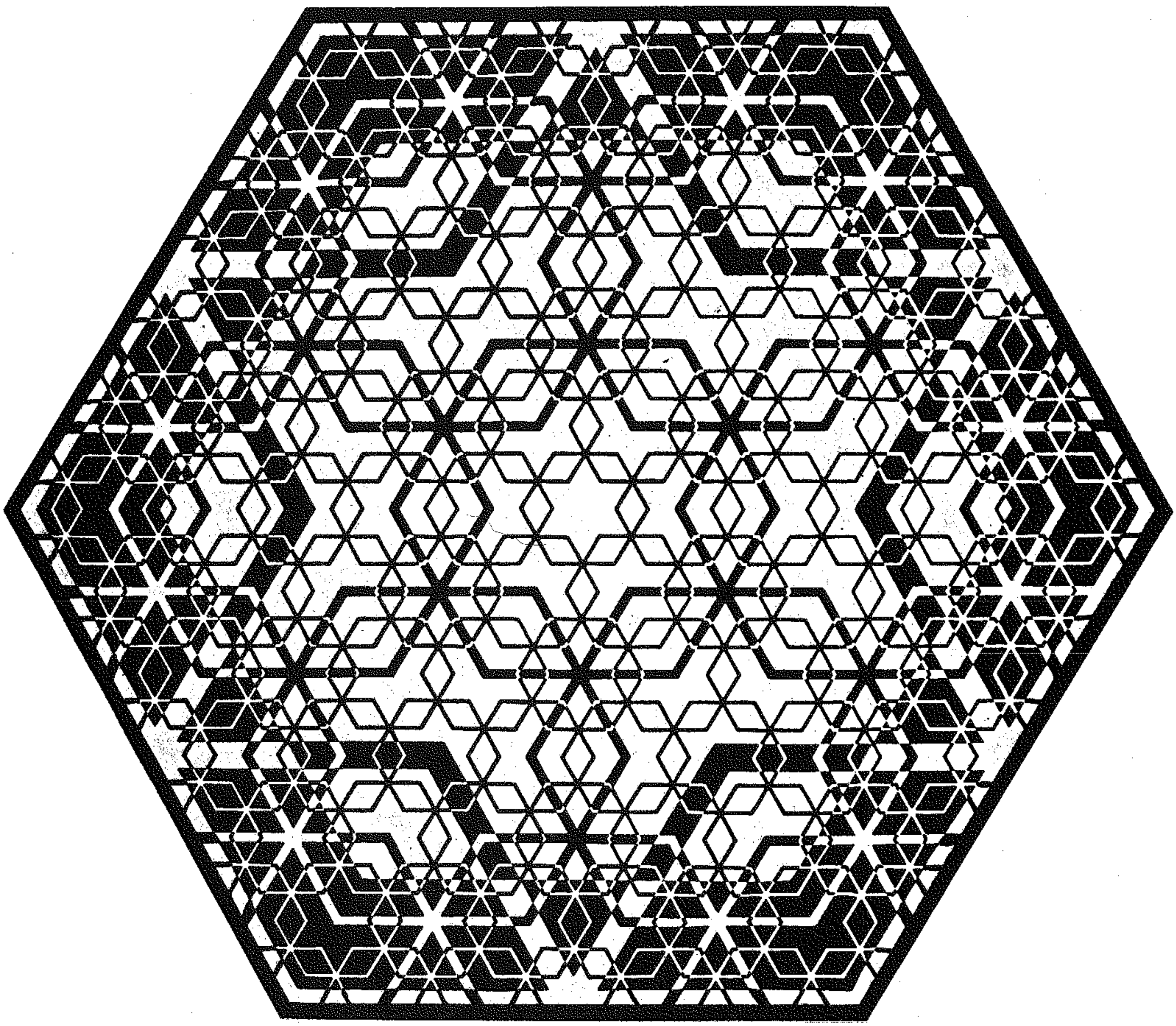
It might even be said that the authors who have produced the materials used in graphics courses have almost done their jobs too well. A well-written book that clearly explains how a problem is to be solved, and one that a student can refer to and use on his own, may cause the student to feel that the material is easy, and therefore unimportant, simply because it is presented clearly. By looking at textbooks in other fields, it can be seen that students rely more on their notes than on their textbooks, which implies that their textbooks fall short. Unfortunately, it is human nature for a person to have more respect for material that he does not understand than for the areas that he understands.

Regardless, it is a tribute to Division and to the field of engineering design graphics that such a wealth of text materials have been produced, edited, rewritten and originated over the years. New titles are being published yearly. This is a sign of a strong and dedicated membership that has made our Division one of the foremost leaders in ASEE.

Jim Earle

By Reinhard Lehnert, West Germany

GEOMETRICAL PICTURES



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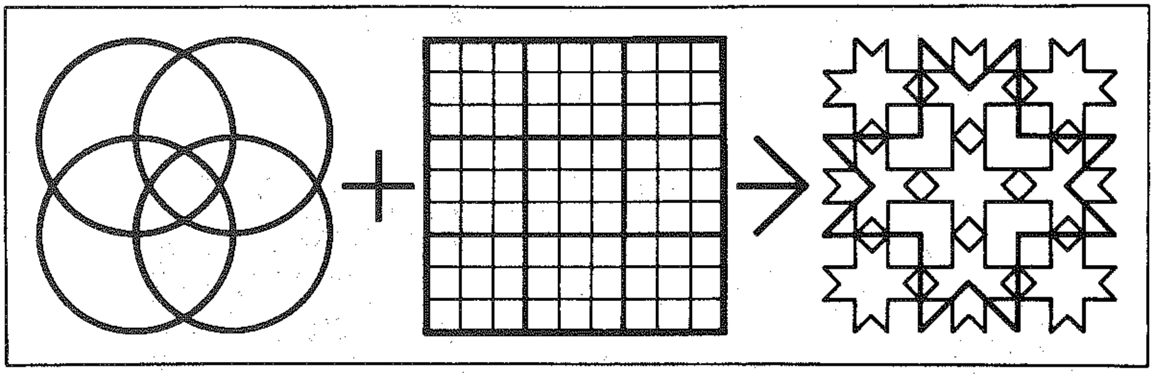
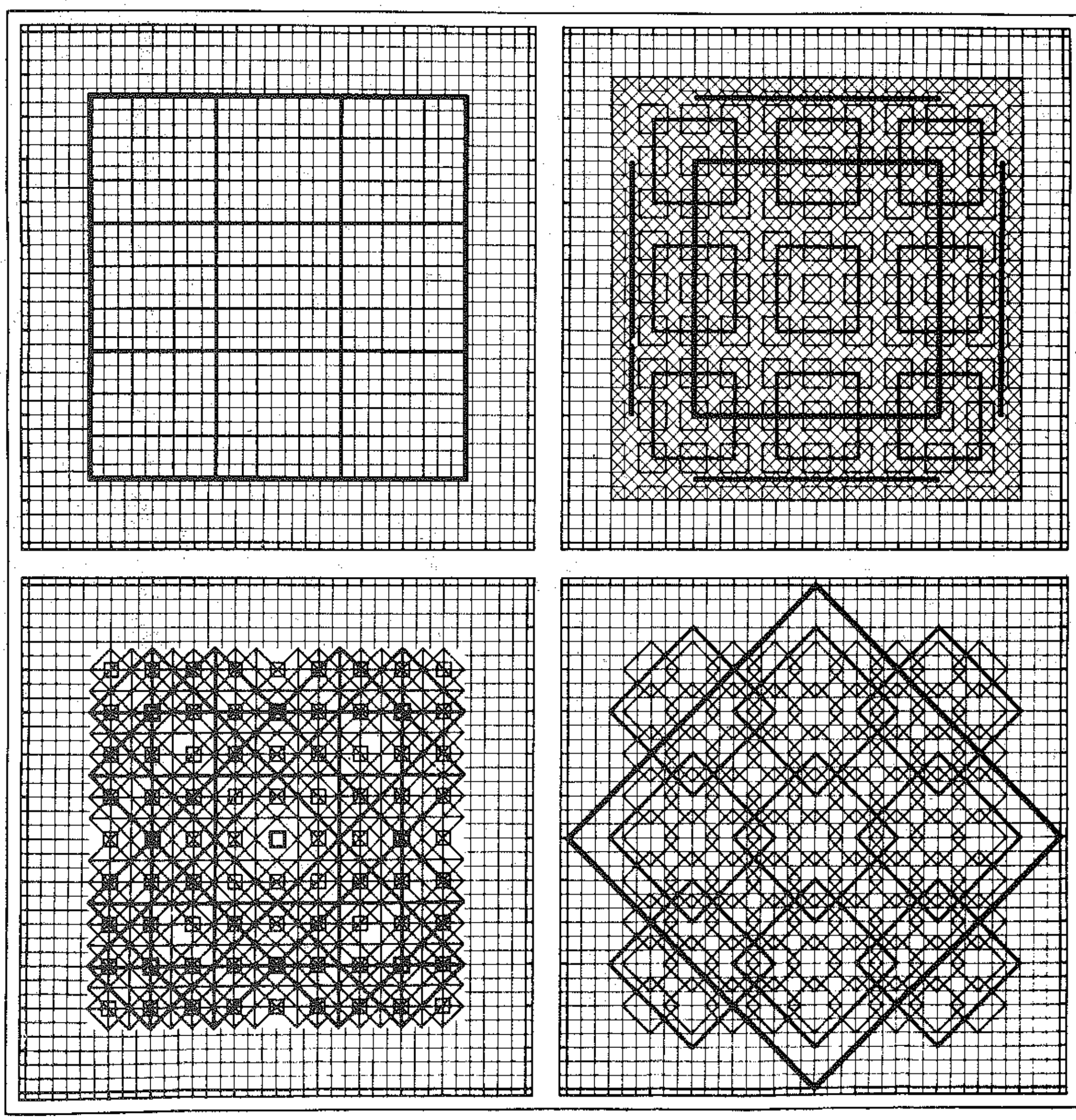
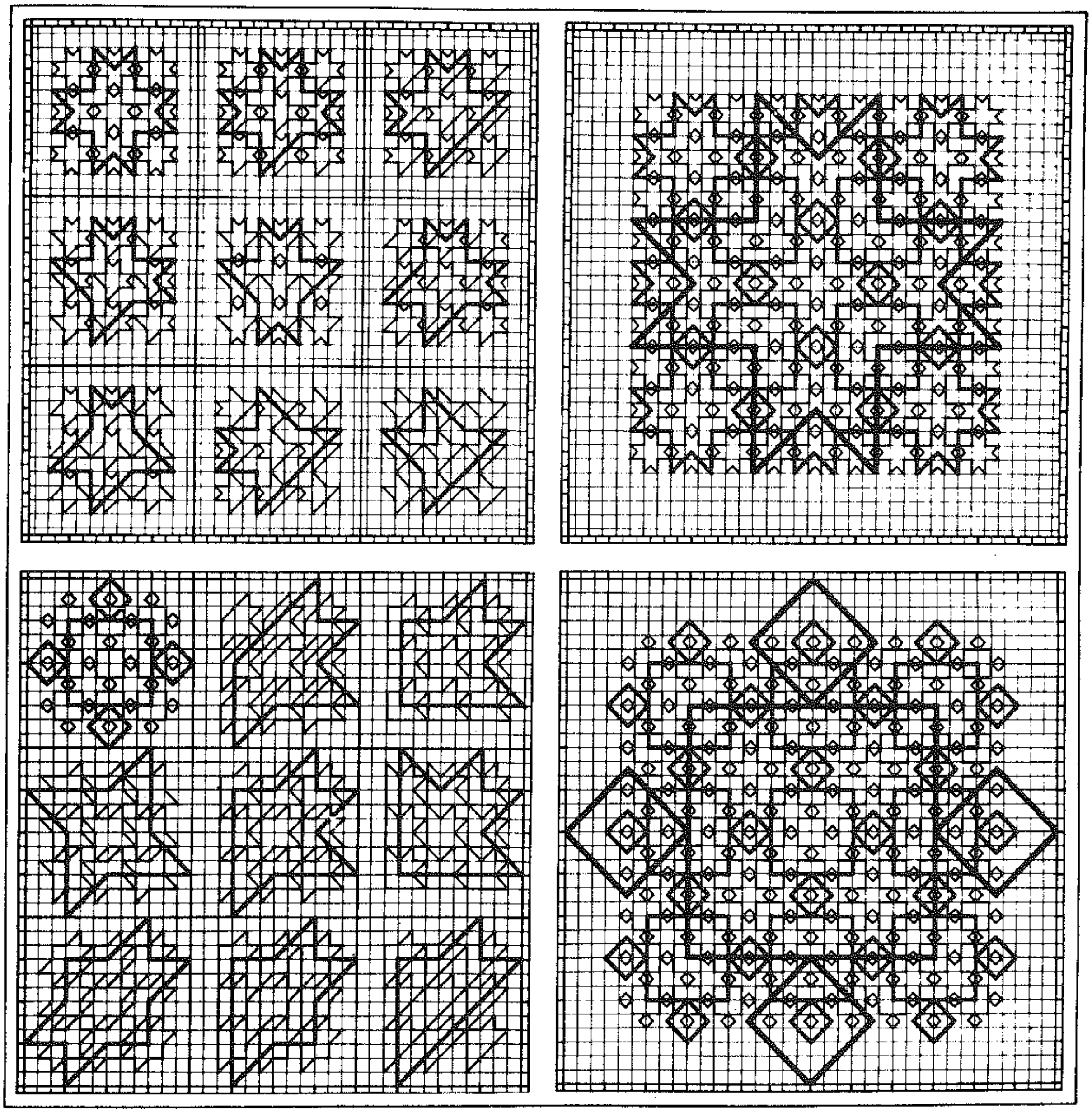
A contribution to a reform of Mathematics and Art Teaching (Part I)



Picture 1



Picture 2



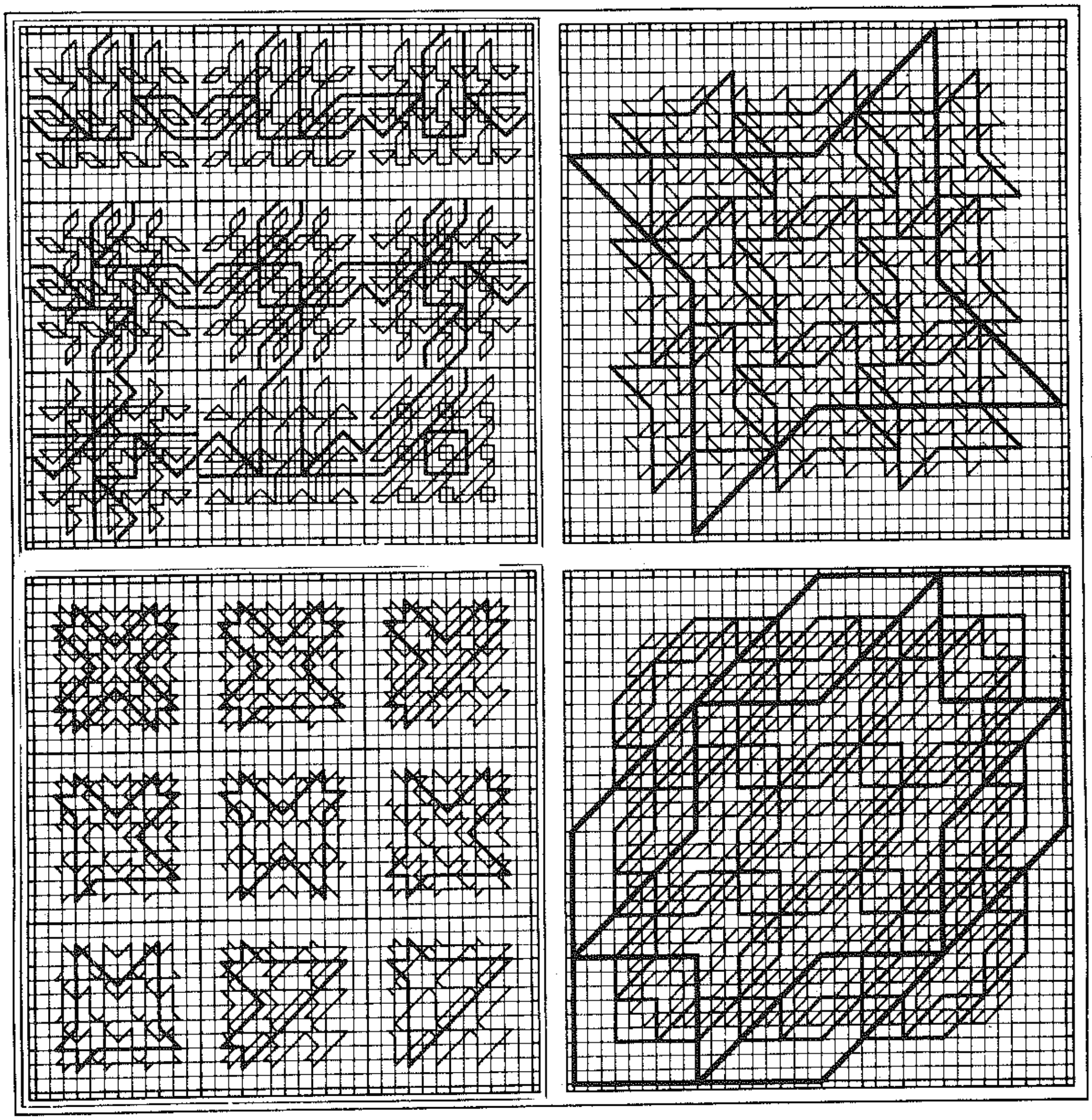
Picture 3

Children play and tinker perseveringly and passionately. They prepare themselves in this way for their future lives. The simplest, the most diversified and effective hobby is drawing and painting. Two-dimensional pictures can be produced more easily than three-dimensional objects. A piece of paper and a lead pencil are always at hand, coloured pencils are to be had at reasonable prices. By playing and tinkering, especially by drawing and painting, also by looking at and examining pictures, the children should be initiated into the study of mathematics, as far as that is possible in this way.

We train our children at a very early age in freehand drawing and painting. Much later (at the secondary school) we train them in constructing with geometrical instruments, that is with rulers and set-squares, with compasses and protractors, and with squared paper. They have to draw triangles, quadrangles, ground-plans and vertical sections, perspective pictures of stereometric bodies and geometrical curves. These are mathematically and technically important and instructive activities. But the results are not eye-catching: they do not often appeal via the eye to the soul and the spirit as do freehand pictures.

If we can succeed in guiding the child to drawing and painting with geometrical instruments, in an activity that catches and satisfies him in a similar way to freehand drawing and painting, we shall have found a natural and incomparably valuable method of guiding the child towards geometry and moreover towards the totality of mathematics. Outlining and drawing the well-known one or two-dimensional geometrical designs can, by no means, meet these aims. These designs are tedious: the base-figure to be repeated can be chosen optionally, and it simply repeats itself. In any case these designs lack totality: if there is only one cell there is not yet a design. But if there are several cells, the total picture "falls" for the human eye into these cells.

Our task is therefore to look for geometrical figures which can be used as screens for the production of numerous geometrical

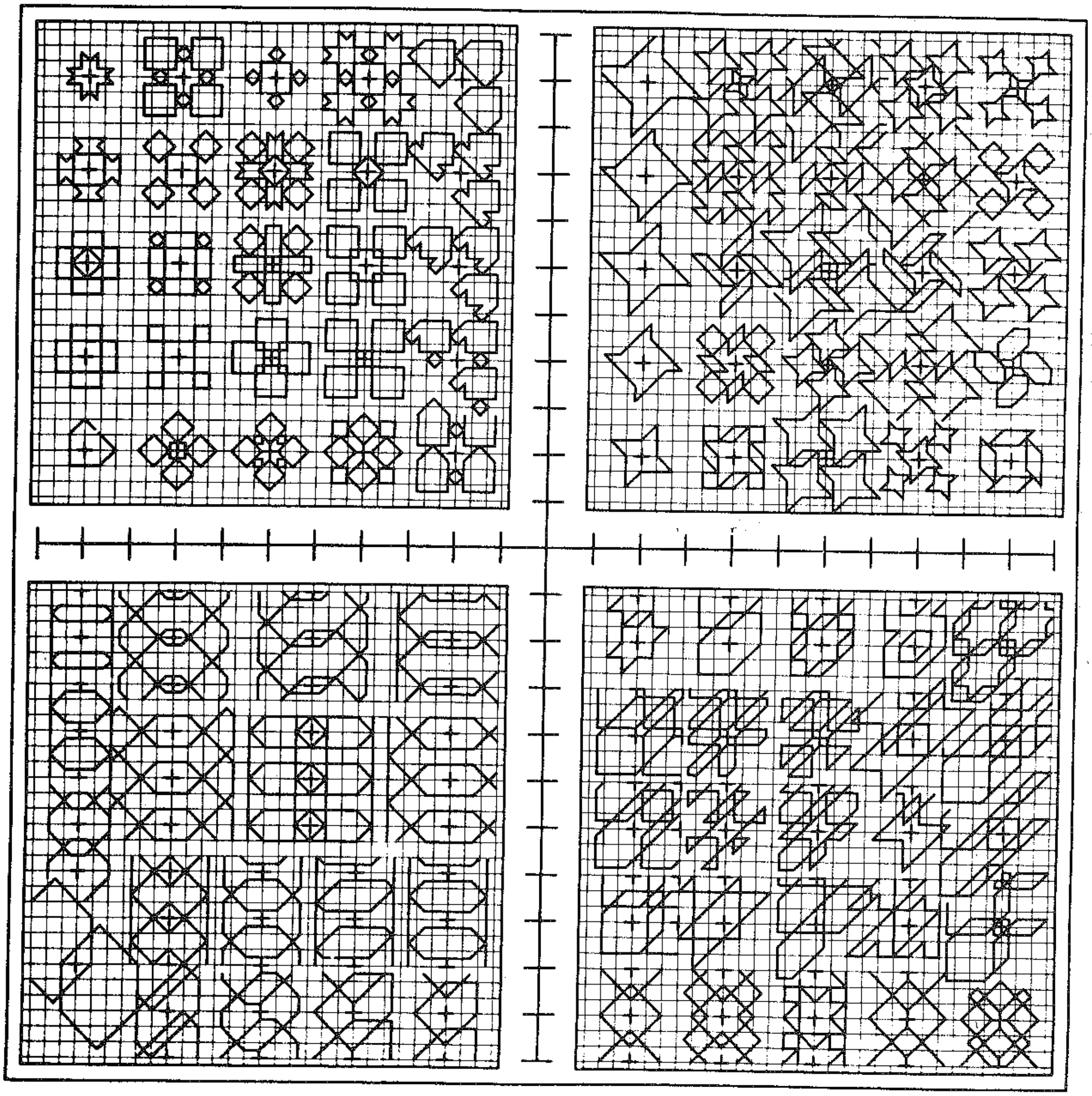


Picture 4

pictures which are aesthetically valuable and highly suggestive. There are such figures. They are layered surface designs (discovered by the author) complying with certain conditions. We call them "inner-stars", the pictures based on them "inner-pictures" (as a rule representing no objects), the films based on them "inner-games". In the following we present some "inner-stars" and "-pictures" and then discuss the question how such figures can be used in elementary mathematical classes. (A suitable treatment in art-classes would also be useful.)

