



JACG NEWSLETTER

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From the Editor's Desk...

In This Issue

Putting together the JACG newsletter is no small task. It requires the collection of materials from contributors including articles, photos, cartoons and advertising. The material has to be read and sometimes revised. In the interest of uniformity almost everything is reprinted to conform to a standard format. Most material then has to be reduced to about 75% of its original size to optimize paper space without sacrificing readability. Photos and cartoons have to be hauled to the photostat camera and be shot as needed. In addition, there is an editorial to write, trading post and table of contents to produce, and an occasional article to be written just for fun or necessity.

Once all of this is assembled everything has to be laid out in a dummy of the finished product to produce, hopefully, a balanced result. Then comes the physical cut and paste operation of clipping material and gluing it neatly to the layout sheets in the correct order. Last minute emergencies or space requirements sometimes complicate this step.

The point of this report is not to complain or ask for a raise but to let you know that it takes an average of 15 to 20 hours a month to get it all together. I am pleased to tell you that I now have help with this task. Matt Hetman has come forward and volunteered his time to do the mechanicals. This will relieve me of considerable work and may allow me to continue as editor. We all thank Matt in advance for his commitment.

Now, your part. For the next issue we need your copy by JULY 16th. Matt will be putting the whole thing together by himself since I will be away. Be considerate and get material to us on schedule. We'll appreciate it and you'll get a better newsletter.

Frank Pazel
Editor-in-Chief, JACG Newsletter

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August Article Deadline

July 16th!

Please Submit Your Contribution Early

MARK YOUR CALENDARS!!

JACG Meeting Schedule

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- August 10, 1985
- September 14, 1985
- October 12, 1985
- November 9, 1985
- December 14, 1985

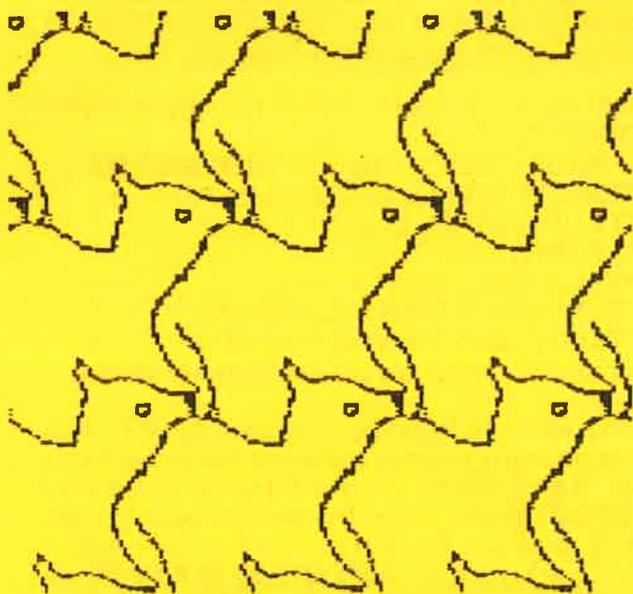
ESCHER SKETCH

by Kirk McDonald - JACG

Did you know that there are 17 different kinds of wallpaper? That is, the mathematicians tell us that there are 17 ways an image can be repeated regularly to fill up a blank wall. This peculiar fact has been utilized by artists to produce intriguing decoration, and at best, compelling works of graphic art. The most famous examples are the drawings of M.C. Escher. (See "The World of M.C. Escher" published by Abrams, Inc. (1971) for an extensive collection of his work.)

You can try your hand at designing all 17 kinds of wallpaper with the program ESCHER SKETCH which runs on a 48K Atari computer. Use a joystick or Koala Pad to sketch an image and the computer will replicate it 6 or 8 times on your TV screen. Then you can save it to disk in Micropainter format, and/or dump it to an Epson FX-80 printer. The disk file can then be read in by Micropainter or MicroIllustrator if you want to add color.