Picture 1 represents the basic idea of the "inner-stars". It shows three partial pictures. The left partial picture represents the "intersection law of seeing": two or even more areas of good form (here: circular areas) intersecting each other can, at the same time, be seen as intact forms. The partial picture in the middle shows layers 0, 1 and 2 of the "cell-star" of the number of extension 3, abbreviated C3. The large square (to be conceived as area) is the "cell" of layer 0, the 3.3 = 9 central ones are the "cells" of layer 1, the 9.9 = 81 smaller ones form layer 2. We add the finer layers correspondingly in our minds, that is 27.27 = 729 "cells" of layer 3, 81.81 = 6561 of layer 4 and so on. The right partial picture shows layers 0 and 1 of an "inner-star" of the number of extension 3. The big star (to be conceived as area) is the "base-figure" of layer 0. The 9 small stars are the "base-figures" of layer 1. We imagine the finer layers to be formed correspondingly.

This "inner-star" results from C3 by a homogeneous change of all "cell-borders". From the "cells" of C3 result in this way the "base-figures" of the "inner-star". Unlike those of the "cells" the borders of the "base-figures" are separated, that is it no longer occurs that parts of border lines of different layers coincide. Border lines of "base-figures" of different layers have only some points in common. (In the present case this is valid also for the "base-figures" of the same layer.)



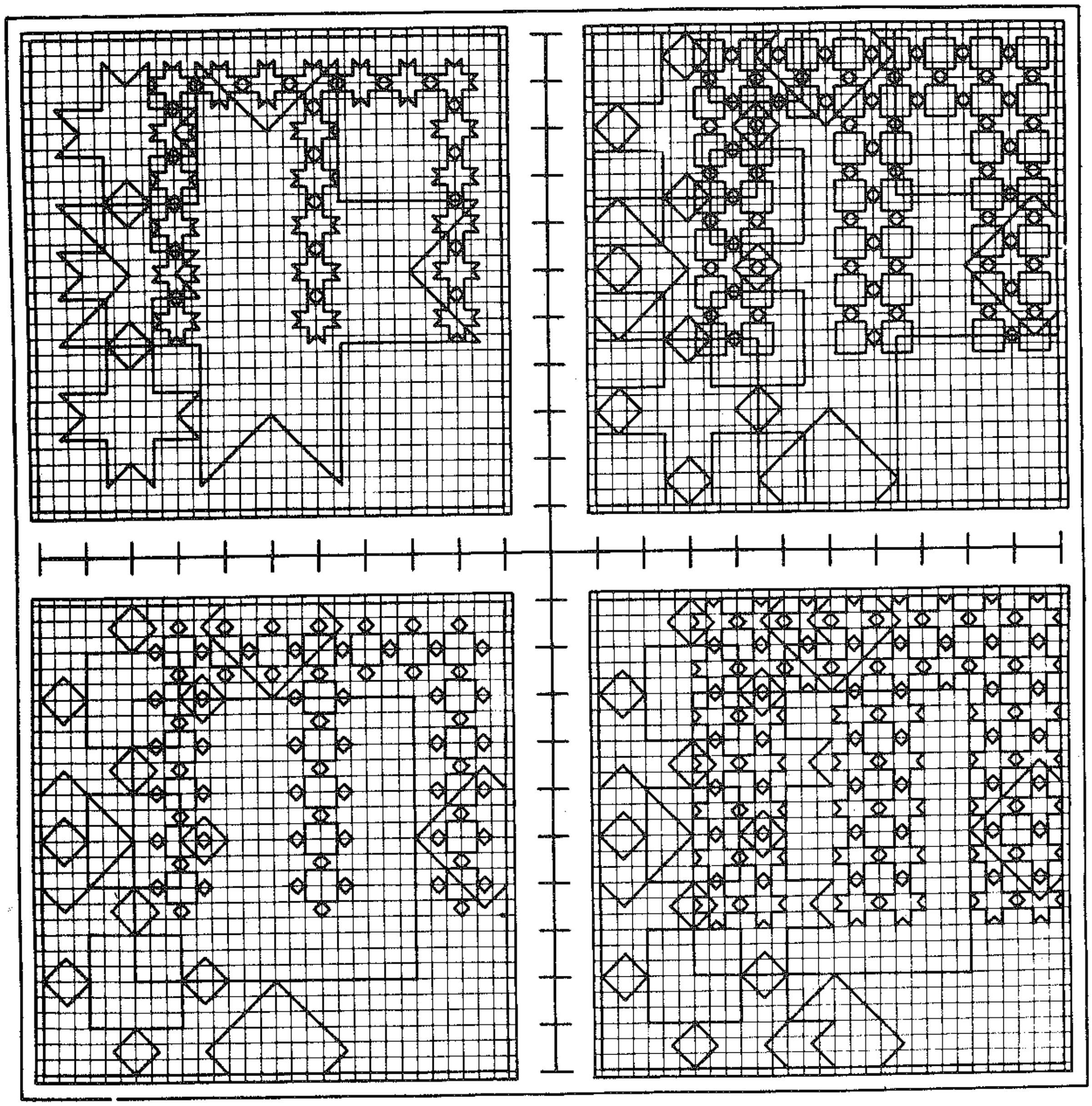
Picture 5

The "base-figures" of this "inner-star" are polygons with 16 angles, that is stars with 8 indentations. Every "base-figure" originates from the corresponding "cell" when from this "cell" a square is cut off at each corner, and a right-angled triangle is cut off in the middle of each side. Its area is (4/9) of the area of the "cell". The interior angles are 45° (8 times) and 270° (4 + 4 times). The "base-figure" of layer 0 has the same area as the 9 "base-figures" of layer 1 together, just as the 81 of layer 2 together and so on (reasons?). Two neighbouring "base-figures" of equal layer (upwards-downwards, or from right to left) have exactly two points in common: they touch each other at these points. Therefore we call this "inner-star" an "adjacent inner-star".

Picture 2;1, that is the upper left partial picture of picture 2 shows the layers 0-3 of the "cell-star" C3. **Picture 2;2,** that is the upper right partial picture shows the layers 0-2 of the "screen-star" S3. The "base-figures" are squares whose distances from their neighbours are half as large as their sides. In S3, the border lines of "base-figures" of different layers have only particular points in common. S3 in this respect is "transparent". In S3, neighbouring "base-figures" have no points in common. S3 in this respect, is not "coherent". Therefore S3 is only an imperfect first stage of the "inner-stars".

Picture 2;4 shows the layers 0-2 of an "overlapping inner-star". The "base-figures" are rhombs. They overlap their neighbours in one rhomb each of which has area $\frac{1}{16}$ as large as their own. Each of these rhombs originates from the "cell" corresponding to it by adding 4 right-angled triangles at the middle of the four sides, and by cutting off four right-angled triangles of double the area at the four angles of the "cell'. (How is the area of a "base-figure" related to that of its "cell"?)

We imagine the "cell-star" C3 continued over the borders of the "cell" of layer 0 over the whole plane (so that then each layer comprises infinitely many "cells"). Furthermore we add in our minds the "cells" of the coarser layers -1, -2, . . . We call the



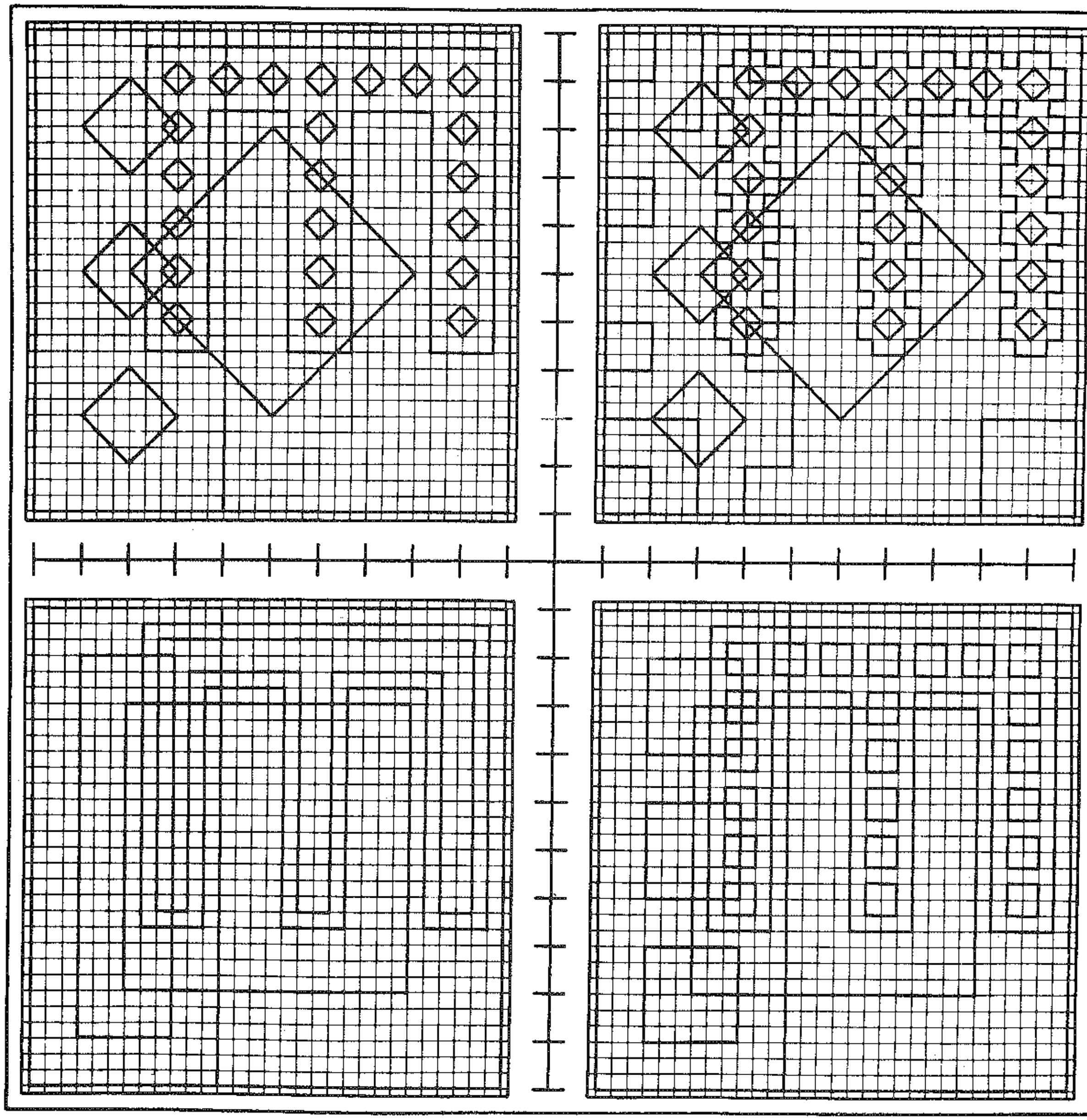
Picture 6

total figure developed in this way the "complete cell-star" cC3. For each layer n = 0, ± 1, ± 2, . . . , of cC3 we call the centres of the "cells" of layer n the "strong-points" of layer n. Only the centre of picture 2;1 is a "strong-point" of all layers. For n = 0, ± 1, ± 2, . . . we call every straight line passing through two (and therefore through infinitely many) "strong-points" a "strong-line" of layer n.

Picture 2;3: For the interior of the central "cell" of layer n all straight lines are shown which we make use of in this article for the disposition of the border lines of the "base-figures" of layers 0 and 1. The reader should examine this in detail. They are "strong-lines" and other straight lines which we call "field-lines". (For further information see my article in "Mathematics Teaching" No.55, Summer, 1971, p.36-43.)

Picture 3;2 shows the layers 0-2 of the "adjacent inner-star" mentioned above. We imagine this "inner-star" continued beyond the borders of the "cell" of layer n. Then we state: Every "base-figure" is bordered by a ring consisting of 4 squares and 4 much smaller rhombs. (What can be said about the areas?) Each ring of this kind has two squares and one rhomb in common with its four neighbours upwards, downwards, to the right and the left. (What part of its area is that?) With each of its four "half-neighbours" upwards to the right, upwards to the left, downwards to the right and downwards to the left, it has a square in common. (What part of its area is that? How many angles has the bordering ring? What interior angles are there?)

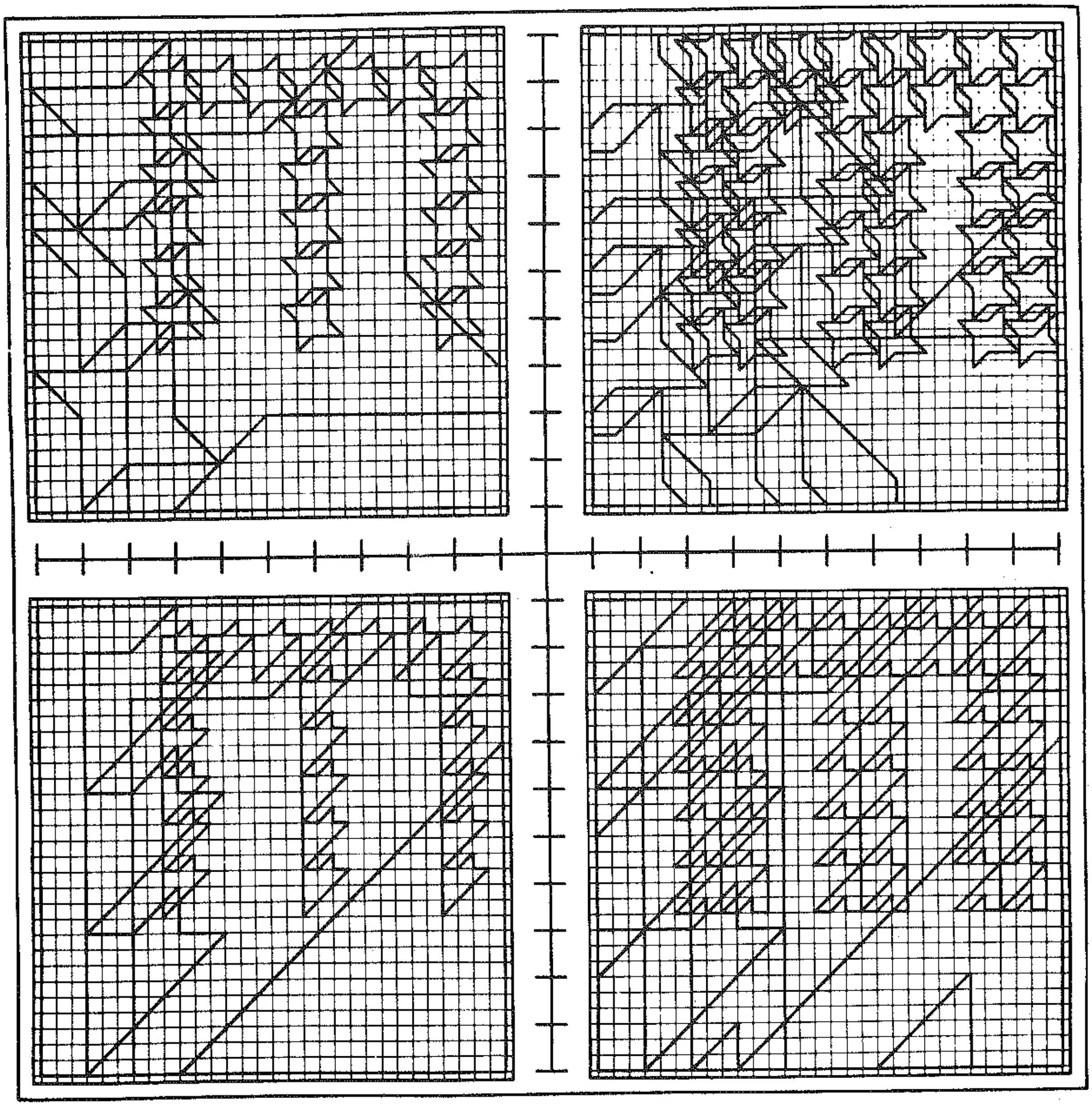
These rings (to be conceived as areas) form a new "inner-star". We call it a "linked inner-star" because in it neighbouring "base figures" are linked with each other by common "separate" areas. "Separate" in this context means that these areas have only particular points in common with the other areas of their "base-figures".



Picture 7

Pictures 3;1;1;1-3;1;3;3 show 9 "adjacent inner-stars" or, more exactly: the layers 0 and 1 of these "inner-stars". 3;1;1;1 shows the "inner-star" of picture 3;2. When we cut off the angle south-south-west in all "base-figures" of 3;1;1;1, then 3;1;1;2 comes into being. When we cut off the angles south-south-west and west-south-west, 3;1;1;3 comes into being and so on. From the "inner-stars" 3;1;1;1-3;1;3;3 originate further "adjacent inner-stars" by folding at the perpendicular line, the horizontal line, the 45°-line or the -45°-line through the respective centre. The same applies for rotation by ±90°, ±180° and ±270°. The same applies when several of these transformations are produced one after another. All "inner-stars" originating in this way, also originate from 3;1;1;1 by cutting off angles. (The reader should examine these connexions. How many different "adjacent inner-stars" come into being in this way? In what ways are the "base-figures" in all these "inner-stars" cut by the border lines of the coarser "base-figures" respectively? What "linked inner-stars" may be formed out of the intermediate areas between the "base-figures", and that by transitions which are similar to the transitions described above from the "base-figures" of picture 3;2 to the rings enclosing them, consisting of 4 squares and 4 rhombs?)

Picture 3;4 shows an "adjacent inner-star" originating from the "screen-star" S3 of picture 2;2 when the centres of the neighbouring sides of neighbouring squares are connected by rhombs. Every "base-figure" consists of a square and four rhombs. These four rhombs together have half as much area as the corresponding square. Two neighbouring "base-figures" each have one rhomb in common. (In what ways are the "base-figures" cut by the border lines of the respectively coarser "base-figures"? What is the area of a "base-figure" to that of one of the corresponding "cells"? Which "linked inner-star" may fo formed by the intermediate areas between the "base-figures"? Answer to the last question: As new "base-figures" we can choose the rings consisting of the respective 4 stars with 8 indentations which surround the former "base-figures". But out of the aggregate of these 4 stars with indentations we can choose every possible part of this aggregate.)



Picture 8

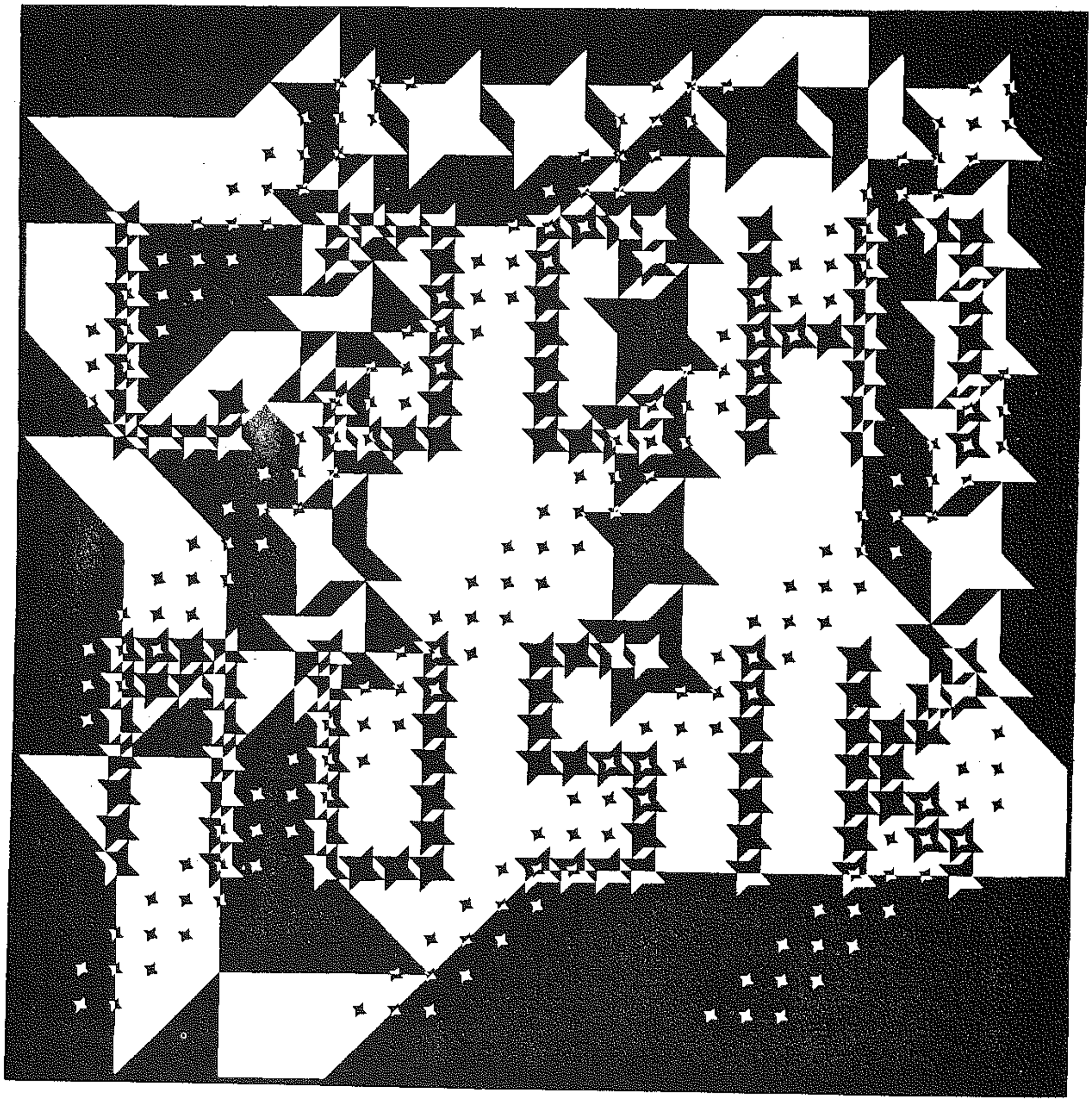
Picture 3;3;1;1 shows the "inner-star" of picture 3;4 with the layers 0 and 1. The pictures 3;3;1;2-3;3;3;3 show 8 "adjacent inner-stars". These come into being from the "screen-star" S3 of picture 2;2, when indentations are added or angles are cut off. About these "inner-stars" we can ask similar questions as those above of the pictures 3;1;1;1-3;1;3;3.