The program is available on a JACG library diskette in either binary form, ESCHER.COM, or as an Action! text file ESCHER.ACT. An instruction manual is included on the file ESCHER.DOC. The program is based on an article by Edward H. Carlson which appeared in the May 1985 issue of Creative Computing magazine. (Another program based on the imagery of Escher appeared in the August 1983 issue of Antic magazine.)



Symmetry 1 - Prairie Dogs

The figures show my attempts to draw interlocking animal images in the 17 possible ways. Symmetry H yielded only rather crystalline patterns--perhaps you will be more successful. I used symmetries 8 and G to illustrate another amusing aspect of the program: patterns which could be implemented with floor tiles. The fascinating subject of "tessalation" has been explored by Martin Gardner in the July

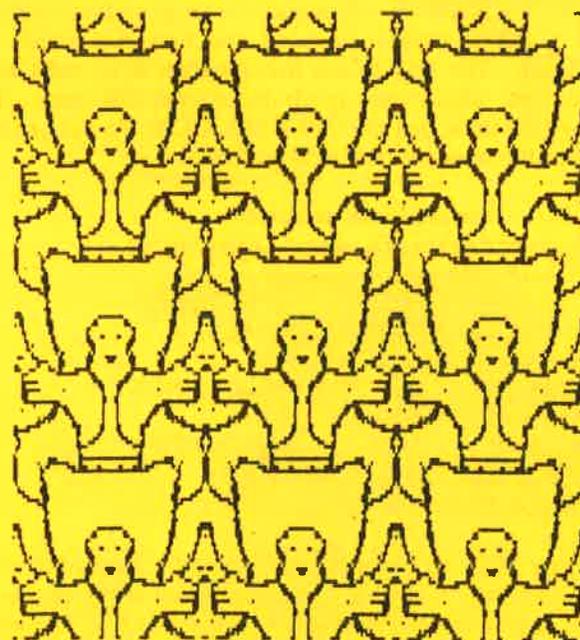
and August 1975 issues of Scientific American.

If you develop a more technical interest in why there are 17 kinds of wallpaper you might peruse the book "Symmetry in Art and Science" by Shubnikov and Koptsik (Plenum Press, 1974).

In any case, the program is quite easy to use, and certainly does not require deep understanding of the geometry it is based on. No great art has ever been created by a mathematician!



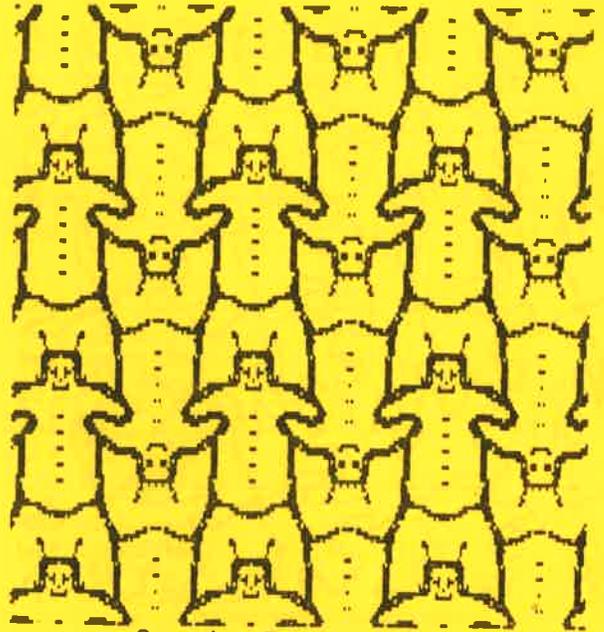
Symmetry 2 - Dinos



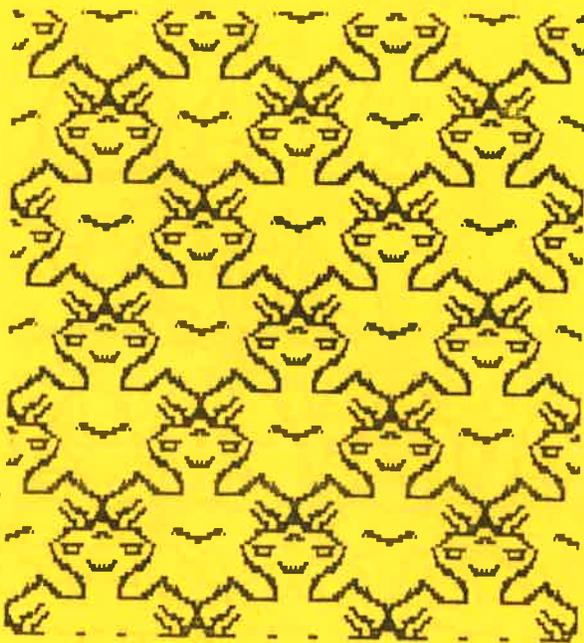
Symmetry 3 - Mutt and Jeff



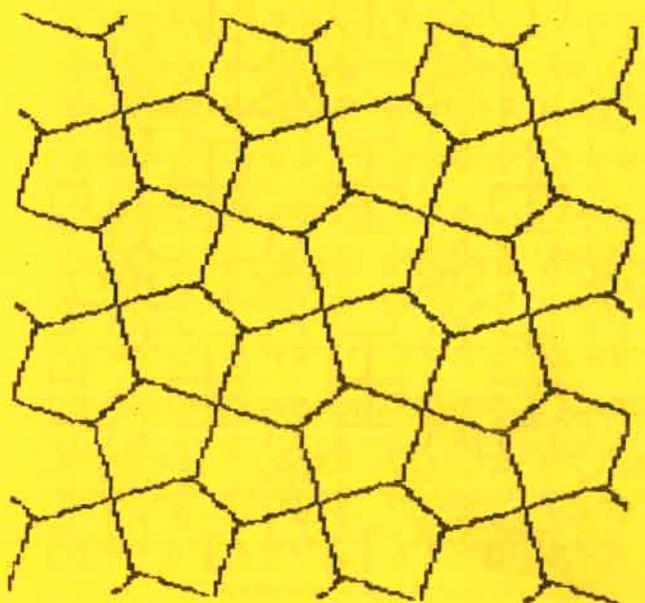
Symmetry 4 - Ducklings



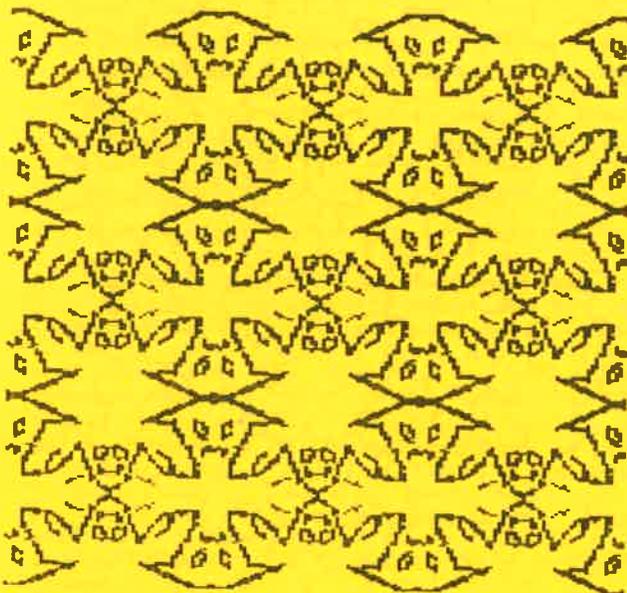
Symmetry 7 - Bee People



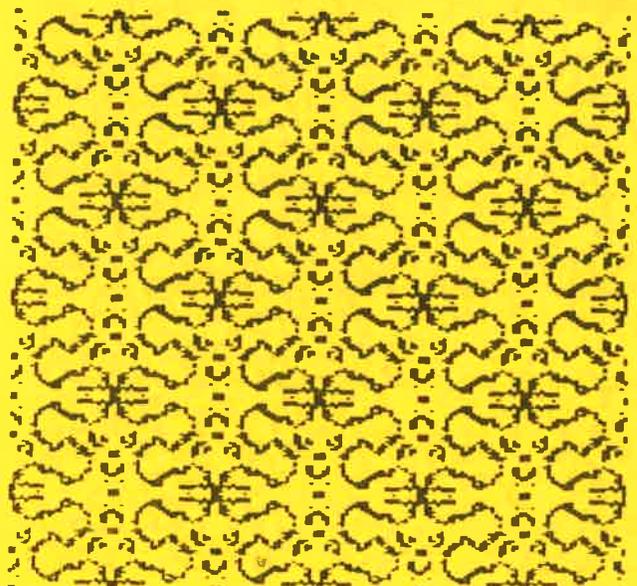
Symmetry 5 - E.T.