Picture 4;2 shows the "adjacent inner-star" of picture 3;3;2;1 in the layers 0-2. Picture 4;4 shows a "linked inner-star" co-ordinated to the "adjacent inner-star" of picture 3;3;3;1. The pictures 4;1;1;1-4;1;3;3 show further "linked-" and "adjacent-linked inner-stars". The **pictures 4;3;1;1-4;3;3;3** show further "adjacent inner-stars".

The **pictures 5;1;1;1-5;4;5;5** show a "base-figure" each producing a square "inner-star" of number of extension 3. 5;1;1;1 produces the "inner-star" of picture 3;2, 5;1;1;3 the one of picture 3;4, 5;2;5;1 the one of picture 4;2, 5;4;1;3 the one of picture 4;4. Picture 5 shows "base-figures" of "adjacent inner-stars" in 5;1;1;1, 5;1;5;1, 5;1;5;5 (inner figure), 5;2;4;2 (inner figure), 5;2;5;1, 5;4;1;1, 5;4;4;4 (inner figure), 5;4;5;3 (inner figure).

Picture 5 shows "overlapping inner-stars" in 5;2;1;1, 5;2;2;1, 5;2;3;1, 5;2;4;1, in all figures of 5;3, in 5;4;1;2, 5;4;2;1, 5;4;2;5, 5;4;3;1, 5;4;3;4, 5;4;3;5, 5;4;4;1, 5;4;4;5, 5;4;5;1, 5;4;5;4. In such a case neighbouring "base-figures" overlap each other in areas which are not separate, that means in areas that have not only particular points but whole straight segments in common with the other areas.

Picture 5 shows a "fusion inner-star" in 5;4;1;4. In such cases neighbouring "base-figures" are to fuse into a total area, if they appear in an "inner-picture" (see later). That presupposes naturally that such "base-figures" are coloured, and in the same colour (see later). Picture 5 shows "linked inner-stars" in all other figures.



Picture 9

Instructions for drawing "inner-stars":

We draw the two-layered "inner-star" 3;1;1;1 or the three-layered 3;2 on squared paper, choosing the size of the picture in such a way that the lines of the squared paper lie twice as densely as the lines of the square net in 3;1;1;1 and in 3;2. The border lines of the "base-figures" of layers 0, 1, 2 are drawn in three different colours, or we draw all of them with Indian ink in different thicknesses of line. (The finer the layer, the thinner will be the lines.)

Or we use single-sided graph paper with the printed side against a white base. Then the screen lines will shine through. On the white reverse of the graph paper we draw the 2- or 3-layered "inner-star" as explained above. (Or we put the graph paper with its printed side downwards on a viewing device made by ourselves (glass-plate and light bulb) and then begin to draw.

I drew the originals of pictures 2, 3 and 4 in size 78 cm X 78 cm on the white reverse of graph-paper with an Indian-ink pen and in lines 0.6 mm, 1.25 mm, 2.5 mm and 4 mm thick. I drew the originals of pictures 5-8 in size 69 cm X 69 cm in lines 0.6 mm and 1.6 mm thick.

The "inner-stars" are not ends in themselves. They serve as screens for the production of "inner-pictures" and "inner-games". An "inner-picture" develops from an "inner-star" in the following way. Among the "base-figures" of the "inner-star" some (a finite number) are chosen to "appear", or to "shine", while the others are to remain invisible. The chosen "base-figures" are coloured. Further details below.

An "inner-game" is a changing "inner-picture". In it "base-figures" can appear (rhythmically), change colour and be extinguished. At a later stage of development they can also move (subject to certain laws) and change size and form. "Inner-games" may be produced with the help of "light-organs". These are electronic devices with viewing screens. Artistically formed "inner-pictures" and "inner-games" could be works of a new art, a static and a dynamic visual music. In this visual music the "inner-stars" would play the same role as the scales (including the 12-tone-scale) in sound-music. Three-dimensional "inner-pictures" are a physical possibility.

Pictures 6;1-6;4 show sketches for three-layered "inner-pictures" belonging to the "inner-stars" of pictures 5;1;1;1-5;1;1;4. Picture 6;1 shows 1 "base-figure" of layer 0, 3 "base-figures" of layer 1 (the other 6 are erased) and 22 of layer 2 (the other 81-22 = 59 are erased). By painting this sketch in black and white or in colours, an "inner-picture" appears. Further details below! All four pictures 6;1-6;4 show the same choice of cells: the "base-figure" for the "cell" of layer 0, the "base-figures" for the 3 left "cells" of layer 1, and those for 22 "cells" of layer 2 forming an "M".

Pictures 7;1-7;4 and 8;1-8;4 also show this choice of "cells". 7;1-7;4 are sketches of very simple "fusion inner-stars". 8;1-8;4 belong to the "inner-stars" of figures 5;2;5;1, 5;2;5;3, 5;4;4;4 (inner figure) and 5;4;4;4 (exterior figure).

Picture 9 is a 5-layered black-and-white "inner-picture" of the "inner-star" co-ordinated to 5;2;5;1. In the layers 0-2 it shows the same choice of "cells" as 8;1. Furthermore it shows 139 "base-figures" of layer 3 forming the stylized letters "LICHT–MUSIK" and 241 of layer 4, forming five rows of ornaments. The picture is coloured according to the following rule: The row at the borders and the background are black. Where "base-figures" in odd numbers cover the area, the colour is white, where in even numbers, it is black.

Instructions for the production of "inner-pictures":
Reproduce the figure of 6;1 or any other of the figures 6;1-8;4 (or a figure formed correspondingly with any figure you like out of 5;1;1;1-5;4;5;5) with a sharp lead pencil on squared paper, choosing the size of the picture in such a way that the lines of the squared paper lie twice as densely as those of the square grid in 6;1. Alternatively put graph paper with the ruled side down on a white base or on a viewing device and draw the chosen line-figure on the white reverse. Then we paint the picture with Indian ink. The colouring rule for black-white pictures mentioned above is used. The pair "black-and-white" can be replaced by any other pair of colours, or course. If there are only two colours at your disposal and if you want to make sure that no part of the border lines of a chosen "base-figure" becomes invisible, the given rule of colouring is the only possible one.

If more than two colours are at your disposal, numerous laws of colouring are possible. Proceed thus: decide that all chosen "base-figures" of the same layer are to be coloured with the same colour. For the row at the borders, the background and the totality of "base-figures" of every layer choose one colour each. For every possible superimposition of "base-figures" decide with which colour the respective areas are to be painted. Use the same rules over the whole picture.

Proposals for choice of colours:
Colour like this: The row at the border will be dark green, the background dark blue, the "base-figure" of layer 0 yellow, the "base-figures" of layer 1 will be light red, those of layer 2 orange. The areas of superimposition of layers 0 and 1 will be lilac, those of layers 0 and 2 dark red, 1 and 2 medium blue, 0, 1 and 2 light green. Of course it is possible to choose quite different colours (and naturally we can make quite different choices of "cells").

Small "inner-pictures" can be painted with coloured fibre-tipped pens. Neat painting of "inner-pictures" with poster colours, acryl or oil colours is difficult.

Colouring pictures with colours out of spray-cans is practicable. The desired form is sketched on graph paper which is fastened on the back of good drawing paper (thickness approximately 200 g/m^2). Attaching the four corners with scotch tape will do. Then the drawing paper with the graph paper on the reverse is put on a viewing device so that the lines shine through. If need be the inner side of a window will do. The whole sheet is now covered with a transparent foil. Then the areas to be coloured with a special colour are cut out of the foil and the colour sprayed on. The rest of the foil is removed, a new sheet substituted and the procedure repeated for the second colour, and so on for all colours.

Another method is to use transparent adhesive coloured foils, as a rule pasting only one foil on each area. Finally, to achieve greater durability, the picture can be covered with a transparent foil.

The essence of the "inner-stars", "-pictures" and "-games":
The difficulty in designing the "inner-stars", "-pictures" and "-games" was found in the necessity of making visible at the same time several screen layers consisting of areas which cover each other, as we are not able to see colours at the same time at the same place, as it were one behind another. This difficulty is overcome in the "inner-stars", "-pictures" and "-games" by

profiting by some geometrical laws as well as by some of a psychological kind. They are:

1. The law of dimension in geometry: in an area there is room for infinitely many pieces of lines, in other words: a piece of line has area zero; it is the same with line and point.

2. The laws of tessellation and the law of similitude in Euclidean geometry: Euclidean geometry allows uniform nets of squares and hexagons and it allows similarities with an optional scale of reduction.

3. The "border-law" of seeing: we see a border line, a distinct boundary between two adjacent areas, in different colours, as at the same time "infinitely thin" and yet very well perceptible.

4. The "border-area-law" of seeing: in addition to an enclosed area we see a boundary-line.

5. The "intersection-law" of seeing: when border lines of "familiar forms", for example of circles or of symmetric stars, intersect each other, but have only isolated points in common, we don't at first "see" the resulting partial areas, but we "see" the "familiar forms" themselves in spite of their mutual intersections. Afterwards we see the areas on which the forms overlap one another. Thus we perceive a sort of "miraculous multiplication of the plane". We "see" the areas intersecting each other separated in depth in an indefinite way. That is to say: it remains open which areas lie further in front and which further behind.

The laws 3.-5. are taken advantage of to a large extent in modern graphic art. The laws 1.-5. are used in the "inner-stars", "-pictures" and "-games". The fundamental ideas of the "inner-star" may be formulated thus:
Square and hexagonal nets which are layered centrally are made transparent for the eye by analogous changes of all borders of "cells", the "intersection-law" of seeing being utilized. The resulting forms make screens for abstract films and pictures.

The essential qualities of the "inner-stars", "-pictures" and "-games":

1. The "inner-stars" are homogeneous (uniform) in layered approximation. Therefore they imitate the homogeneity of space, plane, and straight line in the homogeneous, metric geometries (in the Euclidean, elliptic, and hyperbolic geometry). Homogeneity is the most important quality of these forms, also of time and space-time in classical physics. (This imitation concerns only the point homogeneity of space and plane, not the direction homogeneity.)

2. The "inner-stars" are structured "integrally", and that hierarchically. So they imitate a fundamental quality of the works of art, by-the-way also a fundamental quality of every biological or social organism and a fundamental quality of every system of ideas in language or science.

3. The "inner-stars" are "similar in themselves with regard to the layers", they are "joined in themselves with regard to the layers", they are "transparent with regard to the layers" and "coherent". "Joined in themselves with regard to the layers" means that the "base-figures" are cut in only a finite number of ways by the borders of the coarser layers.

4. The "inner-stars" are (as can be shown) the only possible plane figures possessing these qualities.

5. The "inner-stars" are the natural visible representations of the pairs of n-ary-rational numbers especially for $n = 2$ and $n = 3$.

Technical aids for the production of "inner-stars" and "-pictures":
The most important aids are papers and washable boards with square grids printed on them and suitable pencils. Drawing square grids (with or without rulers) is itself highly instructive. Firstly the square grid itself is geometrically perfect: its lines are sharp, straight, parallel, orthogonal and have the same distance, the same form, because it is potentially infinite, and because of the multiplicity of its elementary applicability and of problems of all degrees of difficulty one has to solve. Secondly inexact drawing is at once revealed not only to the teacher, but also to the pupil himself.

The younger the pupil is, the larger must be the mesh of the square grid to be used, the larger must also be the paper or (better!) the washable board. An area paved with square paving-stones would be ideal. On such a pavement, a sketch of an "inner-star" or "-picture" made with chalk can measure many square metres. Such an "inner-picture" can even be painted with a coarse paint-brush. On the walls of the class-room may hang numerous large boards with square grids impressed on them, preferably one for each pupil, and a supply of long rulers and coloured pencils provided. Certainly the parents of the pupils would be interested in their children's homework as far as the "inner-stars" and "-pictures" are concerned.

The industry producing educational appliances could make 3-layered, later also 4-layered devices for making "inner-pictures". Such a device might be as follows: a 3-layered "adjacent inner-star", for example Figure 4;2, is transferred onto a thick sheet of transparent synthetic material. Where the "base-figure" of layer 0 lies upon it, the surface of the sheet is cut-away by 2mm; where the "base-figures" of layer 1 lie on it, it is cut-away by 4mm, where the one of layer 2 lies on it, by 6mm. Coloured transparent sheets of synthetic material fitting in the depressions should be furnished. With them numerous 3-layered "inner-pictures" of the "inner-star" concerned can be made. They can be looked at by reflected or transmitted light, or can be projected on a screen. When we use these devices we have no control of the "superimposition colours": certain "subtractive mixed colours" are bound to appear which in any case are darker than the colours involved in the "mixture".

For adult artists and older pupils the following device would be useful: to a square frame whose sides are in the directions x and y, a sliding carriage is attached which can move in the direction x. To this sliding carriage is attached another one moving in the direction y with a pin sliding up and down. Under the frame lies drawing paper on which we imagine the "strong-points" of the "cell-star" C3. By suitably calibrated movements of the two sliding carriages in the directions x and y, the pencil pin can be adjusted over every desired "strong-point" of the layers 0-4. For the most important "inner-stars" of C3 and for every layer from 0 to 4 a stamp is cut which can be fixed at the underside of the pin. With the help of these instruments and a pad for colouring the stamp in each case, every "inner-star" can be printed "base-figure" after "base-figure". Of course we would again have no control of the "superimposition colours".

The suitability of the "inner-stars" and "-pictures" as subjects of instruction in classes of mathematics:
In all subjects, instruction must start from concrete and clear given facts, must include activity by the pupil, preferably manual activity. It must supply motivation, motivation which is relevant to the subject-matter. A suitable treatment of the "inner-stars" and "-pictures" in mathematics in primary and secondary schools would comply with these demands.

Designing and drawing "inner-stars" and "-pictures" can replace the authority of the teacher by that of the object. It gives the pupil the opportunity of making innumerable little geometrical "discoveries" independently, and of creating work which is geometrically and esthetically perfect. The pupil is fascinated by the vivid experience of the mathematical accuracy of the pictures and by their inner accordance. Every "inner-star" and every "inner-picture" has a structure understandable down to the minutest details and is intelligibly integrated into the totality of all "inner-stars" and "-pictures". The person who draws an "inner-star" or "-picture" experiences the mathematical and aesthetic perfection of the figures.

Every teacher who has taught elementary geometry has witnessed how beautiful and fertile the classes may be when the children examine the characteristics of a rectangular parellelepiped, the number of its corners, edges, areas, angles, diagonals, the mutual relations of these elements, the possible paths between the corners and edges and diagonals and so on. These are classes in which the children exert themselves to achieve a graphic representation and a linguistic formulation. (Advancement in the command of the mother tongue is one of the most important tasks of every lesson.) After such lessons the teacher regrets that there are not more such forms in elementary geometry at the same time simple, important and interesting. Circle and sphere are of little use at this elementary stage, tetrahedron and so on are too complicated.

I think that the simpler "inner-stars" form a group of figures in which every single figure offers the opportunity of investigation similar to that of the parallelepiped. But hundreds of simple "inner-stars" and innumerable "inner-pictures" are possible. Moreover, in contrast to the cube, these figures can be aesthetically evaluated. They are plane, so that a perspective examinatio is not required, and the examinations can be made of the object itself, not of a picture of the object.

The suitability of the "inner-stars" and "-pictures" for art classes:
We should be grateful for every possibility of getting into contact with other subjects, and of co-operating with teachers of othe subjects.

I think that education in art should use all possibilities from shaping and looking at purely organic forms on the one hand to purely crystalline forms on the other hand. The tension between these poles of the world of forms should be accepted and made full use of, always, of course, within the limits of what is appropriate to the age of the pupil. More about the subjects "inner-stars and education in art" and "inner-stars and art" will be found in other publications.

Didactic-methodological hints:
For an introductory treatment of "inner-pictures" and "-games" there are two ways. The first way leads from picture 2;1 via the pictures 3;1;1;1-3;1;3;3, 3;2, 5;1;1;2, 6;1, 7;1. The second way leads from picture 2;2 via the pictures 3;3;1;1-3;3;3;3, 3;4, 5;1;1;4, 6;3, 7;4. Both ways may be followed by a treatment of the two-layered "inner-stars" possibly to 5;1;3;1, 5;1;2;4, 5;1;4;1, 5;1;4;2, 5;1;3;3 (without rhombs), 5;1;4;4, 5;1;5;2, 5;1;5;4, 5;2;5;1, 5;4;5;1.

In the first part of our instruction about "inner-stars" and "-pictures" we draw especially simple two-layered "inner-stars" as sketches with two different colours on the blackboard and suggest that the pupils imitate them. After that a detailed discussion takes place. **In the second part** we have the same "inner-stars" in three-layered manner drawn as sketches with three different colours on the board, or better on several boards; or we show the pupils such a drawing previously made by ourselves. Another discussion takes place after that. **In the third part** we ask for simple two- or three-layered "inner-pictures" (for instance showing the first letters of the pupil's name) drawn on a board and we show the finished "inner-pictures". Extensive discussions take place again. Simple home-work is possible, too. Co-operation with the art teacher would be welcome. Secondary and later levels of education could resume and continue the subject.

A detailed didactic and theory of methods of realization of the "inner-stars" and "-pictures" in classes cannot be given here. It can only be gained by trial in class-rooms. I invite all teachers of mathematics and of art to think the matter over, to try it, and to publish the results, if possible. As a motto the words of a poet may be esteemed: "Look at the stars, look out in the streets!" (Wilhelm Raabe).

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READABILITY OF ENGINEERING DRAWINGS —THE IMPLICATIONS OF TYPOGRAPHIC RESEARCH

Andrew K. Clark
University of Alberta
Canada

Few in the technical world would disagree with the statement that engineering drawings are a major communications media in that world. The checker's role in verifying that the drawing will communicate accurately is admittedly a key one, but is it possible that the communicative power of a drawing is weakened by factors which are outside the checker's sphere of reference? There is a considerable body of typographic research findings which suggest that a potential source of error in engineering drawings lies in the collective drafting practices involving lettering on drawings.

Scope of Problem

It is true that some drawings may contain very little in the way of notes; others may have a considerable amount. The use of notes in modern drawings is partly a by-product of the simplified drafting canon, of which one of the first principles is the elimination of duplication or unneccessary delineation by using descriptive notes, a principle with which most would agree. A few of the aspects with which general or local notes on drawings may be concerned include: dimensioning, finish, heat treatment, quantities, stock sizes, tolerances, hardness, assembly instructions, and there are dozens more.

Readability

By readability is meant the property of communicating to the reader the exact message as written. There may be other defects in the notes, such as: misspelling, erroneous information, ambiguity or obscurity. Hopefully, errors of this type will be edited before the drawing reaches the user. It is also noted that readability does not refer to reader preference on artistic, aesthetic or other grounds.

A listing of the typographic variables which can affect the readability of a written message is given below. Some of these factors have limited importance for engineering drawing, but they are included and discussed briefly to indicate how much is perhaps taken for granted in drafting practice.

In the following discussion the recommended practices are based on a survey of a selection of leading texts in the field, namely those by French and Vierck (1966), Giesecke et al (1967), and Luzadder (1965). The rather arbitrary criterion for selection being the fact that each of these texts has gone through many editions.

Minor Factors

Line Length. No specific recommendations by drafting texts. Research indicates the optimum line length for normal drawing notes should be 3-1/2" to 4". Lines of print which are too lengthy cause the reader's eyes to lose the place sometimes when he comes to the next line. Also, with a shorter line of print the reader gets a foretaste of the following text which results in greater reading efficiency.

Type Face. Although there is a considerable research literature on the relative merits of type faces such as serif and nonserif, the findings have little relevance for drafting practice. A possible exception might be in numerically controlled or computer-aided drafting applications where a choice of type-face balls is available for print-out. In this situation it may be assumed that a type face similar to the ASA letter standards would be used.

Inter-Letter, Word, or Line Spacing. Although there are minor discrepancies in the recommended

French & Vierck	Giesecke *et al*	Luzadder
Vertical capitals standard for titles, reference letters.	Either vertical or inclined lettering may be used.	Vertical lettering more generally used.
Inclined capitals preferred by many draftsmen.	Vertical lettering more difficult to execute.	Many draftsmen favor inclined lettering.
Vertical lower case not commonly used in machine drawings.	Vertical lower case very seldon used on machine drawings.	Lower case lettering suitable for long notes and statements.

Table 1: Summary of lettering recommendations of major drafting textbooks.

practices, in general they follow accepted printing practice, which is also supported by the research findings.

Size of Letters. This is not usually a factor affecting readability in drawings. Research does not indicate that letters which are too large affect reading efficiency as adversely as letters which are too small. Recommended letter sizes should be satisfactory unless reduction of the drawing is contemplated, in which case it could become a factor of consequence.

Ink and Paper Color. No problem here, surely --what could be more readable than black ink on white paper? Well, for one thing, black ink on yellow paper has generally proved to be a more readable combination, evidently because the black tends to spread into the white, resulting in a grayish perception effect. The superiority of black on yellow is not great enough to be of much significance, the most important point being the contrast between the ink and paper. It should also be noted that after reproduction the ink/paper contrast may be drastically reduced. The writer has seen machinists trying to work from drawings so poorly reproduced that from a distance of several feet it was difficult to discern the lines of the drawing from the background.

A significant point is that while the presence of only one of these marginal conditions may affect readability by a small or negligible amount, the presence of two or more in combination may result in a considerable reduction in reading efficiency.

Major Factors

As indicated, some of the above typographical factors could be relevant in certain circumstances; the following factors are considered to be highly significant for drafting practice. Table 1 contains a summary of the lettering recommendations of the statements, not only in the practices recommended but in the justification or accompanying comments.

Vertical or Inclined Lettering. While there is some difficulty in separating the recommended practices here from those concerning upper and lower case, there appears to be some concensus in favor of inclined over vertical lettering. While the research findings vary considerably in the magnitude of the superiority, the direction is invariably in favor of vertical print over inclined for ease of readability. At this point it should be noted that the major sources for typographic research findings were Tinker's (1963) comprehensive review of this century's relevant research on print legibility, and Carte's more recent (1973) article on the same topic.

The suggested reason for the greater readability of vertical over inclined (or normal over italic) type is that vertical letters are more familiar to the reader from ordinary experience with printed material. When only one word or phrase is in italics for emphasis it serves its purpose by slowing or stopping the reading process; when the whole text is in inclined print this principle is no longer operative.

Capitals or Lower Case. Although there is a certain ambivalence in the statements in Table 1 concerning upper or lower case there is an apparent leaning towards the use of capitals for everyday use. (This trend was also noted in other drafting texts not cited in Table 1).

Against this recommendation must be considered the fact that research findings uniformly confirm that print in capitals adversely affects reading efficiency by from ten to fifty per cent. It is

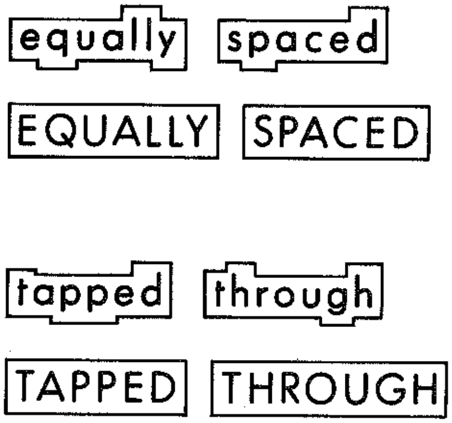

Figure 1: Characteristic word forms of words in upper and lower case.

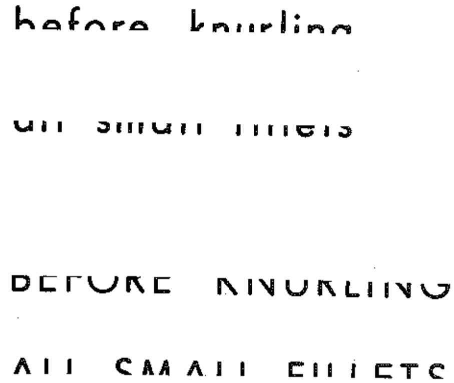

Figure 2: Comparison of top and bottom halves of upper and lower case words.

true that research shows individual letters to be more recognizable from a distance as capitals than as lower case, but this is not the condition under which normal reading takes place.

The major reasons advanced for the superiority in readability of lower over upper case print relates to the differences in letter shapes and word shapes between capitals and small letters.

The difference in word shapes of notes in upper and lower case may be compared in Figure 1. It is apparent that words entirely in capitals lose the advantages of the clues to the reader provided by "risers and descenders", which are present in exactly half of the lower case alphabet.

The absence of these clues apparently causes an appreciably larger number of eye-fixations during reading, in extreme cases resulting in reading letter-by-letter instead of by word or phrase, as in optimal reading conditions.

The circumstance that there are nine "risers" and only five "descenders" in the lower case alphabet results in the top half of lower case words being generally more interpretable than the lower half, as illustrated in Figure 2. With upper case lettering, of course, there is little difference between top and bottom halves of the words.

Two other points may be noted from Figures 1 and 2. Although the capitals and lower case phrases are the same type size, those in capitals take up from 20-25% more space. More relevant for drafting practice is the fact that inter-letter spacing is not required for lower case printing, but is usually recommended for printing in capitals.

Traditional ways of doing things can be an expensive luxury. When an inexplicable error is made in executing instructions on a drawing, instructions which are apparently correct in all respects, it is impossible to determine whether the error was caused by the typographic variables discussed here or by the attention or emotional state of the reader. It should also be borne in mind that the use of vertical lower case printing, based on typographical research, is perfectly compatible with recommended drafting lettering practices of the American Standards Association.

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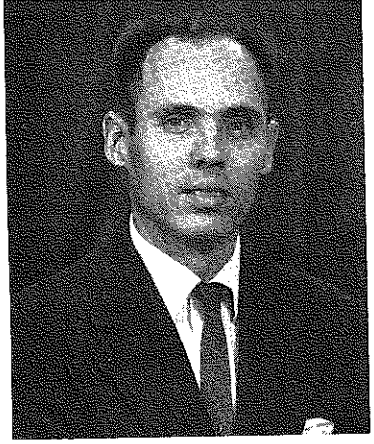

Tim Coppinger, Chairman
Creative Design Display
Engineering Design Graphics Department
Texas A&M University

CREATIVE ENGINEERING DESIGN DISPLAY

THE EIGHTH CREATIVE ENGINEERING DESIGN DISPLAY

The Creative Engineering Design Display is sponsored by the Engineering Design Graphics Division of The American Society for Education. In the past seven years it has become one of the highlights of the Annual ASEE Conference. This year the Conference will be held at Colorado State University in Fort Collins, June 16-19, and will be the largest and best ever.

Established to encourage and reward creativity in Engineering Design, the display will have entries from technical institutes, universities not only in the United States, but also Canada and Mexico. Displays in the past have ranged from design sketches and working drawings to complete design reports with models. Each school may enter as many as seven projects: two freshman, one each from the sophomore, junior, senior, graduate levels and one from a cooperative program. Teams submitting entries must not exceed eight members.

ASEE division chairman, individuals from industry and distinguished educators will judge the displays. Cash awards will be made to the first place winners in each catagory and plaques given to the schools they represent. All other winners will receive certificates. Financial support for the display comes from industry and the James S. Rising Memorial Award.

The Creative Engineering Design Display Committee wishes to invite your participation.

In order to establish the space requirements for the display, it is necessary to know the number of entries to anticipate. If you desire additional information or entry applications and are not on the Committee's mailing list, please complete the form below, and return to:

J. Tim Coppinger, P.E.
Chairman, Creative Engineering Design Display Committee
Engineering Design Graphics Department
Texas A&M University
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1975 CREATIVE ENGINEERING DESIGN DISPLAY

We anticipate submitting the entries checked below to the 1975 CREATIVE DESIGN DISPLAY.

( ) Freshmen, 2 entries ( ) Sophmore, 1 entry ( ) Junior, 1 entry
( ) Senior, 1 entry ( ) Graduate, 1 entry ( ) Co-op, 1 entry
( ) Sorry, can't make it this year. ( ) Keep us on the 1976 mailing list.

Faculty Member & Title____________________

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A lesson for Detroit—student taught

Recent projects from students at Art Center, long the breeding ground for the nation's auto designers, indicate a capability to go beyond Detroit's cliches given freedom and proper encouragement.

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When you read the words "Art Center" what immediately comes to mind? Auto design? Styling? Detroit? Whatever the specific associations, they probably reflect the image and reality of the Los Angeles' school's intimate marriage with the automotive industry.

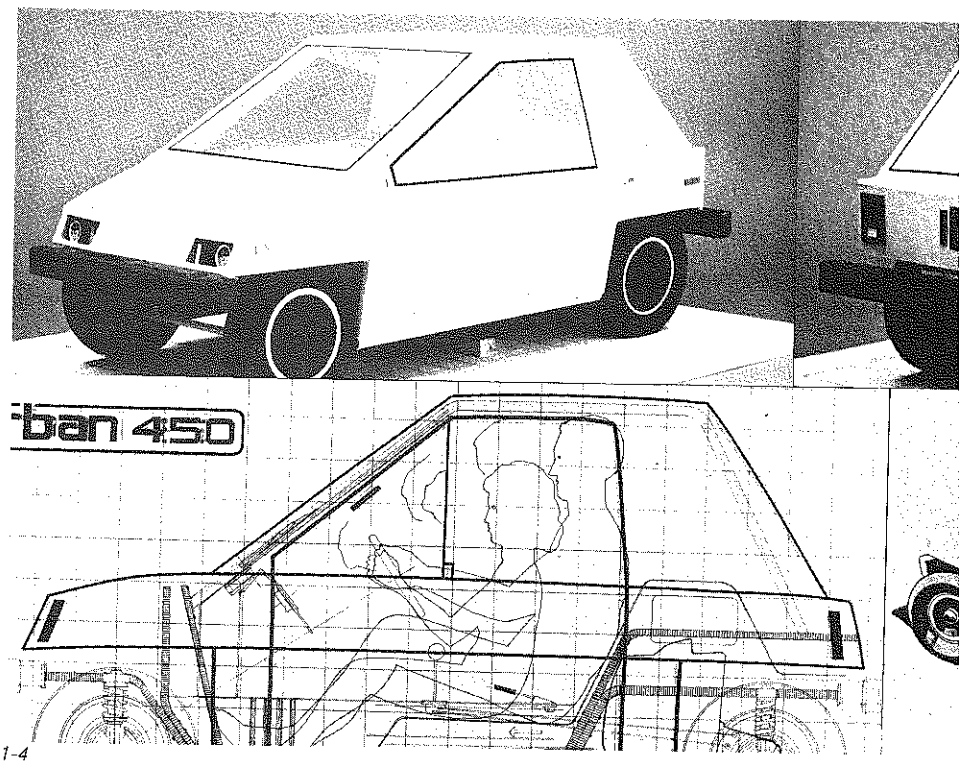
While The Art Center College of Design is actively engaged in non-automotive design disciplines, it has over the years received tremendous financial and technical support from the automakers. In turn, the school has provided an abundant supply of graduates ready-made for the Detroit design studios.

Yet, three recent automotive projects from the school do seem to indicate that no matter how well the students satisfy the expectations of their godfathers in Detroit, when relieved of these constraints they demonstrate a capacity to provide more imaginative solutions. Although all three manifested the increasing concern with the environment, petroleum shortage, safety, materials selection, manufacturing processes, compactness, efficiency and merchandising, the one project which resulted in the fewest cliches is the one not intended for manufacture by Detroit and, thus, is also least associated with industry manufacturing/design procedures. The parameters for each project and some results follow.

Mini-vehicle for Southern California

Harry Bradley's advanced transportation design students were to assume that a Los Angeles company with an annual volume of $3 to $4 million from shaping and forming metal and manufacturing metal products had approached them to develop a small, low-cost, two-passenger, commuter vehicle which would meet current environmental and energy conservation goals. Yet the company wanted to utilize its own technology and plant facilities and to draw heavily on local resources.

The vehicle was to be marketed exclusively in Southern California for between $1200 to $1400. Although the vehicle was not intended for use on freeways but for local transportation, all federal safety standards would apply unless specific exemptions were requested. Comfort and pleasing appearance were designated goals but gimmicks and styling cliches were discouraged. Maximum dimensions were to be: length, 126 in.; width, 53 in.; height, 53 in.; wheelbase, 83 in.; and tread, 50 in. Final proposals were to be executed principally in 3D form including: ⅛ scale models of frame and all chassis components, ⅛ scale model of body and interior easily disassembled to demonstrate fabrication elements, drawings of the body mold and renderings of the interior, a list of all drive train, suspension, lighting, material and labor phases to include cost and suppliers.



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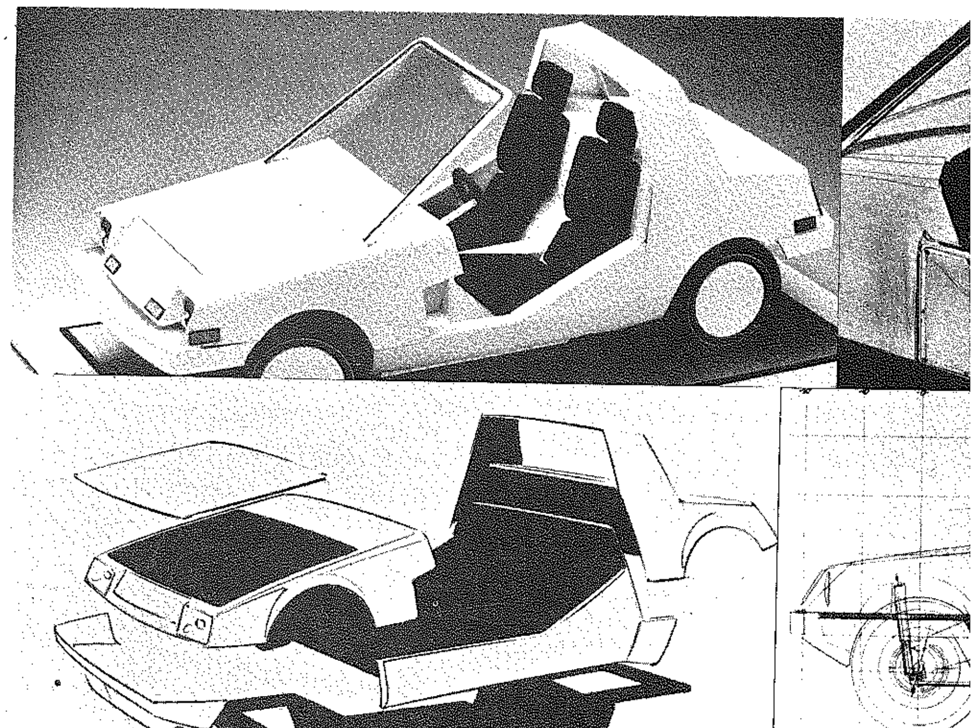

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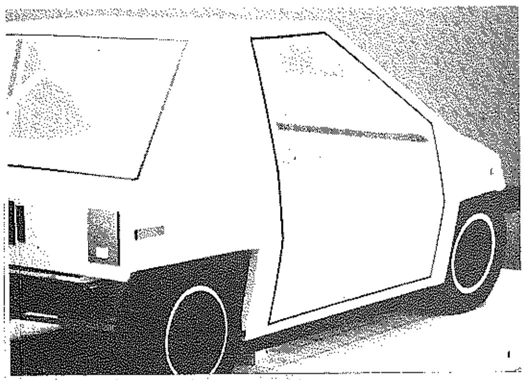
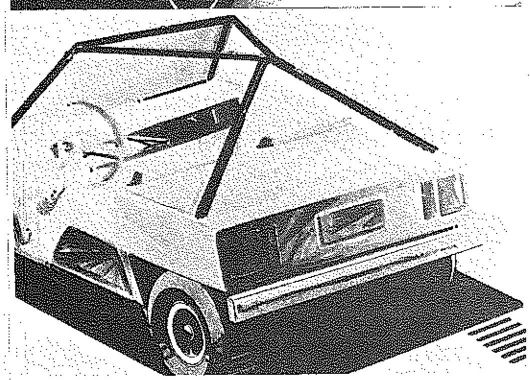
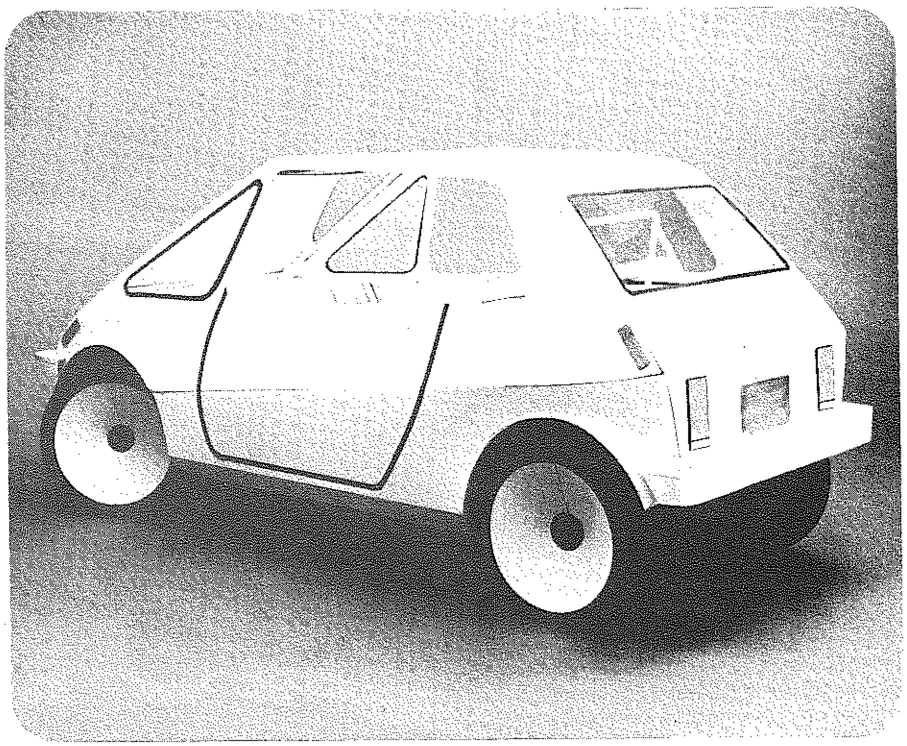
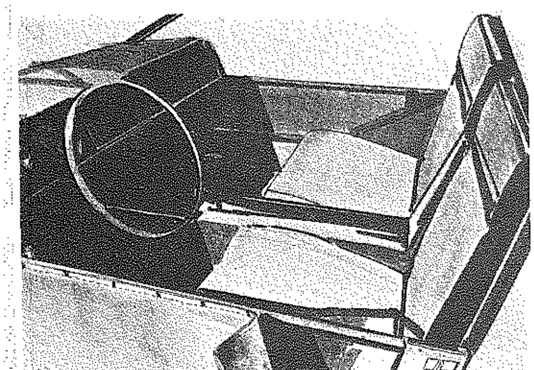
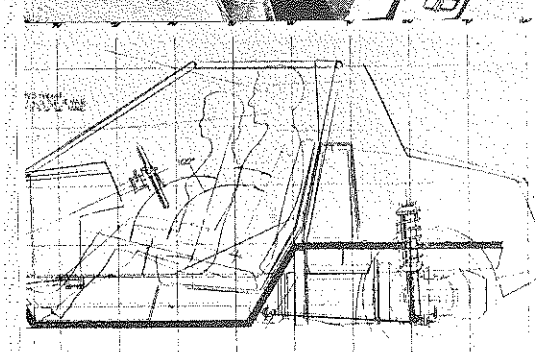










Mini-vehicle for Southern California

1-4

The "Urban 450," designed by Stephen L. Hansen, is powered by a 450 cc, two-cylinder, rear-mounted engine driving a two-speed automatic transmission. A two-seater, the car has a length of 119 in., width of 50 in. and a wheelbase of 78 in. The frame is aluminum honeycomb with integral roll bar structure. Inner and outer body structures are ABS while lights and trim are off-the-shelf items. Engine air intake ducts are under the front bumper. An open roadster variation is proposed, 4.

5-8

The "Oppidan" (city dweller), designed by Theodore L. Renteria, is a two-seater with mid-engine / rear drive, powered by a two-cylinder, air-cooled, gas engine. Length is 127.5 in.; width, 51 in.; height, 51 in.; and wheelbase, 83 in. The structural components include: a one-piece chassis made with aluminum honeycomb from Hexcel Corporation and using aluminum plate supports where necessary. Front and rear body sections are one-piece, vacuum formed ABS using Uniroyal's Kralastic compound SRS. Interior section is a one-piece spray-up using General Electric's fiber glass-reinforced epoxy.

9

Designed by David Heller, this two-passenger minicar is powered by a four-stroke, air-cooled, motorcycle-type engine with two-speed, automatic transmission. Front and rear suspension are independent with spring shock absorbers. Length is 115 in.; width, 53 in.; wheelbase, 78.5 in.; front and rear tread, 50 in.; front overhang, 19.5 in.; and rear overhang, 17 in. Wheels are 18-in. diameter by 4 in. wide, with welded steel construction; tires are motorcycle-type 4.00 x 18 bias ply pneumatic. The car is composed of three major units: chassis and all running gear, interior shell and exterior body shell. The welded steel tubular chassis and vacuum formed plastic interior shell are bonded together with "nut and bolt" hardware and epoxy glues. The fiber glass exterior body uses a chopper-gun method of layup. To facilitate mounting the body to the chassis, tabs and brackets are mounted during the fiber glass body formation.

A lesson for Detroit—student taught

Wankel cars circa 1978

10

William R. Bohn's preferences for manufacturing his proposal would include a foam sandwich floor pan, high roll center suspension geometry and full, 180-degree visibility for the driver.

11-12

Jacques S. Ostiguy felt that a small, four-door sedan such as this "ought to look light and graceful in order to truthfully suggest its driving advantages and reach its intended market." He would incorporate a rear hatch.

13

Woodrow W. Pollett Jr. says, "Paramount concern with function helps avoid superficial design detours and encourages an awareness for realistic refinement on this two-passenger sports coupe."

14

Jeffrey Pollizzette settled on the sportswagon body concept for its advantages in interior space use, comfort and visibility. The car is a two-door with rear hatch.

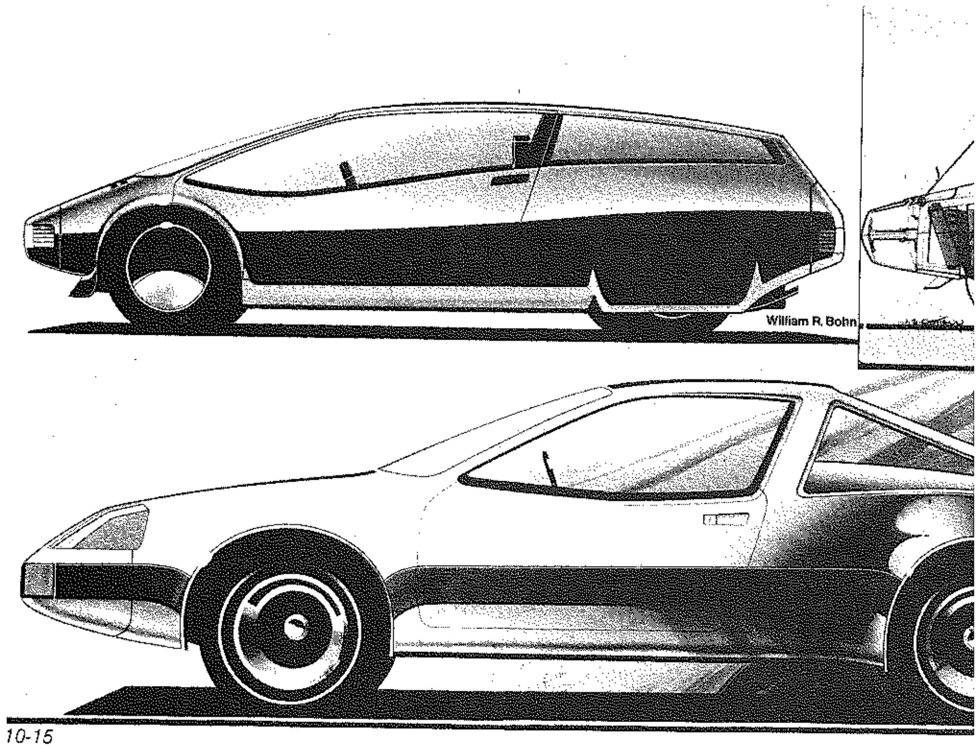
15

All vehicles in this project were designed to meet the federal government's new pendulum bumper test.

The Wankel circa 1978

Research by Strother MacMinn's junior-year students determined a package that seemed to offer the greatest potential in a five-year projection for maximum fuel economy, environmental needs and merchandising capability. Maneuverability and lightweight were major factors in determining dimensions: wheelbase, 90 in. (two-passenger) and 114 in. (four-passenger); maximum length, 180 in.; and width, 75 in.