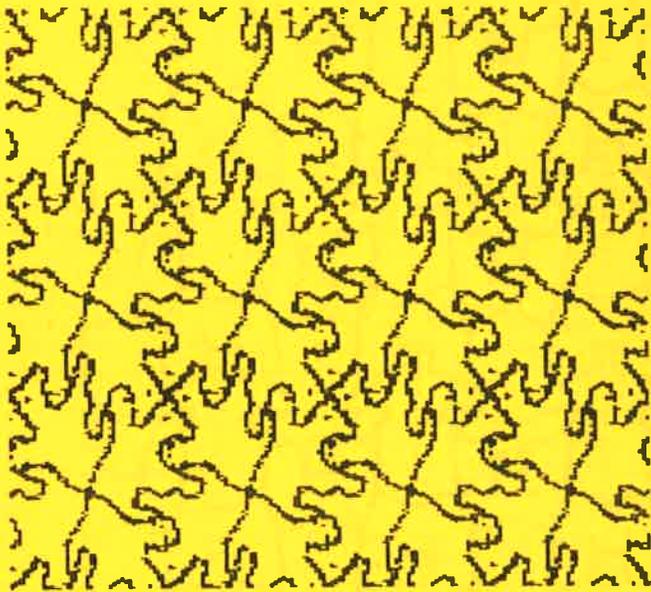
Symmetry 8 - Cairo Tiles



Symmetry 6 - Double Headers



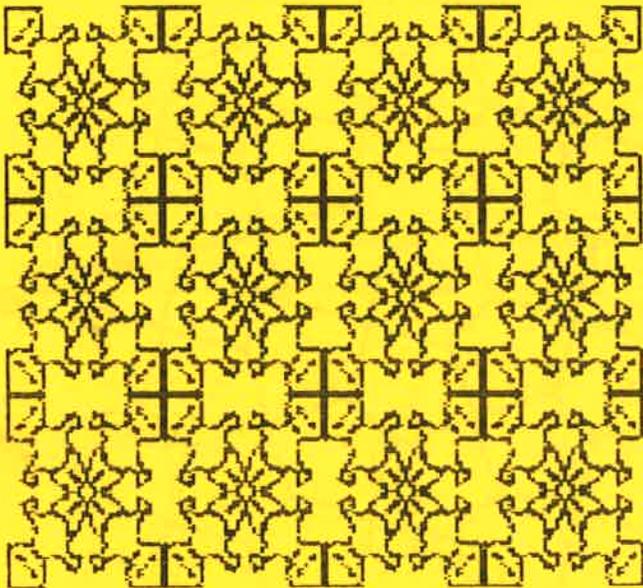
Symmetry 9 - Wombats



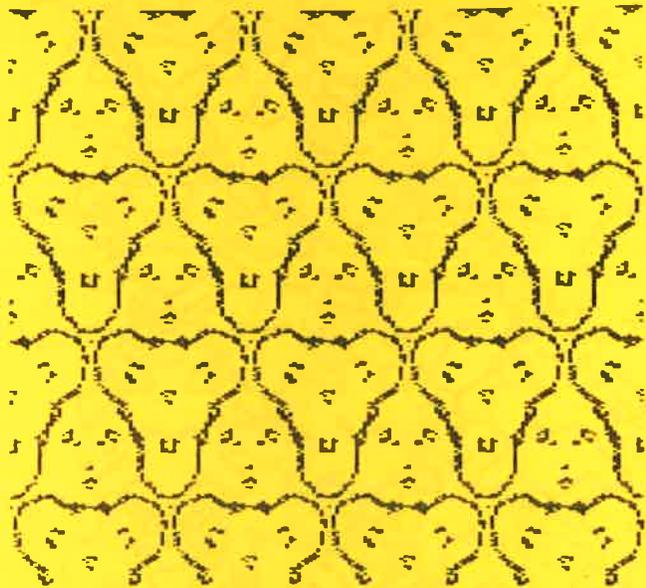
Symmetry A - Horsemen



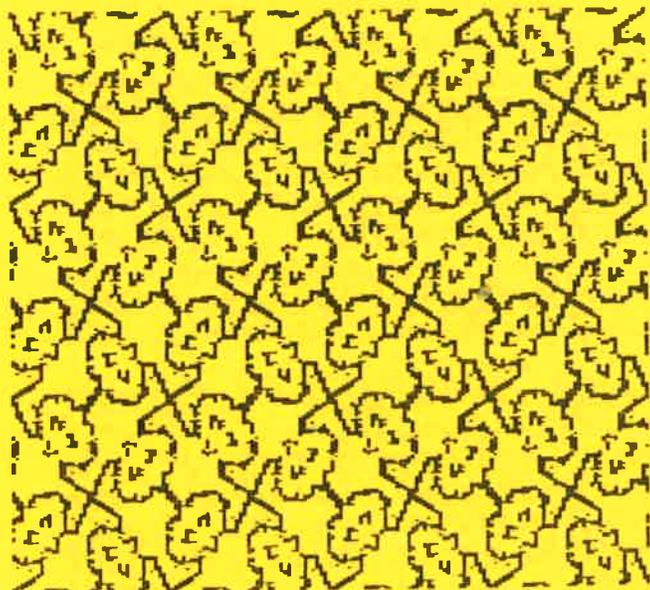
Symmetry D - Ghosts



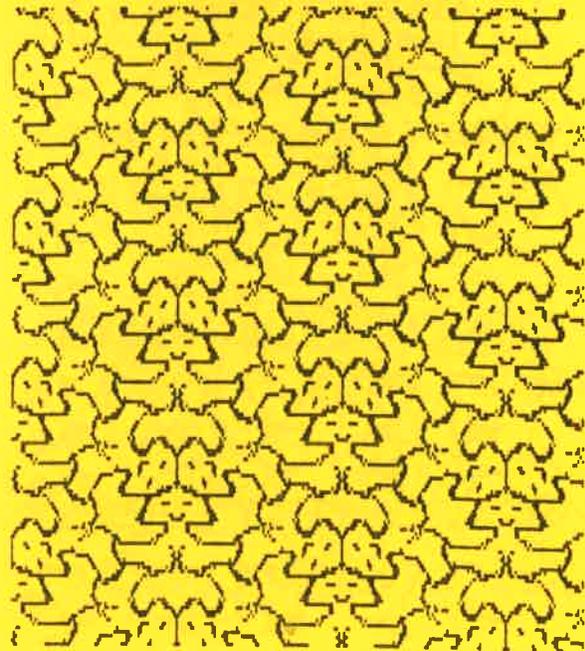
Symmetry B - Coneheads



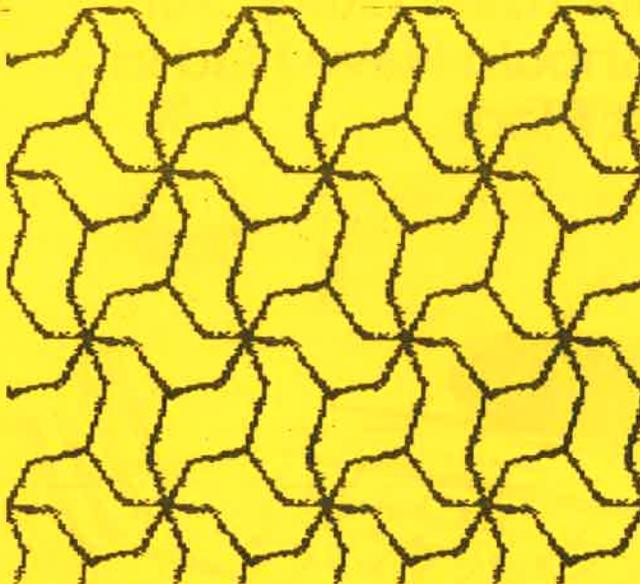
Symmetry E - Two Faces



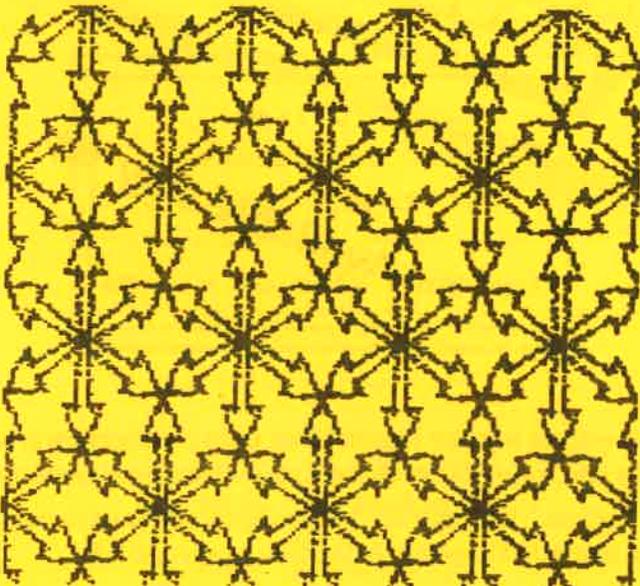
Symmetry C - Owls



Symmetry F - China Dolls



Symmetry G - Alhambra Tiles



Symmetry H - Snowflakes

FASCINATING 153 by Kenneth J. Pietrucha - JACG

One of the interesting things about playing with numbers is the things that are discovered along the way. None of the things I am about to tell you happened "One day as I sat down at my computer", or over any special time period, they just happened.