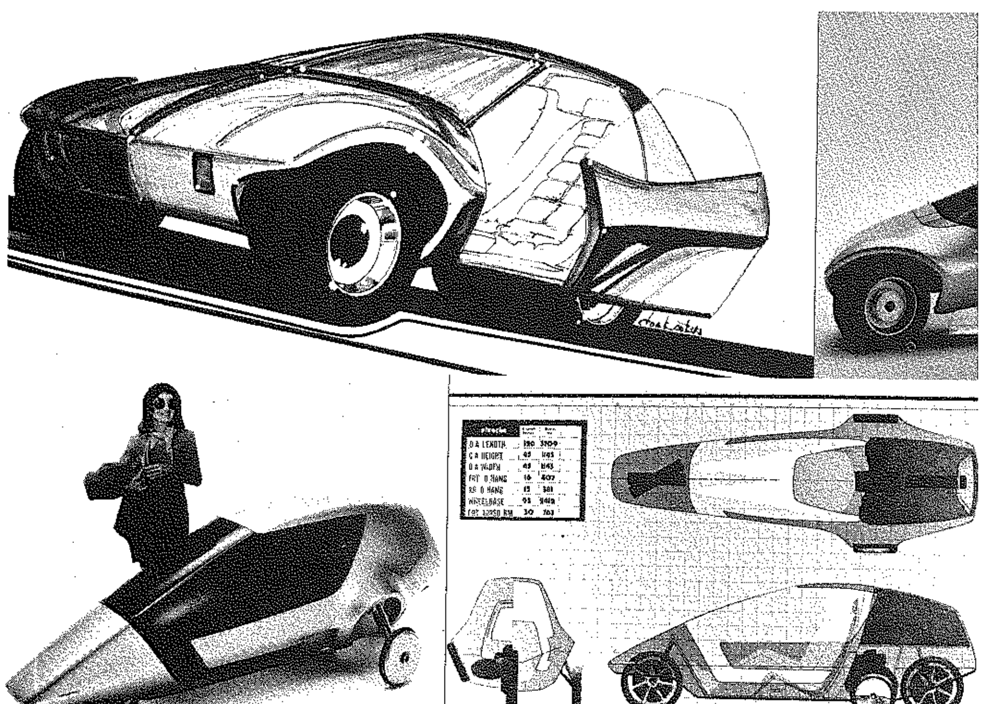
Two packaging features emerged which would provide better space accommodation and design flexibility. The first was a two-rotor Wankel engine mounted transversely and coupled to a front-wheel drive. This combination could be located fore or aft of the passenger compartment for the four-passenger or a mid-engine, two-seater sports version with a high degree of interchangeability. The second feature concerned a suspension geometry which would give good handling and comfort with low manufacturing cost. Adjustable torsion bars would allow a reduction in suspension parts inventory from 24 to 6. Collision safety was improved through relocation of other front suspension components to allow the front wheels to move outward and downward on impact. Essential elements included a rollcage complemented by front and rear extensions engineered for controlled collapsibility in high-speed crash conditions but capable of sustaining loads for engine mounts and energy-absorbing bumper systems. Strategically placed accordion-formed sections and structural foam-reinforced metal floor panels for predictable collapse were incorporated by most students. Federal bumper height requirement (1974) was mandatory. Vehicle target price was $2900 with optional versions ranging up to $3900 in 1978. Development was based on industry practice.



10-15

GM mini-car

Last year's General Motors' project for Keith Teter's senior transportation students called for a new commuter and/or shopper vehicle to bridge the gap between the motorcycle and the current subcompact. Powered by a compact rotary, gas turbine or 750 cc motorcycle engine, such a vehicle could get up to 40-45 mpg. The proposal specified that the three- or four-wheel vehicle carry a maximum of three passengers with space for accessories and package storage. It had to meet all federal safety and emission control regulations while reflecting the latest manufacturing techniques. Convenient entry/exit, all-weather protection and pride of ownership by both sexes were among the guidelines for the proposals which were presented according to industry practice.—*G.T.F.*



16-24

GM mini-car

16-18

"Firebug," designed by Donald Booten II, is a two-passenger hatchback, powered by a front-mounted, 750 cc motorcycle engine. Four link reward sliding doors permit easy access, while hammerhead shape allows outbound wheels to decrease over-all length, and wide front stance accommodates engine mounting and side-by-side passenger seating. Length is 110 in.; width, 63 in.; and height, 47 in.

19

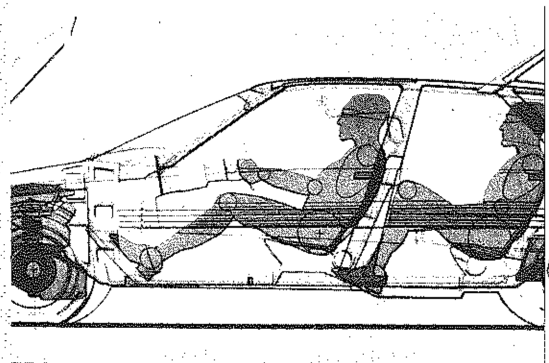
"Dune," designed by Woodrow Pollett Jr., is powered by a 750-900 cc motorcycle engine and is designed to combine the advantages of the motorcycle and subcompact. The concept uses Hovair pad stabilizers. Length is 135 in.; width, 60 in.; height, 45 in.; and wheelbase, 115 in.

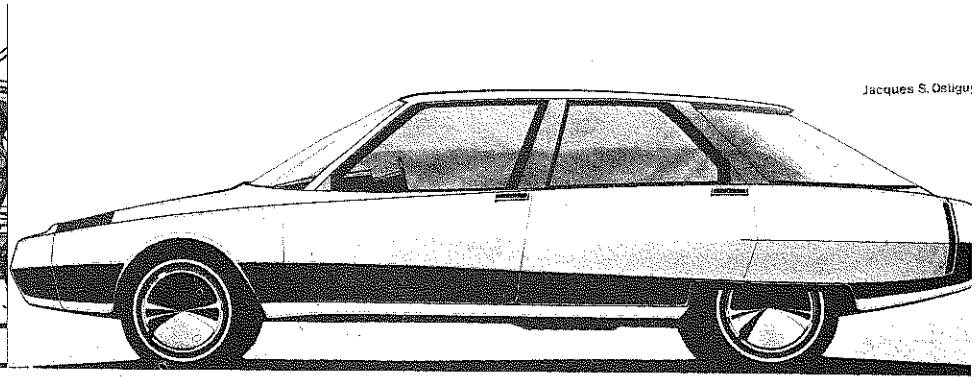
20-22

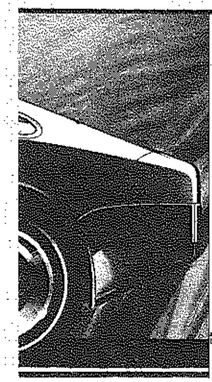
"Vivache," designed by John Manoogian II, is powered by a 900 cc motorcycle engine and is also intended to combine the advantages of a motorcycle with those of a subcompact. Basically a two-wheel vehicle, Vivache is balanced by two, small, retractable, outrigger wheels at speeds up to 40 mph. Entry is through a single, hatch door on the left side, while access to 8 cu. ft. of storage space is through a hatch on the curb side. Body is energy absorbing structural foam. Length is 126 in.; width, 45 in.; and height, 45 in.

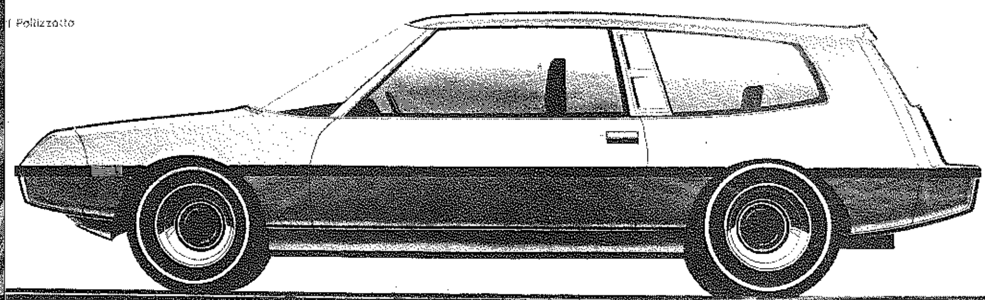
23, 24

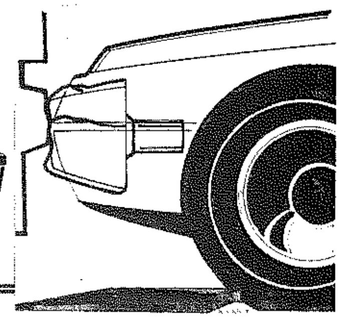
"Angra IV," designed by Roger Ross, is a four-wheel, two-passenger vehicle powered by a rear-mounted, regenerative gas turbine engine. The car has a plastic ore metal frame and plastic body attached to a platform chassis enclosing the passenger compartment. Angra IV features Ackerman 90-degree steering, sliding doors, sunroof and hatchback. Length is 112 in.; width, 61 in.; height, 50 in.; and wheelbase, 80 in.

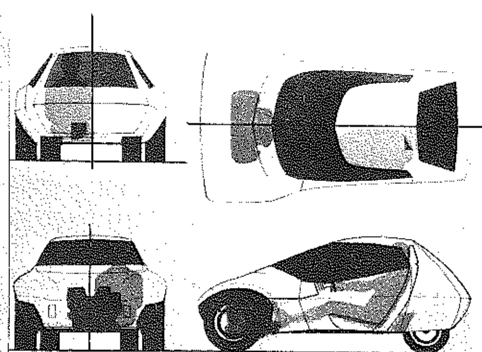


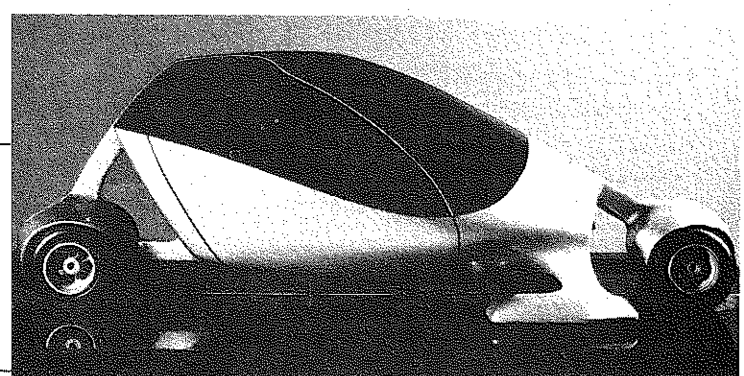


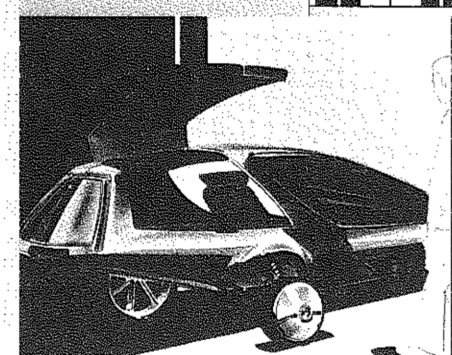


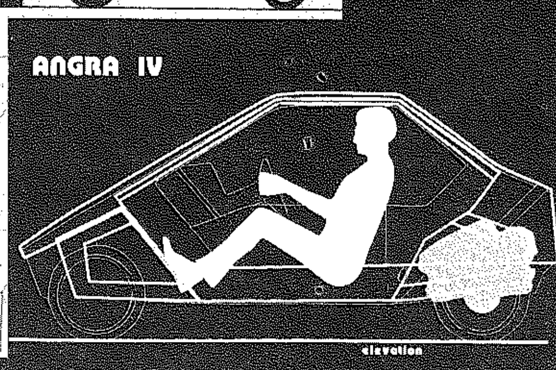


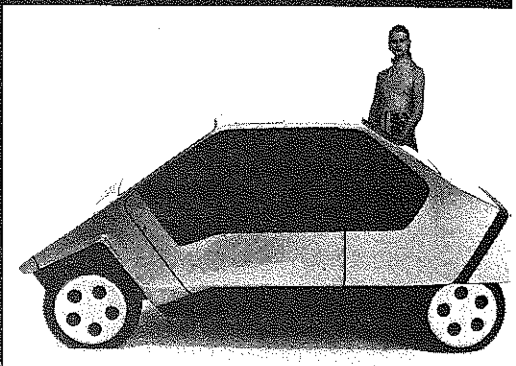












GRAPHIC SCIENCE AND DESIGN,
Third Edition
Thomas E. French and **Charles J. Vierck**, University of Florida.
1970, 848 pages, $15.50.

The highly recommended Third Edition increases the coverage and scope of graphics to meet the newer concepts of representation, documentation, graphic counterparts and design.

No other available graphics text offers a presentation so relevant to the needs of the profession. New chapters on graphical-mathematical counterparts, fundamentals of design, and professional problems supplement the text. In addition to its four-color format, the book has been methodically reorganized to stress continuing breakthroughs in graphic knowledge.

PROBLEMS IN GRAPHIC SCIENCE,
Third Edition
Charles J. Vierck, University of Florida, and **Richard I. Hang**, Ohio State University.
1972, 60 pages, 135 pages loose-leaf, $7.95.

Designed to accompany GRAPHIC SCIENCE AND DESIGN, Third Edition, the problems in the new edition reflect the current trend toward making graphics more mathematical for computer graphics purposes. Two features which set the book apart from others in the field are the authors' use of the "direct method" for solving descriptive geometry problems and the use of both preplanned (partially drawn) and non-preplanned problem sheets which allow the instructor maximum flexibility in assigning problems.

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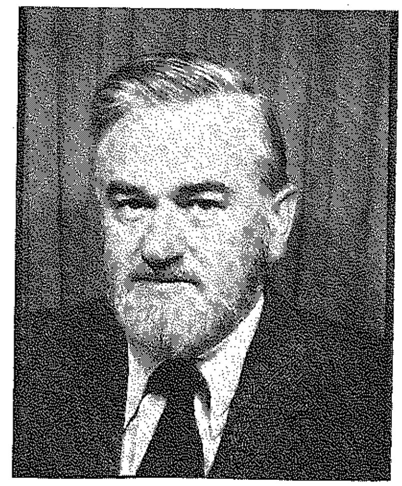


Engineering-Computer Graphics

Many topics in engineering graphics provide suitable theory for applications in computer graphics. This paper illustrates results in several areas and discusses how to start to build up a system of engineering-computer graphics software. The approach used here in a simple fortran program has been extended to develop a complex projection system called COGR based on the principles of descriptive geometry. COGR is designed for use in teaching computer graphics as well as for general use.

Before we get involved in techniques let us establish our goal by examining a few examples of output.

All the accompanying illustrations involve a form of perspective projection. It is most easily recognized in Figures 1 to 5, where perspective theory was used to produce an architectural view of a house. Another use of this technique is illustrated in Figures 6 and 7. Here the three-dimensional data of a sphere was generated and projected to form a stereographic net. This represents the sphere as viewed from a point on the equator. The resulting diagram is used by geologists to solve three-dimensional space problems.

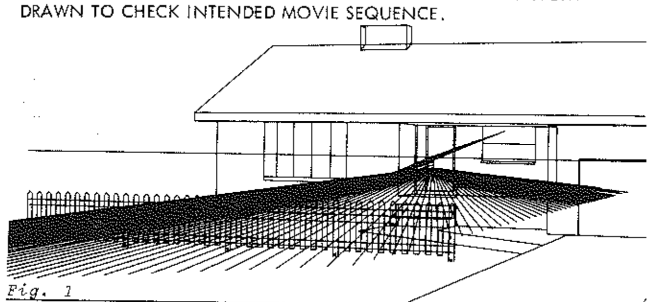
Multiple views of an object from various locations can result in stereographic pairs. Figure 8 is one view of a stereographic pair produced by a research student who required a model of the underground workings of Kidd Creek Mine. Similarly Figure 11 is one view of a pair produced to represent a graphite crystal.

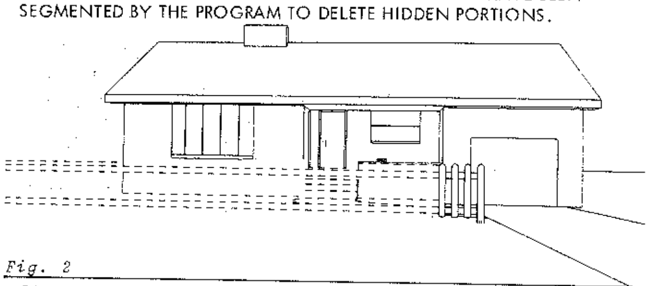
A series of views can result in the frames of an animated movie. The movement can be simulated in several ways: by moving the object, moving selected components of the object, moving the viewer, or any combination of these methods. Figures 2 and 3 are frames prepared for an animated movie shown at the 1973 ASEE Conference. The method used was to move the viewer to obtain the views seen along a series of "lines of sight". This technique was developed using a series of these lines of sight, where each line defines the set-up for one frame of the movie. These lines of sight were generated on the computer and the sequence checked by projecting them as part of the object(Figure 1).

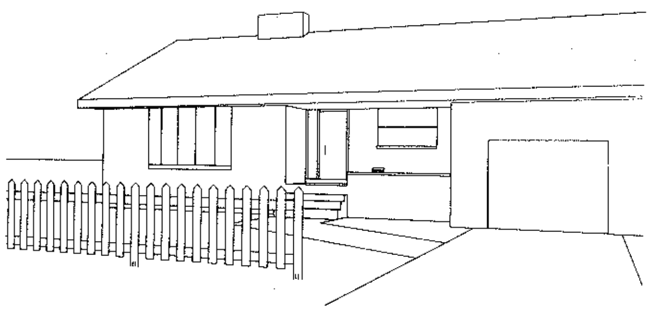
Examples of more advanced work based on the theory of descriptive geometry include hidden line delection (Figures 2, 3 and 11) and perspective in distortion (Figures 12, 13 and 14).

This paper was prepared to complement other presentations at the annual meeting of the ASEE (1973). The chairman requested that the content illustrate to those who are active in engineering graphics, how they can get involved in computer graphics. With this in mind let us consider a very basic facility-- that of general projection.

All forms of pictorial, including orthographic, are based on the projection of the details of a three-dimensional object onto a two-dimensional surface, controlled by the location of a viewing point. The relative position of these three elements, the object, the picture plane, and the eye position determine the type of pictorial.







Figures 1-3: A series of views drawn as part of an animated movie.

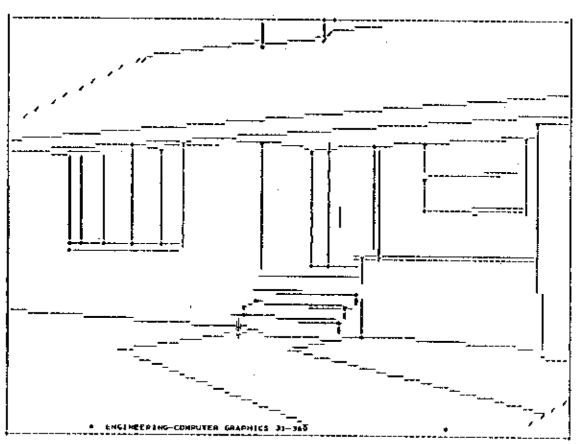
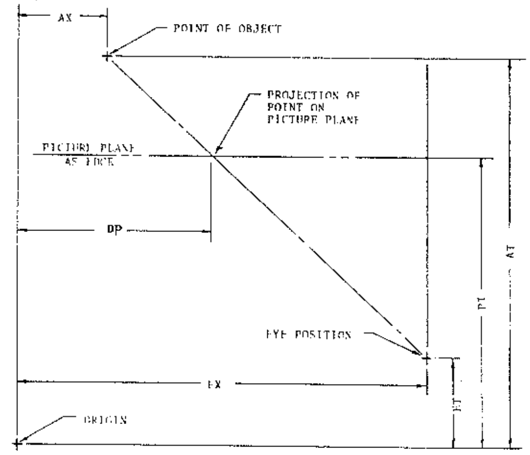


Figure 4: A perspective of a house on LPLOT System with the plotter simulated on the line printer.



The projection of a point of the object on the picture plane is established by the geometric relationship:

$$DP = EX - (EX - AX) * (PT - ET) / (AT - ET)$$

Figure 5: The geometric relationship for projection.

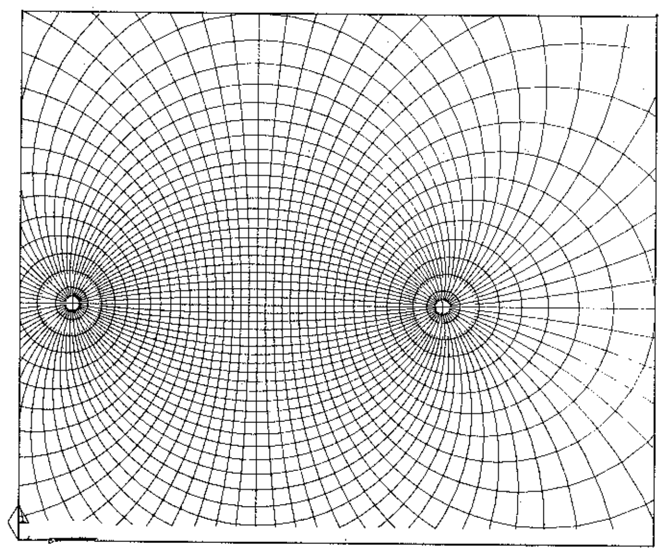


Figure 6: A stereographic net projected from data of a complete sphere.

A three-dimensional coordinate system has to be chosen which will describe the object as a number of lines, locate the plane of projection or picture plane, and also establish the viewing point or eye position. This represents a minor step used to advance from the drawing board to the computer data. Using the theory involved in descriptive geometry: projection, revolution, intersection, etc., the computer program is developed to process this data and generate the simple X-Y coordinates required to describe a complex two-dimensional pictorial. By simply controlling the relative position of the three main elements, the object, picture plane and eye position, all the common forms of pictorial can be obtained.

There are various coordinate systems which can be used. Arbitrarily, we chose a left handed system, since it was most convenient when preparing data from a multiview orthographic source.

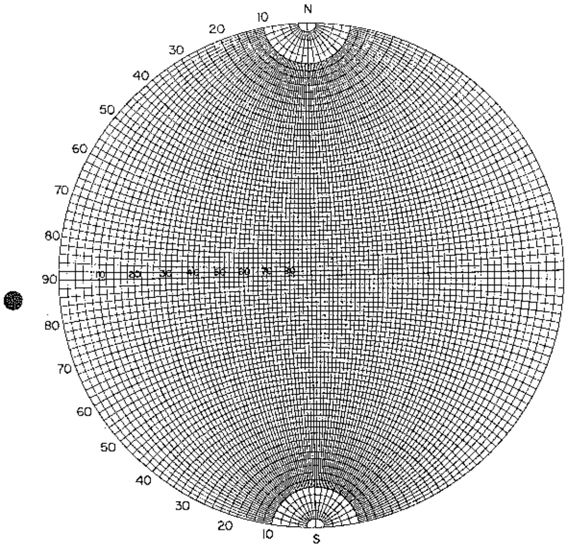
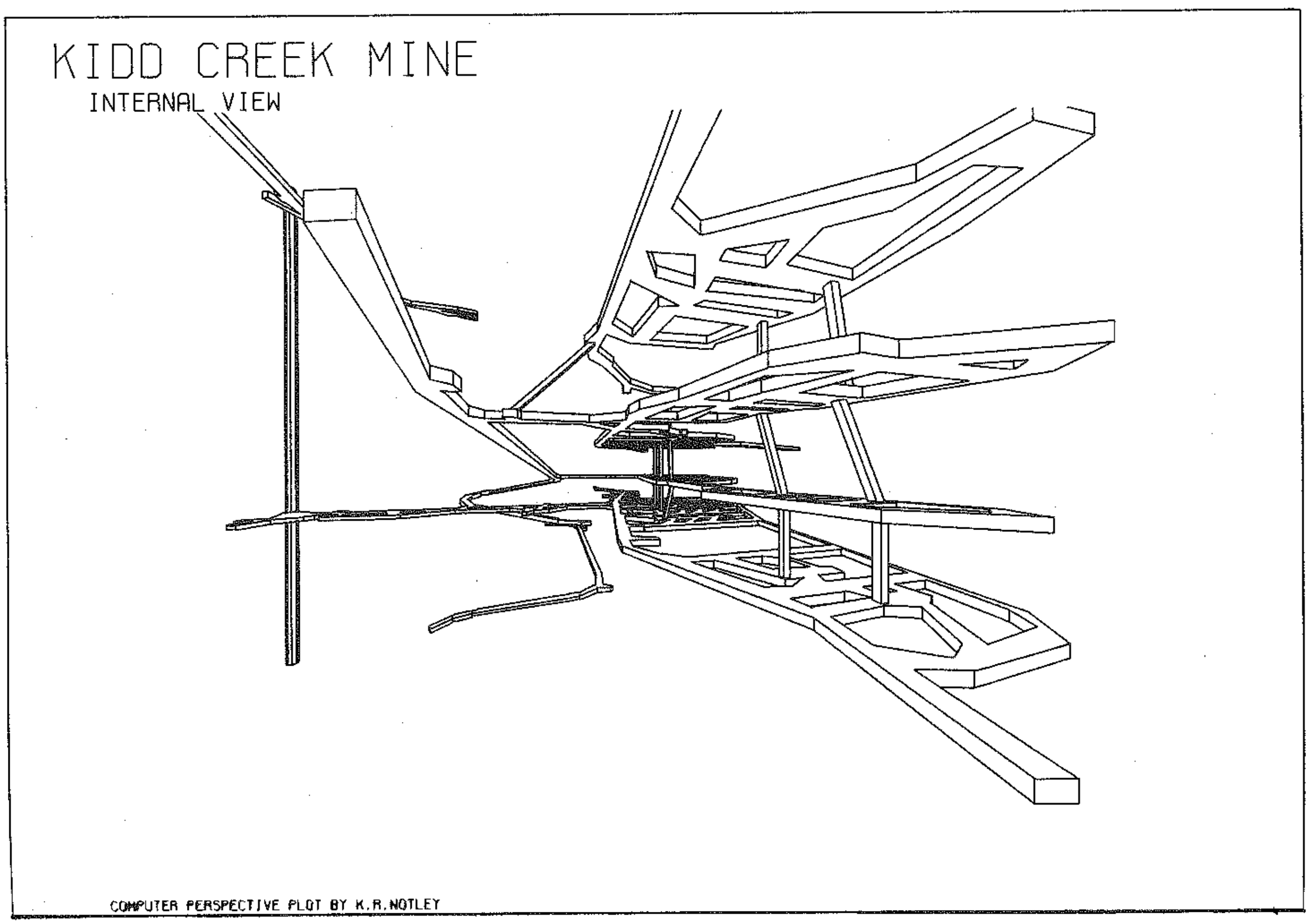


Figure 7: A stereographic net of a sphere.

Figure 8: One of a pair of stereographic views of the underground workings of a mine.



In this system the origin can be considered in the bottom left hand corner, the "X" direction is to the right, parallel to a frontal-horizontal line, and "Y" is upward parallel to a frontal-profile line, and the Z (or "T") direction is back in a horizontal-profile direction. Other systems can be obtained by interchanging letters and signs as required. All lines, planes and points for the location of the projection elements are then described as coordinate data.

Using this coordinate system the fortran statements can be developed as shown in Figure 10. Here the three elements are shown in simplified form and the image location, DP (or DPAX) is determined by similar triangles (see Figure 5). Similarly for the Y coordinate we find that:

DPAY = EY - (EY-AY)*(PT-ET)/(AT-ET)

The variables containing the letter "A" in these statements are for one point "A" on a line A-B. Similar formulae can be used for the "B" end. In actual use, constant values such as (PT-ET) would be replaced by a single variable.

The data for the object can also be processed further, before projecting, to move, rotate, assemble or disassemble, delete, or duplicate various elements. This can result in output such as animated movie sequences, and to the deletion of data which would not be seen at the specified eye position.

One of the earliest solutions to the "hidden line problem" was included in this work and illustrated in an article published in the winter edition(1967-8) of the quarterly bulletin of the Canadian Information Processing Society.(1)

My approach to the hidden line problem is simple but the logic is complex. It is not restricted to views of a single object, but is a general solution such that an object can obscure part of another and the program will determine which parts are in full view. Using the principles of descriptive geometry and describing the objects as lines and obstruction planes, the data is regenerated to delete any portion of a line which is obscured behind an obstruction plane. A single line then may be regenerated as many lines, if viewed through a series of obstructions such a picket fence (Figure 3).

Let's apply this theory to the logic of a computer program (Figure 10). We want the program to accept the data describing the location of the elements, and from it, calculate the X-Y coordinates required to draw lines on a plotter.

As an example of the simplest form of program suitable for student use, consider the following logic which:

1. Initializes the standard calcomp subroutines
2. Reads in permanent data which establishes the eye position and picture plane

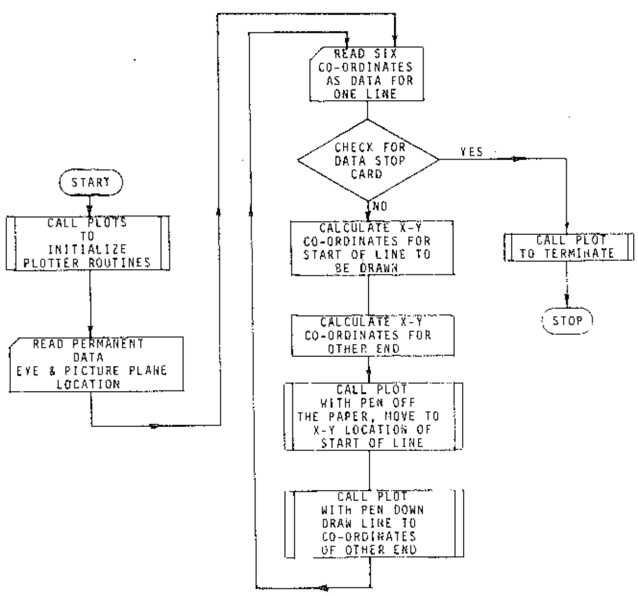


Figure 9: The logic of the computer program.

```
                    ENGINEERING-COMPUTER GRAPHICS
                              31-360
C       BASIC PLOTTING PROGRAM FOR PERSPECTIVE OF THREE DIMENSIONAL OBJECT
C       INITIALIZE PLOTTER SUBROUTINES
        DIMENSION   WK (1024)
        CALL PLOTS  ( WK,4096 )
C       READ IN PERMANENT DATA FOR EYE AND PICTURE PLANE
        READ (5,5001) EX,EY,ET, PT
 5001   FORMAT (4F5.2)
C       START LOOP TO PROCESS LINES, SIX CO-ORDINATES EACH
     10 READ (5,5002) BX,BY,BT, AX,AY,AT
 5002   FORMAT (6F6.2)
C       CHECK FOR DATA STOP CARD, 999999 IN FIRST FIELD
        IF (BX.GT.998.0)  GO TO 20
C       CALCULATE 2D CO-ORDINATES FOR PERSPECTIVE
C       REF. FIG. 1, C.I.P.S. JOURNAL, VOL 8, NO 1, 1967-8
C       "A" END OF LINE
        DPAX = EX-(EX-AX)*(PT-ET)/(AT-ET)
        DPAY = EY-(EY-AY)*(PT-ET)/(AT-ET)
C       "B" END OF LINE
        DPBX = EX-(EX-BX)*(PT-ET)/(BT-ET)
        DPBY = EY-(EY-BY)*(PT-ET)/(BT-ET)
C       PLOT LINE; MOVE PEN TO CO-ORDINATES OF "A"
        CALL PLOT   ( DPAX, DPAY, 3 )
C       DRAW LINE TO CO-ORDINATES OF "B"
        CALL PLOT   ( DPBX, DPBY, 2 )
        GO TO 10
C       TERMINATE DRAWING
     20 CALL PLOT (10.0, 0.0, 999)
        STOP
        END
```

Figure 10: The computer program.

PERSPECTIVE PLOT OF GRAPHITE CRYSTAL. HIDDEN LINE DELETION NOT USED ON BOTTOM PORTION TO ILLUSTRATE WHAT PROGRAM HAD TO DELETE IN TOP LAYER.

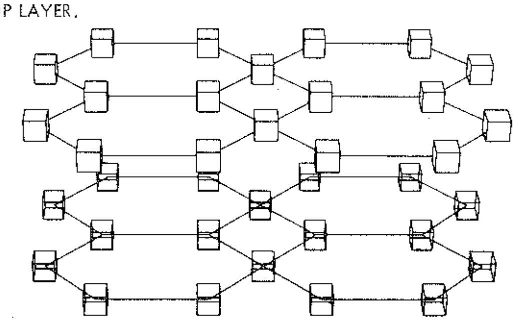


Figure 11: A perspective of a graphite crystal. The subroutine was written to generate cubes complete with obstruction planes and also, to locate them as required. Hidden lines were not deleted on the bottom portion to illustrate the results.

3. In a loop, reads in data for one line
4. Checks for data stop (end of data) and branches to terminate if required
5. Calculates the four coordinates for the 2D picture from the 3D information
6. Sends the pen to the first of the line, then has it draw the line to the other end
7. Continues in the loop by reading another card.

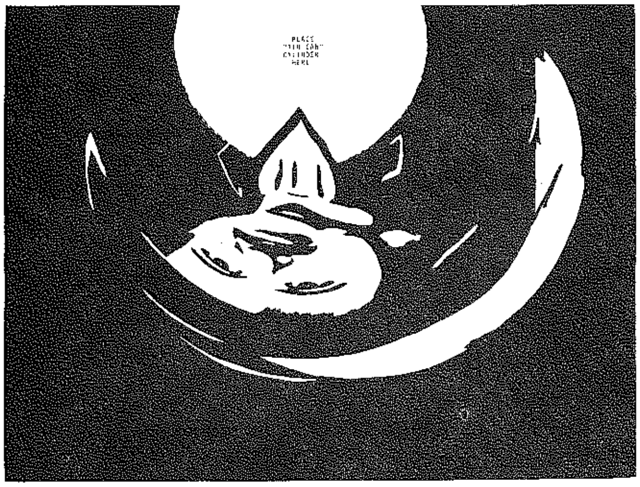


Figure 12: A perspective in distortion called "Anamorphosis."

This is only the beginning of a system of general projection software. It can be done in about 16 statements. You will want to add additional programming to move and revolve the object, limit the drawing size and take care of unreasonable data such as elements of the object which are behind the eye position.

The COGR system which we use, has all the logic for various operations such as projection, framing, revolution, storing, etc., coded as a set of subroutines which the student can use with his own main program. The COGR system also has a main program which processes data prepared in a standard format. This system will even establish suitable parameters if the user is uncertain what data would give him a suitable view.

COGR can be used as a utility to process pictorials with no further programming or, on the other hand, in teaching, as an interim supply of logic for a student developing his own software.

Each subroutine to be effective must be designed to handle every conceivable type of problem, for example lines which are not visible due to their location behind the eye.

Engineering-computer graphics at Queen's University is presented as an extension to descriptive geometry, and other engineering graphics topics as well as computer programming. Topics in graphics are reviewed to determine how the same logical approach can be applied on the computer. The student has the temporary use of

Figure 13: Anamorphosis using a horizontal cylinder.

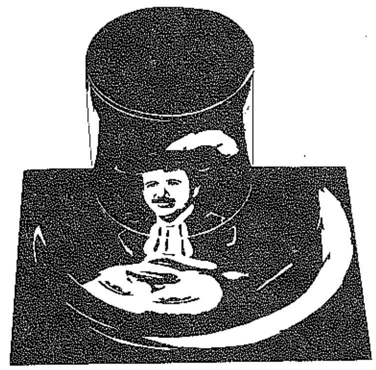


Figure 14: Anamorphosis using a vertical cylinder.

"canned" programs in the form of restricted library subroutines which he can use while he is developing his own software and finding new uses for computer graphics in engineering.

In the sixteenth century an artist, looking for a new challenge placed a reflecting cylinder on a canvas and then, using a "secret" technique called anamorphosis drew a scene which was distorted. When viewed as a reflection on the cylinder, the distortion was cancelled, giving a normal picture. (2)

This challenge proved to be an interesting project in descriptive geometry to get the modern computer to do the same thing. The results are as shown in the illustrations. The location of each line on the distorted picture was computed and the resulting drawing produced on the plotter. The "artist" completed the drawing by colouring the areas and then projecting it from a cylinder.

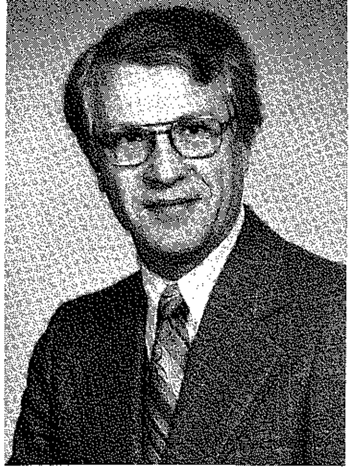
The distorted view in Figure 12 can be viewed with a tin can of the required size and will result in an undistorted view of a historic gentleman.

Figure 13 shows anamorphosis for a horizontal cylinder. Figure 14 is a view of a computer graphics display prepared for the ASEE Conference.

References:

(1) Formerly the Computer Society of Canada

(2) Life Science Library - Mathematics



Richard Hang
Department of Engineering Graphics
The Ohio State University

Computer Drawn Curves Using Spline Techniques

Anyone who has had to draw a graph knows the problem of drawing the curve representing the function being graphed. Freshman graphics or engineering drawing introduced most of us to fiendish device known as the french or irregular curve. Very often the curve we finally drew bore a minimal relationship to the correct curve. But we went blithely on with our "eyeball" methods because we really lacked better methods. Professional draftsmen had a curve-drawing device called a spline, really a flexible strip which could be bent to an eyeball correct curve and then held in place while the curve was drawn. At least the spline eliminated the lumps and discontinuities we often obtained. The chore of drawing a graph was treacherous enough to dissuade many of us from doing it. Not to mention the chore of calculating data points and plotting them. We all like graphs, we just don't like to produce them.

The computer and computer-driven graphics devices have simplified the labor of creating graphs but have created a minor monster in that we must try to reproduce our "eyeball" techniques with computer programs. Given a known continuous function, the computer and plotter will draw a very accurate graph of the function. Although lacking in artistic merit, the resulting graph is accurate and far easier to prepare from our viewpoint.

A preceding statement contains the nucleus of a problem. The computer needs a known function so that it can calculate y values for given x values. Given only a set of discrete x-y pairs, the only way to draw a curve connecting these data points is to interpolate between these points by some mathematical function. We are back where we started, we need a function to draw a curve. Graphics students will remember exercises in curve fitting or empirical data and equations, two names for this process.

People with some experience in the area of curve fitting know that it consists usually of guessing a suitable function and then determining if the guess was a good one. Least squares curve fitting and regression analysis are two of the methods used to see if we made a good guess. The real difficulty is that the guessing requires some experience, luck and perseverance to determine a suitable function to match some data. What is even more pertinent, the whole process requires such numbers of calculations as to discourage all but the most determined individual.

My interest in computer graphics has been to try to develop computer programs to do conventional graphics with as little intervention by the user as possible. Drawing a graph is one of a number of programs developed. The methods I have used are already known although of sufficient newness to warrant some attention.

Students of mathematics and computer science study a topic called interpolation. This is merely curve fitting in another guise. It would seem that any method providing a way to find correct values of y for values of x intermediate to known points would permit us to draw a curve representing given data points. This is indeed the best way to go at the present time. Most mathematical interpolation methods consist of determining a polynomial which closely approximates the function represented by the data points. The list of common polynomials used for this purpose reads like an honor roll of early mathematicians: Newton's Forward Difference Formula; Lagrange Interpolating Polynomial; Hermite, Legendre, Laguerre and Chebyshev orthogonal polynomials. There are others but this is a representive list. Any one of these polynomials can be used successfully to interpolate a function and hence to draw a curve. But all suffer from the same malady. If a polynomial is to go through n data points, it

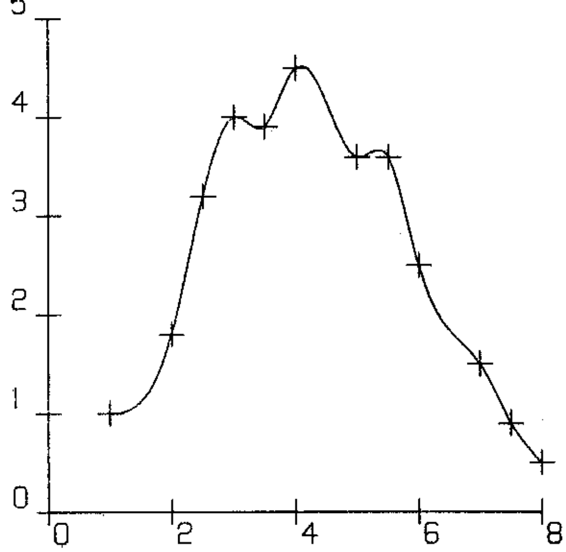


Figure 1A: The spline curve drawn without smoothing.

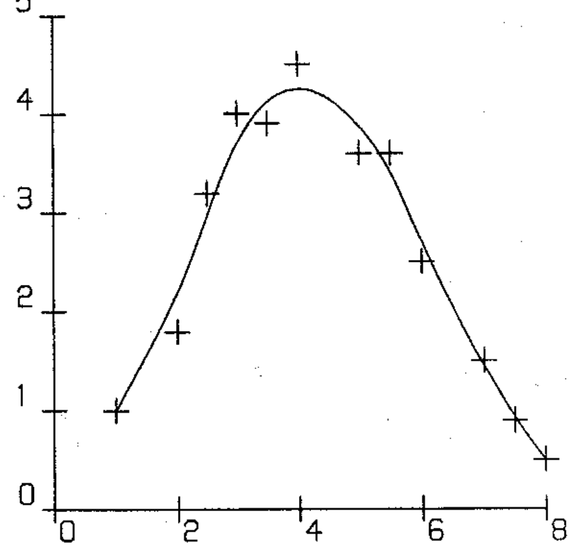


Figure 1B: The spline curve drawn with smoothing.

often must be of order n-1, creating an unwieldy equation to use. Also, a polynomial may go though all data points and yet take such a snake's trail path in so doing that it does not truly interpolate the data. This is somewhat akin to trying to find one french curve which will draw all of the curve in one setting. It usually can't be done.

Some of the polynomials limit their usage to a specific interval such as -1 to 1. This creates a better interpolation function but limits the usefullness of the method or at least requires scaling of the data. A solution to the usual polynomial dilemma is to use a type of function known as a spline function. A spline function duplicates the action of the draftsman's spline although the function is not continuous but piece-wise. For n data points there will be n-1 separate spline functions. Spline functions are easily calculated by computer programs and easily used by computer-driven graphics devices to draw a curve.

The usual spline function used for interpolation is a cubic. The most unusual thing about spline cubics is the restrictions placed upon pairs of adjacent functions. Consider two adjacent spline cubes, F1 and F2. They join at a point x. At this junction point x, the functions must obey the following conditions:

1. F1 must equal F2, which means that the curves drawn by each must join.
2. The values of the first derivatives of F1 and F2 must be equal. This means that the curves must have identical slopes at this point, they cannot join with a "lump".
3. The values of the second derivatives of F1 and F2 must be equal. This means that the curves must have the same curvature at this point. An auto driver who ignores this rule steers very jerkily.

Spline functions do not solve all the problems in drawing a curve through a series of data points. Cubic splines in particular, have a mean tendency to add some extra "S" curves to the total curve which are esthetically somewhat displeasing. Figures 1a and 2 a illustrate this tendency. Research has been done in the area of eliminating this difficulty. A very interesting work by A. K. Cline (1) deals with the problem so that cubic splines can be used in interpolate contour lines. The restrictions Cline placed on his smoothing methods included the fact that the curve must do through all data points. Because eyeball curves often do not go through all data points, I used a different smoothing technique. The two methods are based on different assumptions and cannot be compared directly. Probably the only thing the two methods have in common is the fact that too much smoothing tends to make the curve useless. Too much Cline smoothing will make a curve which acts like a string stretched between pins, just a series of straight lines. My method would reduce a sine wave to a straight line with too much smoothing. It seems we haven't eliminated judgement from our procedures, merely changed the items we judge. Figures 1 through 8 show curves drawn by a Calcomp plotter driven by a Hewlett-Packard 2115A computer. The 'a' part of the figure is the spline curve without smoothing, while the 'b' part of the figure is with smoothing. The good examples are very good, while the poorer ones probably aren't much worse than some amateur efforts.

I shall give a brief summary of how cubic spline functions are developed. The algebra which goes between steps has been omitted to conserve space. The interested reader is referred to one of the articles or books listed in the bibliography.

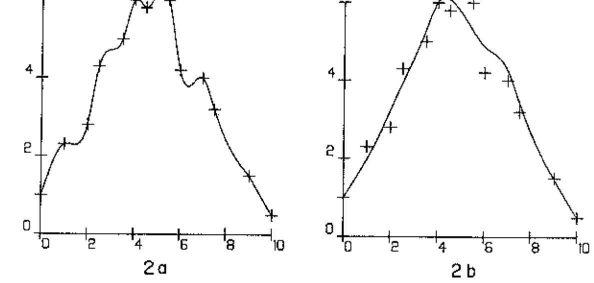


Figure 2: The spline curve drawn without smoothing (A) and with smoothing (B).

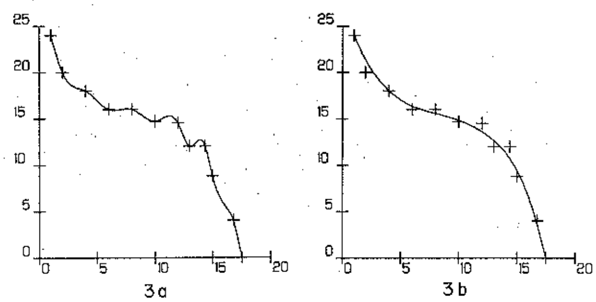


Figure 3: The spline curve drawn without smoothing (A) and with smoothing (B).

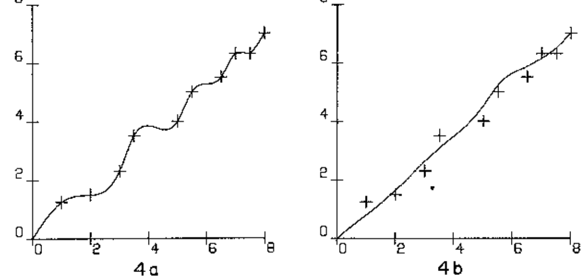


Figure 4: The spline curve drawn without smoothing (A) and with smoothing (B).

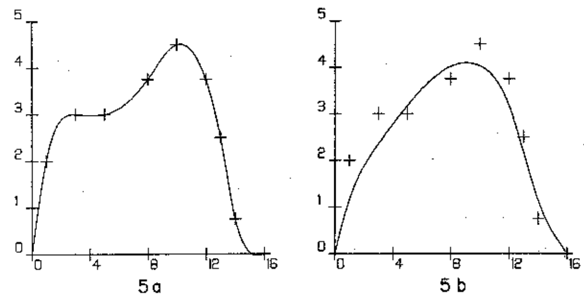


Figure 5: The spline curve drawn without smoothing (A) and with smoothing (B).

All mathematics will be based on have n known x-y data points. These data points must be arranged so that:

$$x_{i+1} > x_i \quad \text{for } i = 1 \text{ to } n-1$$

There will be a separate spline function for each x interval

$$S_i \text{ for } x_i \text{ to } x_{i+1} \quad \text{for } i = 1 \text{ to } n-1$$

For these n-1 spline cubics the following conditions must hold:

$$\left.\begin{array}{l} 1.\ S_i(x_{i+1}) = S_{i+1}(x_{i+1}) \\ 2.\ S'_i(x_{i+1}) = S'_{i+1}(x_{i+1}) \\ 3.\ S''_i(x_{i+1}) = S''_{i+1}(x_{i+1}) \end{array}\right\} \text{all for } i = 1 \text{ to } n-1$$

Also $S''_1(x_1) = S''_{n-1}(x_n) = 0$ (there are n values of S''_i)

The spline functions are cubics, so it can be stated that the second derivative is of the form:

$$S''(x) = kx+C$$

We can write an interpolation equation of linear form so that we can evaluate S'' at any point x we desire. In general, to obtain a point y for some x, knowing the values y_i and y_{i+1} corresponding to x_i and x_{i+1}, we can write the following linear interpolation equation:

$$y = \frac{x_{i+1}-x}{x_{i+1}-x_i} y_i + \frac{x - x_i}{x_{i+1}-x_i} y_{i+1}$$

If we define the following substitutions:

$$h_i = x_{i+1} - x_i$$

$$D_i = S''(x_i)$$

we can rewrite the interpolation as the following equation:

$$S''(x) = \frac{x_{i+1}-x}{h_i} D_i + \frac{x-x_i}{h_i} D_{i+1}$$

By integrating this equation twice and applying the restrictions of cubic splines noted above, the following cubic spline equation appears:

$$S(x) = \frac{1}{6h_i}[D_i(x_{i+1}-x)^3 + D_{i+1}(x-x_i)^3 + (6y_i - H_i^2 D_i)(x_{i+1}-x) + (6y_{i+1} - h_i^2 D_{i+1})(x-x_i)]$$

Differentiating this equation and imposing the spline conditions yields:

$$h_{i-1}D_{i-1} + 2(h_i+h_{i-1})D_i + h_i D_{i+1} = 6\left(\frac{y_{i+1}-y_i}{h_i} - \frac{y_i - y_{i-1}}{h_{i-1}}\right)$$

Earlier we defined $D_1 = D_n = 0$

$(S''_1(x_1) = D_1 = 0;\ S''_{n-1}(x_n) = D_n = 0)$

The above equations are the basis for n-2 simultaneous linear equations of the form:

$$\begin{array}{ll} b_2D_2 + c_2D_3 & = k_2 \\ a_3D_2 + b_3D_3 + c_3D_4 & = k_3 \\ a_{n-2}D_{n-3} + b_{n-2}D_{n-2} + c_{n-2}D_{n-1} & = k_{n-2} \\ a_{n-1}D_{n-2} + b_{n-1}D_{n-1} & = k_{n-1} \end{array}$$

This is the classic tridiagonal system of simultaneous linear equations. Various schemes exist for solving systems of this type. For systems of 20 to 30 equations, a modified Gauss elimination method is suggested. See any good text on numerical methods. All Gauss methods have limitations and the user is

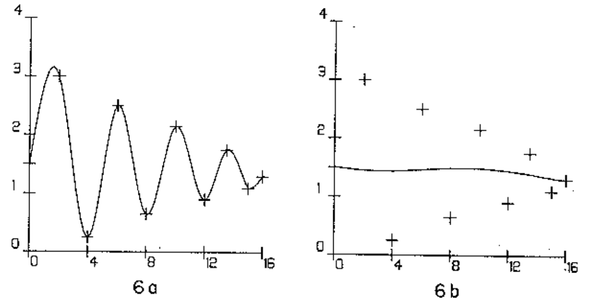


Figure 6: The spline curve drawn without smoothing (A) and with smoothing (B).

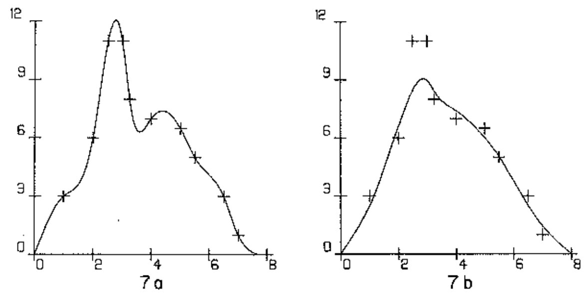


Figure 7: The spline curve drawn without smoothing (A) and with smoothing (B).

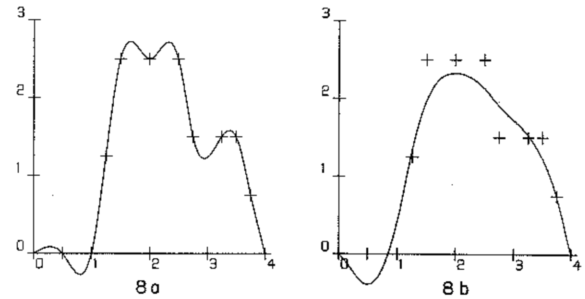


Figure 8: The spline curve drawn without smoothing (A) and with smoothing (B).

advised to carefully check these limitations before using the method. Systems of larger than 30 equations often should be solved by iteration or relaxation methods.

Once D_1 through D_n are obtained from the solution of the linear system, it is a simple task to substitute the correct D's into the spline equations and use the appropriate equation to plot or interpolate the section of the curve desired. Each cubic equation is valid for the interval x_1 to a_{i+1}.

It was previously mentioned that spline curves tend to have extraneous "S" curves. Also the curve that represents a trend of some data may not go through all the data points. Becuase of these two reasons, smoothing is performed on the data before fitting the spline curve to the data. The technique used is simple but again a typical candidate for a computer program. If a quadratic equation is fitted to data points 1, 2, 3, 4 and 5 it will be found that an exact fit on points 1, 2, 4 and 5 will often cause point 3 to need some adjusting to fit the quadratic. If point 3 is adjusted, moved up or down to fit the quadratic, it will produce a smoother curve for points 1 through 5. Using the new point 3, the procedure is repeated for points 2, 3, 4, 5 and 6. Point 4 is corrected or smoothed this time. The process is repeated for all data points to the end of the data. It can be seen that all data points except points 1, 2, n-1 and n have been moved in this smoothing process. Thus, some of the smoothing is somewhat inaccurate. So the process could be repeated for all data points, hopefully getting a better smoothing in this process. Because smoothing tends to remove the character of a curve it should be limited to a few iterations. I usually use two or three smoothings for those curves requiring it. Figure 6 illustrates a curve for which no smoothing should have been applied. The 'b' part of the figure shows how smoothing removes all character from this data. All 'b' figures are the corresponding 'a' figure curve with three smoothing iterations.

It would seem that using a quadratic for smoothing and a cubic for the spline is inconsistent. Smoothing performed with a polynomial of order n causes the first and last n points of the data not to be smoothed or moved. Using a cubic for smoothing would require seven points at a time and would not smooth the first and last three points. This is to much wastage for the type of curves I intended the procedure for. In addition to using a quadratic for smoothing, I introduced an extra data point between points 1 and 2 and another between point n-1 and n to permit original data points 2 and n-1 to be smoothed. This extra point is interpolated into correct position for each smoothing. Because it is located very close to the first and last data points, it has little effect on the trend of the curve but does permit better smoothing. The procedure needs refining but does produce better trend curves than if not used.

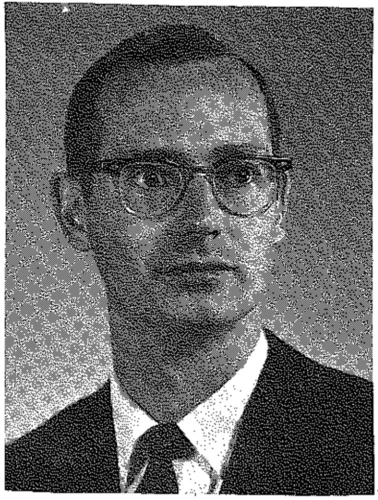
In conclusion, spline interpolation methods are probably superior to conventional polynomial methods when used for curve fitting. Their use is still something of an art and cannot be called automatic by any stretch of the imagination. Spline methods are ideally suited to computer methods and do not require complex programs to solve just the spline functions. Unfortunately, the best spline curve may be the result of trying several smoothing techniques and using the best one in the judgement of the user. Additional work is needed to automate the computer drawing of spline curves.

The computer program spline curve smoothing

```
C SPLINE INTERPOLATION DEMONSTRATION PROGRAM WRITTEN BY:
C RICHARD HANG, THE OHIO STATE UNIVERSITY
C THIS PROGRAM DETERMINES Y FOR ANY X USING SPLINE FUNCTIONS TO FIT
C  N X-Y DATA POINTS EITHER WITH OR WITHOUT SMOOTHING
      DIMENSIONX(25),Y(25),H(25),D(25),F(25),T(25),S(10)
      READ(5,101)N
 101  FORMAT(I5)
      READ(5,102)(X(I),Y(I),I=1,N)
 102  FORMAT(8F10.4)
C INPUT SMOOTHING FACTOR AS = 0 TO 3
      READ(5,101)MS
      IF(MS.EQ.0)GOTO10
C ADD 2 EXTRA DATA POINTS FOR SMOOTHING
      X(N+2)=X(N)
      Y(N+2)=Y(N)
      DO5I=3,N
      L=N+3-I
      X(L)=X(L-1)
 5    Y(L)=Y(L-1)
      N=N+2
      X(2)=X(1)+.1*(X(3)-X(1))
      X(N-1)=X(N)-.1*(X(N)-X(N-2))
C START OF SMOOTHING ROUTINE TO FIND Y(I) FOR EACH X(I)
      DO15I=1,MS
      Y(2)=Y(1)+.1*(Y(3)-Y(1))
      Y(N-1)=Y(N)-.1*(Y(N)-Y(N-2))
      K=N-2
      DO15J=3,K
      DO25L=1,7
 25   S(L)=0.
      DO30L=1,5
      LI=L-3
      D1=X(J+LI)-X(J)
      D2=Y(J+LI)
      S(1)=S(1)+D1
      S(2)=S(2)+D1*D1
      S(3)=S(3)+D1**3
      S(4)=S(4)+D1**4
      S(5)=S(5)+D1*D1*D2
      S(6)=S(6)+D2
 30   S(7)=S(7)+D1*D2
C IF S(1) = 0, POINTS ARE UNIFORMLY SPACED, USE FORMULA IN LINE 35
C ELSE USE NON-UNIFORM SPACING EQUATIONS DIRECTLY FOLLOWING
      IF(S(1).EQ.0.)GOTO35
      S2=(5.*S(2)-S(1)*S(1))*(S(2)*S(3)-S(1)*S(4))-(5.*S(3)-S(1)*S(2))
     1*(S(2)*S(2)-S(1)*S(3))
      S1=(S(5)*S(1)-S(6)*S(3))*(S(2)*S(2)-S(1)*S(3))-(S(1)*S(7)-S(2)
     1*S(6))*(S(2)*S(3)-S(1)*S(4))
      Y(J)=S1/S2
      GO TO 15
 35   Y(J)=(-3.*Y(J-2)+12.*Y(J-1)+17.*Y(J)+12.*Y(J+1)-3.*Y(J+2))/35.
 15   CONTINUE
 10   N1=N-1
      N2=N-2
C SET UP COEFFICIENTS OF TRIDIAGONAL LINEAR SYSTEM
      DO20I=1,N1
 20   H(I)=X(I+1)-X(I)
      DO40I=2,N1
      T(I)=2.*(H(I)+H(I-1))
 40   F(I)=6.*((Y(I+1)-Y(I))/H(I)-(Y(I)-Y(I-1))/H(I-1))
      D(1)=0.
      D(N)=0.
C MODIFIED GAUSS METHOD TO SOLVE TRIDIAGONAL LINEAR SYSTEM
      DO45I=3,N2
      V=H(I-1)/T(I-1)
      T(I)=T(I)-V*H(I-1)
 45   F(I)=F(I)-V*F(I-1)
      DO50I=2,N1
      J=N+1-I
 50   D(J)=(F(J)-H(J)*D(J+1))/T(J)
C FIND Y FOR 100 X POINTS USING CORRECT SPLINE EQUATION
      DX=(X(N)-X(1))/99.
      I=1
      DO55J=1,100
      R1=(J-1)*DX+X(1)
 65   IF(I.EQ.N-1)GO TO 60
      IF(R1.LT.X(I+1))GO TO 60
      I=I+1
      GO TO 65
C SOLVE SPLINE EQUATION FOR Y VALUE
 60   D2=D(I)*(X(I+1)-R1)**3+D(I+1)*(R1-X(1))**3+(R1-X(I))*(6.*Y(I+1)
     1-D(I+1)*H(I)**2)+(X(I+1)-R1)*(6.*Y(I)-D(I)*H(I)**2)
      D2=D2/(6.*H(I))
 55   WRITE(6,104)J,R1,D2
 104  FORMAT(I10,2F15.4)
      STOP
      END
```

Bibliography

1. Cline, A.K., "Scalar-and-Planar-Valued Curve Fitting Using Splines Under Tension", Communications of the ACM, April 1974, pp 218-220.
2. Carnahan & Wilkes, "Digital Computing and Numerical Methods", John Wiley and Sons, Inc. (1937) pp 307-310.
3. Ralston & Wilf, "Mathematical Methods for Digital Computers", Vol. 2. Chapter 8, pp. 156-168 is an excellent article on spline curves by T.N.E. Greville. The bibliography is excellent. However, the Fortran program is incorrect.
4. Ahlberg, Nilson and Walsh, "The Theory of Splines and Their Applications", Academic Press (1967).



Robert J. Foster
Pennsylvania State University

Arizona State in 1976

MID-YEAR CONFERENCE AT ARIZONA STATE 1975-76

Plans are under way for the Engineering Design Graphics Division Mid-Year Conference that will be held at Arizona State University. Dates of the meeting are January 7-10, 1976 with the papers being presented on January 8 and 9. The theme of the program is NEW FRONTIERS.

You are invited to submit papers for this program. Several suggested areas for papers are listed below.

Areas for papers:

1. "What Industry Needs in Design Engineers" - a keynote to start the meeting on January 8. It should challenge the group to our responsibilities in teaching for a design world. A paper from a person in industry (or consulting in industry) is desirable.

2. "What Engineering Design Graphics Teachers Need from Industry" - a statement from the academic side of the fence, from an EDG member with recent industrial experience.

These papers will be given back-to-back followed by audience reaction to the speakers with a panel moderator.

3. "Recommendations from Industry for Improving Freshmen Engineering" - a considered opinion from an industrialist close to the realities of industry and education.

4. "How Teachers Can and Are Improving Freshman Engineering, with Emphasis on Graphics" - an EDG member with recent success in motivating and/or increasing the performance or retention of freshmen.

These papers will also run in sequence, in the afternoon of January 8. A panel discussion is planned to involve the speakers and a moderator with the audience. The probable theme is "New Frontiers in Graphics - Fact or Fancy?".

5. "Recent Innovations in Teaching Design Graphics" - a good "success" story.

6. "'Old' Teaching Methods that are Still Great" - examples of methods which lie half forgotten being effective still.

The morning of January 9th would contain these contributions, plus a group discussion on "Where does this Conference leave EDG?"

If you are at all interested in being involved in this conference, please drop your ideas to Prof. Gordon Sanders, 403 Marston Hall, Iowa State University, Ames, Iowa 50010.

PREPARE NOW FOR AN EXCELLENT PROGRAM!

POSSIBLE PROGRAM SCHEDULE
FOR 1976 MID-YEAR CONFERENCE

Engineering Design Graphics Division

January 7, 8, 9, 10, 1976
THEME: NEW FRONTIERS

Wed. Jan. 7

3:30 - 5 P.M.	Registration and conversation (with coffee, donuts)
6:30 P.M.	Executive Committee Dinner

Morning
Thurs. Jan. 8

8:00	Registration (with coffee) plus Table Exhibits.
9:00	Greetings from ASU: Appropriate Dean or officer.

9:15 First speaker: "What Industry Needs in Design Engineers" - a keynote to challenge those present to our responsibilities in teaching for a design world. Speaker to come from the Phoenix area.

9:45 Second speaker: "What Engineering Design Graphics Teachers Need from Industry" - a statement from the academic side of the fence, from an EDG member with recent industrial experience. (Note each of the above two speakers shall have advance copies of the respective papers).

10:15 Coffee break

10:45 Reactions and Propositions from the the audience to the panel of Speaker 1, Speaker 2, and a Moderator from EDG: What are the implications of what has been said?

11:45 Adjourn for lunch.

12:00 Business Luncheon - Bob LaRue presiding.

Afternoon
Thurs. Jan. 8

1:45 First speaker: "Recommendations from Industry for Improving Freshmen Engineering" - a considered opinion from an industrialist close to the realities of industry and education.

2:15 Second speaker: "How teachers can and are improving the freshman year in engineering, with emphasis on graphics" - and EDG member with recent success in motivating and/or increasing performance of freshmen.

2:45 Quick coffee.

3:00 Dialogue between the audience and the panel of afternoon speakers and a moderator with the theme: "New Frontiers in Graphics - Fact or Fancy?" Are education and industry pulling together toward new goals of excellence in our graduates, or are we in trouble?

4:00 Adjournment to committee meetings.

6:30 "An Evening at Rawhide" - steak dinner and entertainment, open to all members, guests, and wives.

Morning
Fri. Jan. 9

8:00 Table Exhibits

9:15 First speaker: "Recent Innovations in Teaching Design Graphics" - a good "success" story.

9:45 Second speaker "'Ole' Teaching Methods that are still great" - that which lies half forgotten may be useful yet.

10:15 Coffee break.

10:45 Group discussion "Where does this Conference leave EDG?" This would be a probing analysis of ourselves, our mission, our reaction to what we have heard for two days, to be moderated by the Executive Committee members.

11:45 Adjourn for lunch.

1:30 A tour to an industrial concern of significance and interest.

7:00 An entertainment opportunity for those members caring to partake (e.g. theatre party, ets.).

Saturday, Jan. 10

A.M. Opportunity to visit the greater Phoenix Area.

jobs

This column is a new feature of the JOURNAL that will be available to those who wish to advertise vacant positions that would be of interest to our readers. This will be a free service offered to both the employer and our membership. We look forward to hearing from you.

ENGINEERING DESIGN GRAPHICS INSTRUCTOR

The Engineering Design Graphics Department of Texas A&M University is seeking applicants for an assistant or associate professorship that must be filled by September of 1975. Duties will include the teaching of engineering graphics and descriptive geometry for freshmen engineering students. Also, it is desired that applicants be competent to teach speciality courses such as computer graphics, electronic drafting, pipe and vessel drafting, nomography, etc.

Salary is open: to be based on qualifications of the applicant. Texas A&M University is an equal opportunity employer.

NEWS

CREATIVE DESIGN EMPHASIS AT COLORADO STATE

Plans are well under way for "accentuating the positive" relating to the current interest and impetus in the realm of Creative Design in the E.D.G. division of ASEE during the upcoming meeting at Colorado State. Not only will a bigger and better competitive design display be developed by the very able and active Creative Design Committee but plans are well developed to generate additional interest in the area during at least one of the technical sessions.

The plans include inviting a student member from one of last year's winning teams to participate in a panel discussion about the subject involved, along with one of the instructor's from the winning school, a representative or two from industry and someone from engineering education. It looks like a great way to get some important reactions from others than just the peddlers of the product.

If you have any ideas for topics worthy of discussion etc., contact Borah Kreimer or Gordon Sanders, Program Director.

See and hear you at the session.

C. Gordon Sanders

NEW DIVISION MEMBERS

The Engineering Design Graphics Division of ASEE announced the addition of nine new members as of October 2. We take this opportunity to welcome each of the following to both the Division and its Journal.

Dr. Norman C. Ashcraft, Chairman
Division of Engineering Technology
Southwest Minnesota State College
Marshall, Minnesota 56258

Professor James R. Burnett
Michigan State University
College of Engineering
East Lansing, Michigan 48824

Mr. Horace Gambell
80 La Cueva
Los Alamos, New Mexico 87544

Professor John H. Jackson
Vermont Technical College
Randolph Center, Vermont 05061

Mrs. Mary A. Jasper
P. O. Box 155
Mississippi State, Mississippi 39762

608 W. Palladium Drive
Joliet, Illinois 60435

Professor Peter F. Pfaelzer
San Francisco State University
1600 Holloway Avenue
Division of Engineering
San Francisco, California 94132

Professor J. David Pfeiffer
McGill University
Mechanical Engineering
P. O. Box 6070
Montreal, Quebec
Canada H3C 3G1

Professor John B. Rapka, PE
50 Harvard Road
Parlin, New Jersey 08859

Oppenheimer Award

Once again the Frank Oppenheimer Award, presented at annual and mid-year meetings to reward excellence in the presentation of papers, resulted in a tie for first place. The dual winners of the award at the annual conference in Troy, New York were Professor John S. Daniel and Professor Richard I. Hang.

Professor Daniel is located at the Universite du Quebec. His paper entitled "Lap Dissolve Projection" was presented at a session co-sponsored by the Engineering Design Graphics Division and the Educational Research and Methods Division.

Professor Hang from Ohio State University presented a paper entitled "Computer Drawn Curves Using Spline-Techniques" at a session co-sponsored by the Engineering Design Graphics Division and the Computers in Education Division.

Professors Daniel and Hang will split the well deserved $100 that accompanies the award.

Limerick Laureates

Thanks to Robert LaRue
Professor at Ohio State U.
Hilliard did not holler
And we're sending Bob a dollar
Compare his line below with your fall issue.

"If you don't, you'll hear Hilliard holler!"

This column got off to a good start
But only a few readers are taking part
To keep from reading limericks of mine
You'll have to send in more than a line
Let's fill this column with limerick art.

You try it too; we'll give you a green five
To help keep this column strong and alive
Send in the best five lines to capture the purse
Design Graphics limericks make excellent verse.
I'll be waiting to read what you contrive.

Macmillan has the

ENGINEERING GRAPHICS, Second Edition, The late Frederick E. Geisecke, The late Alva Mitchell, The late Henry Cecil Spencer, Ivan Leroy Hill, and Robert Olin Loving; both, Illinois Institute of Technology

The second edition of Engineering Graphics is now completely updated with the latest trends in engineering education and with the latest developments in industry. Comprehensive in scope, it is written for courses which include technical drawing and design, descriptive geometry, and graphs and graphical computation.

Organization is the same as the first edition; consisting of three sections—Part I Technical Drawing, and Design; Part II Descriptive Geometry; and Part III Graphs and Graphical Computation—which cover basic principles and applications of engineering graphics. Included in this book are seven chapters on descriptive geometry covering: Points, Lines, and Planes; Parallelism and Perpendicularity; Intersections; Developments; Line and Plane Tangencies; Cartography, Geology and Spherical Geometry; and Graphical Vector Analysis. The text begins with the fundamentals of drawing, and essential lettering and layout techniques, followed by 26 topically arranged chapters. The successful approach of the first edition was carried over to the second edition, where material in each chapter logically follows the information in the preceding chapter.

Almost every chapter has been updated, revised, re-written or includes new material. Changes in this edition reflect the changing curriculum for beginning engineering students, emphasizing the design function of engineers early in the book. The authors have carefully maintained the outstanding quality of the illustrations, and in many cases the illustrations have been improved with the addition of a second color. Important *new* features of the Second Edition include:

- A discussion of the importance of design and its relationship to graphics included in Chapter One.

- Extensive revision and expansion of Chapter 14, "Design and Working Drawings" now containing new material on the design process which involves: identification of the problem; formulation of concepts and ideas; compromise solutions; preparation of models or prototypes and the finished working drawings for production.

- A wide variety of industrial examples of the design process, and a broad sample of student projects are provided as open-ended assignments. Suggested guidelines are given for preparing written and oral reports.

- Many problems and illustrations have been redrawn or revised.

- Increased use of decimal dimensions, including the metric system, tables and equivalents.

- A simplified system of notation is introduced in the chapters on descriptive geometry, as a time-saving tool.

- Approximately half of the 1200 line illustrations were revised and many of these were converted to decimal notation.

- Many new halftones were added.

- Many drawings have been converted to the decimal-inch system now being used extensively in industry.

There are many problems at the end of each chapter, most of which are designed for 8½ x 11" sheets, although many problems in advanced chapters will require larger sheets. The most recent developments of the American National Standard Y 14 Drafting Manual have been followed, and are featured in an extensive appendix. This text is now accented with two color printing and a two column format for easier reading.

1975 approx 928 pages

An excellent complement to Engineering Graphics:

ENGINEERING GRAPHICS, PROBLEMS, SERIES I, Second Edition. The late Henry Cecil Spencer, Professor Emeritus, Illinois Institute of Technology, Ivan Leroy Hill, and Robert

Professors Eubanks (Mississippi State) and DeGuise (Montreal) are shown visiting with Mr. B. J. Clark of McGraw-Hill Publishing Company,

Professor and Mrs. Wendell Deen (University of Houston), Mr and Mrs. Bill Whitworth (Hughes Tool Company) and Jody Adams (Virginia Polytechnic Institute) visit during the social hour.

Wives of former faculty members of the U. S. Military Academy--Martha Rogers, Shirley Hammond, Pat Kirby, Mary Devens, and Shirleigh Marvin.

Williamsburg
VIRGINIA

MID-YEAR MEETING

A successful midyear meeting was held at Colonial Williamsburg from December 11-14, in one of the most unique settings for a meeting ever. Attendees were treated to excellent surroundings and many outstanding presentations.

Co-chairmen for this excellent meeting were Bud Devens, Ed Mochel, and Bill Rogers. They are to be commended for the manner in which they handled all arrangements and preparations for the meeting.

Several photographs of some of the attendees are shown here during a social hour of the meeting. Also, the minutes of the business meeting is reproduced as a record of the executive meeting which was chaired by Chairman Claude Z. Westfall of the University of Maine.

The Engineering Design Graphics Division can be proud of another outstanding meeting held for its membership.

candidates

The following names have been submitted by the Nominations Committee and approved by the Executive Committee. These nominees will be voted on this spring and will take office immediately following the annual 1975 ASEE meeting. Ballots will be mailed in early spring to all members of the Engineering Design graphics Division.

VICE CHAIRMAN

Clarence Hall, Louisiana State University
Borah Kreimer, Northeastern University

JOURNAL ADVERTISING MANAGER

Leon Billow, U. S. Naval Academy
Garland Hilliard, North Carolina State U.

DIRECTOR -- ZONES

George Devens, Virginia Polytechnic Inst.
Al Romeo, Ohio State University

ANNUAL MEETING

EXECUTIVE COMMITTEE BUSINESS MEETING

1974 MIDYEAR CONFERENCE

WILLIAMSBURG, VA., WEDNESDAY - December 11, 1974

MINUTES

Meeting called to order at 8:00 p.m. by Chairman Claude Westfall. Chm. Westfall appointed Robert H. Hammond to act in J. H. Earle's absence as a member of the committee. The committee concurred.

Present:
Claude Westfall, Chairman
Bob LaRue, Vice Chairman
Ken Botkin, Past Chairman
Paul DeJong, Sec'y, Treas.
Bob Hammons
Klaus Kroner, Director
Charles McNeese, Director
Ed Mochel, Director
Gordon Sanders, Director

ORDER OF BUSINESS

1. Secretary's Report -- DeJong
Minutes of the 1974 Annual Conference Executive Committee Meeting and Division Business Meeting minutes were reviewed. Motion by Sanders to accept as entered was made. Botkin seconded, passed. Importance of early distribution of minutes was discussed.

2. Treasurer's report -- DeJong
Bank account has a balance of $2217.74. $604.71 belongs to Creative Engineering Design Display Committee. Permanent accounting books are being developed.

The 74-75 budget was presented and reviewed and discussed. Discussion followed concerning the use of idle funds. The treasurer was directed to discuss with ASEE headquarters the possibility of holding some funds in interest bearing accounts.

The existence of two separate treasuries was discussed and it was decided that the publications committee whould be consulted in the preparation of budgets. LaRue pointed out that the Design Display Committee would have to use ingenuity to raise $1750. The freshman trip award was discussed and the CEDD study committee was directed to determine its future character and limitations. The trip to the 1975 conference will consist of travel, registration, meals and lodging. Budget acceptance was moved by LaRue, seconded by Hammond, and passed.

3. Policy Committee -- Bob Hammond
The Proposed Changes in the Division By-Laws were read, discussed, and modified slightly. LaRue seconded as modified, passed. Bob Hammond volunteered to take care of printing and distributing of revised by-laws following 1975 annual conference; approved.

The proposed 2-year division chairmanship was discussed. Members were asked to discuss this with colleages and be prepared to vote on the proposal at the 1975 annual conference executive committee meeting. Wladaver's letter in opposition to the proposal was read.

4. Director's Reports
a. Liaison -- Kroner
Reports indicate need for energetic workers on most committees. A proposal to establish a committee on metrication was entered and discussed. Motion: The Chairman of the Division shall establish, and appoint members to, a new ad hoc committee to be known as the "Committee on Metrication".
LaRue seconded, passed.

b. Programs -- Sanders
Report includes organization for programs through January 1976. Motion made to approve 1975 Annual Conference program proposal submitted by Byard Houck. Seconded, Mochel, passed. Discussion followed regarding efforts and outcome at Washington planning meeting attended by Westfall and Houck. Resolution unanimously passed as follows:

"The Executive Committee of this division wishes to make a special expression of appreciation to Byard Houck for his outstanding efforts in planning and preparing the divisions program for the 1975 Annual ASEE Conference."

The secretary directed to send a copy of the resolution to Dean Ralph Fadum, N.C. State.

c. Publications -- Earle (Hammond)
Interim report of finances was received.

5. Vice-Chairman's Report -- LaRue
Creative Engineering Design Display Study Committee makeup was outlined. Possible interest in Freshman Engineering and creation of a Division Newsletter were discussed. Letters of invitations were read from Ecole Polytechnique and University of Alabama for 76-77 Midwinter conference. Hammond extended invitation to N.C. State for 77-78. Discussion followed. Hammond moved that chairman Westfall should accept invitation from Ecole Polytechnique and that LaRue should find out if Alabama wishes to extend their invitation to 77-78. Committee indicated probably acceptance of Alabama bid for 77-78 and N.C. State for 78-79 midwinter conferences.

Appointment of Eldis Reed to replace Al Romeo, seconded by Hammond, approved.

6. Chairman's Report -- Westfall
Committee unanimously approved the appreciation award to be presented to Frank Oppenheimer for his long and valuable service.

Oppenheimer Award discussed and letter from Frank read to committee, indicating his interest in having Oppenheimer Award made for excellence at midwinter conferences. Moved by DeJong, seconded by LaRue, to make Oppenheimer Award for and during Midwinter Conference: passed.

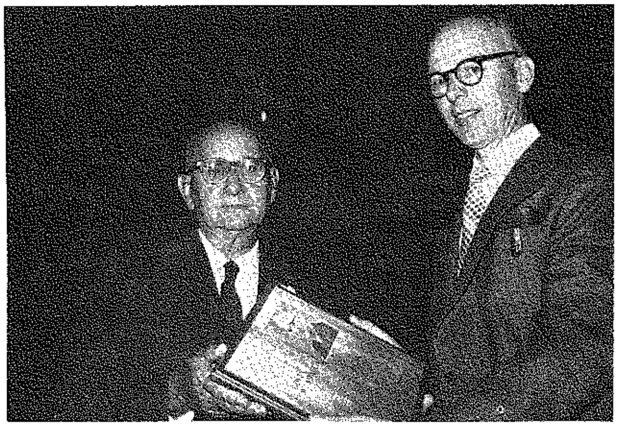
Use of durable metallic plaques for awards was discussed and current awards examined.

Creative Design committee operating. Possible elimination of judge's luncheon was discussed. Concluded that Coppinger and Houck must communicate and work out any changes.

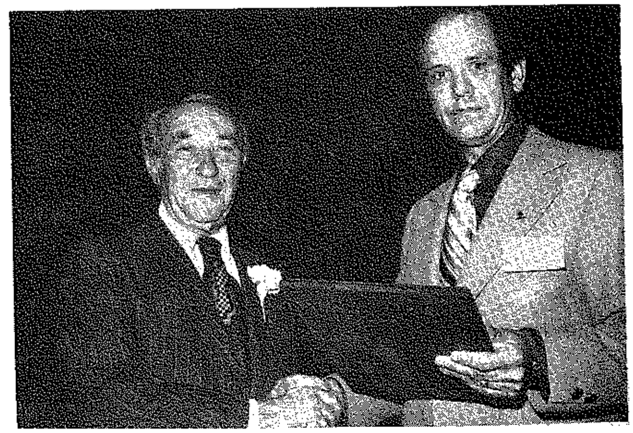
Adjourned 11:30 p.m.

Respectively submitted,

Paul DeJong
Secretary



Professor Irwin Wladaver (L) receives the Distinguished Service Award from Klaus Kroner.



Frank Oppenheimer (L) accepts the Oppenheimer Award from Chairman Claude Westfall.

Distinguished Service Award

Irwin Wladaver was officially presented his award, the Distinguished Service Award, at the annual banquet of the midyear meeting at Williamsburg, Virginia. Professor Wladaver was named recipient of this award last spring, but he was unable to attend the annual meeting to receive the award in June due to poor health.

Professor Klaus Kroner of the University of Massachusetts made the presentation of plaque signifying this award to Professor Wladaver.

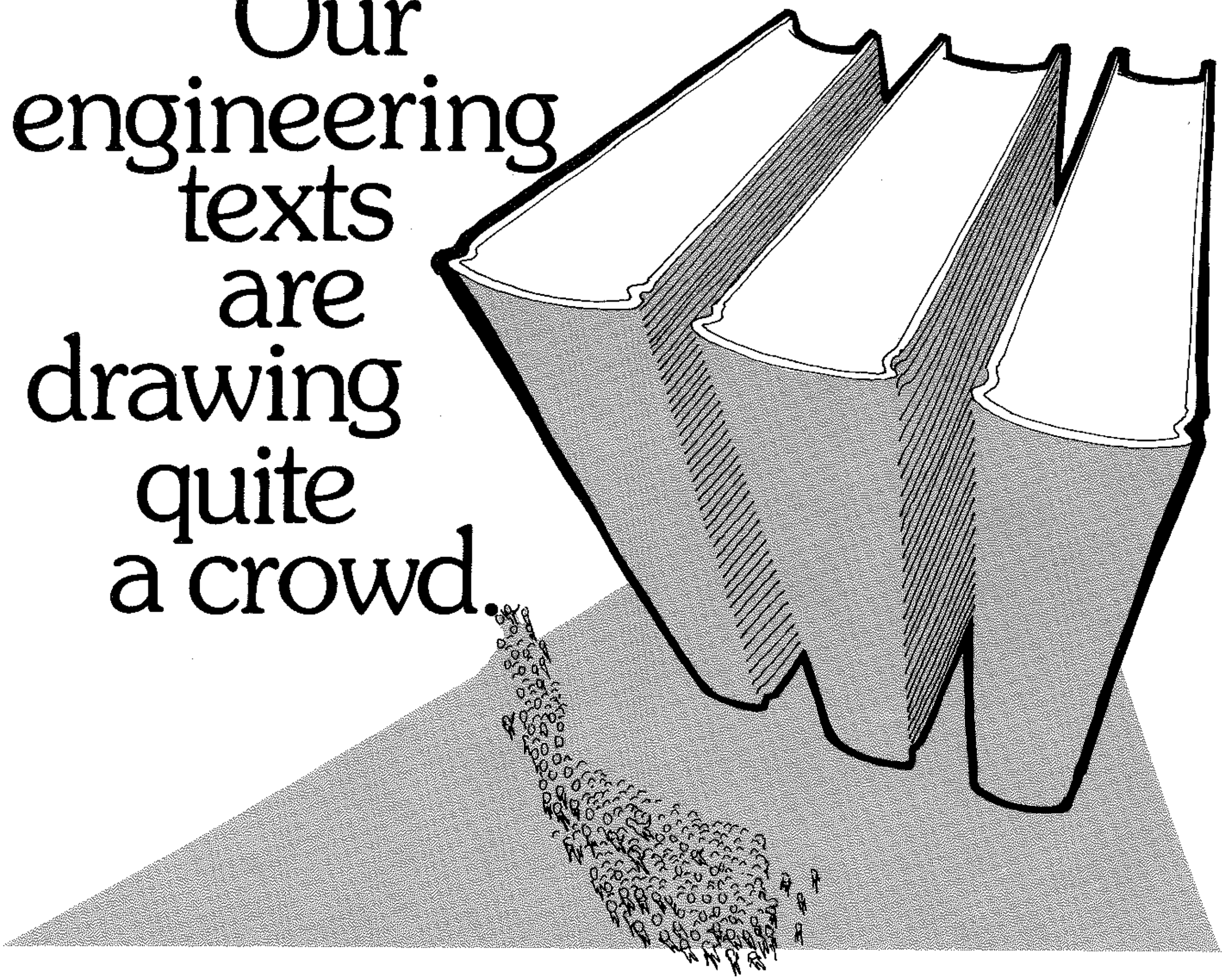
Oppenheimer Award

Frank Oppenheimer, the donor of the Frank Oppenheimer Award was the recipient of the Oppenheimer Award at the Williamsburg Meeting. Mr. Oppenheimer was awarded this recognition for his expertly presented paper entitled "The History of Drawing Instruments."

This award is given at each Engineering Design Graphics Division meeting to the presenter of the best paper. In addition to a certificate of recognition, a cash award of $100 donated by Mr. Oppenheimer is awarded.

Upon receipt of this award, Mr. Oppenheimer domated the cash award to the Creative Design Display committee to use in preparation of their display at the annual meeting to be held in Colorado in June.

Our engineering texts are drawing quite a crowd.



Descriptive Geometry

Grant: PRACTICAL DESCRIPTIVE GEOMETRY, Second Edition, $7.95

Hood/Palmerlee/Baer: GEOMETRY OF ENGINEERING DRAWING, Fifth Edition, $12.50

Wellman: ALTERNATE PROBLEM LAYOUTS FOR TECHNICAL DESCRIPTIVE GEOMETRY, Second Edition, $7.50

Wellman: PROBLEM LAYOUTS FOR TECHNICAL DESCRIPTIVE GEOMETRY, Second Edition, $6.95

Engineering Drawing

Grant: ENGINEERING DRAWING WITH CREATIVE DESIGN, Second Edition, $10.95

Grant: ENGINEERING DRAWING PROBLEMS, SERIES ONE, Second Edition, $8.95

Vierck/Hang: ENGINEERING DRAWING PROBLEMS, Third Edition, $7.95

Vierck/Hang: FUNDAMENTAL ENGINEERING DRAWING PROBLEMS, Third Edition, $7.95

Zozzora: ENGINEERING DRAWING, Second Edition, $12.75

Zozzora: ENGINEERING DRAWING PROBLEMS, Second Edition, $8.50

Engineering Graphics

Levens/Edstrom: PROBLEMS IN ENGINEERING GRAPHICS, SERIES VI, $8.50

Schneerer: PROGRAMMED GRAPHICS, $13.50

Vierck/Hang: PROBLEMS IN GRAPHIC SCIENCE, Third Edition, $8.50

Prices are subject to change without notice.

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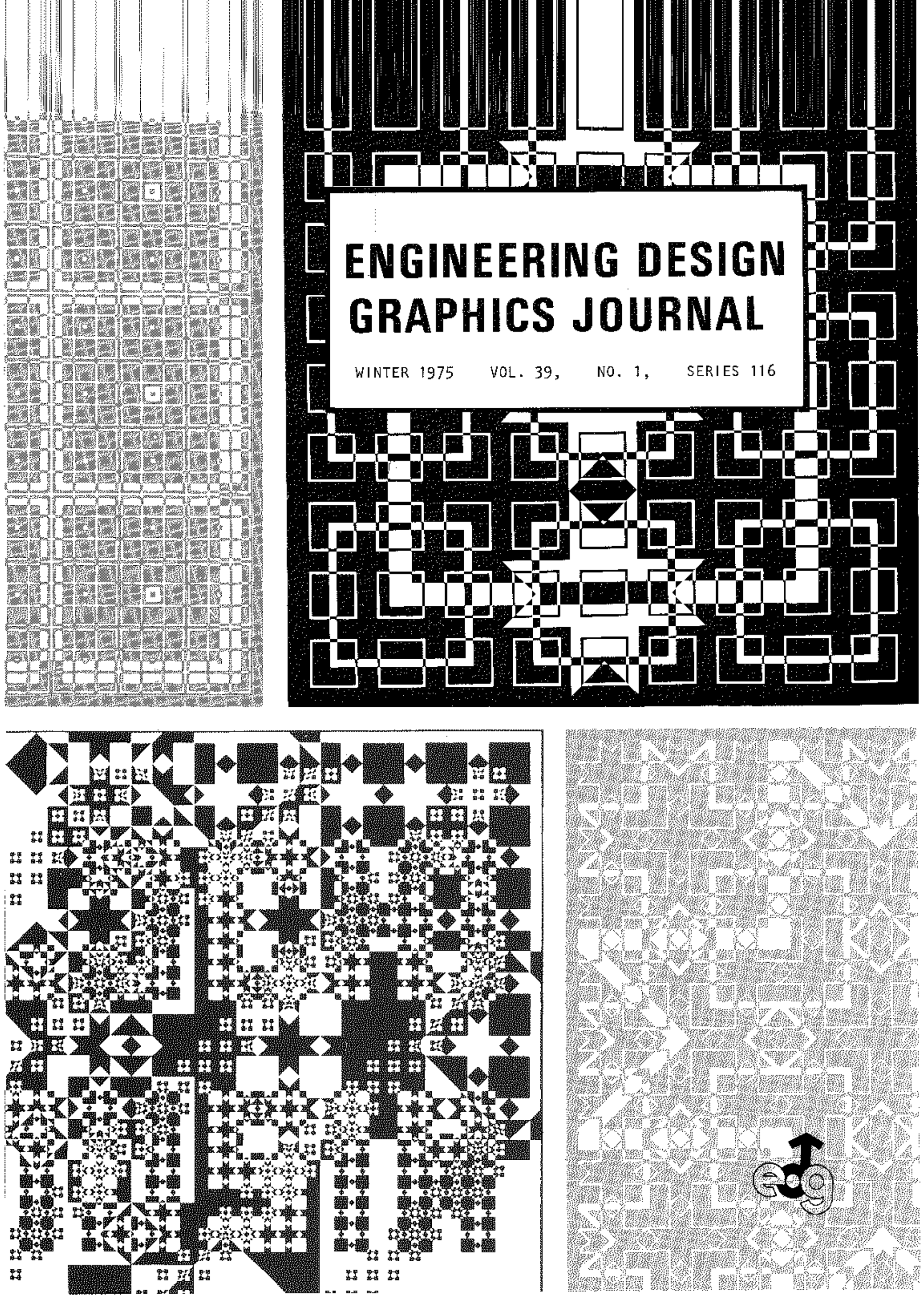

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