Take for example, the first time I discovered Narcistic or Armstrong numbers. Briefly, these are numbers where the sum of the cubes of the individual digits is equal to the original number. As an example, take the number 153, the first of the Armstrong numbers, and the star of the show. If we take 1 cubed plus 5 cubed plus 3 cubed, we get $1 + 125 + 27 = 153$, which is our original number. This in itself is not very earth shattering. As a matter of fact, like prime numbers, Armstrong numbers are often used as programming exercises. Since 153 is the first of these numbers, it is easily remembered.

A variation of Narcistic numbers is that if you add the cubes of the digits of any number that is a multiple of three, and keep repeating the process on the answer, you will eventually reach the number 153.

Here is the program I wrote to test this conjecture. If you have a printer, remove the REM statements from the beginning of line 5 and line 160.

```

1 REM MULTIPLES OF THREE EVENTUALLY
2 REM REACH 153 WHEN SUM OF CUBES
3 REM ARE CHAINED.
4 REM KENNETH J. PIETRUCHA--5/28/85
5 REM POKE 838,166:POKE 839,238:REM SEND
  RUN TO PRINTER
9 DIM A$(5)
10 FOR T=100 TO 1000
20 IF T/3(<)INT(T/3) THEN GOTO 150
25 LET X=T
30 A$=STR$(X)
40 LA=LEN(A$)
50 FOR N=1 TO LA
60 B=VAL(A$(N,N))
70 C=B*B*B
80 SUM=SUM+C
90 NEXT N
100 PRINT SUM;" ";Z=Z+1
110 IF SUM=153 THEN GOSUB 200:GOTO 150
120 X=SUM
130 SUM=0:C=0:B=0
140 GOTO 30
150 NEXT T
160 REM POKE 838,163:POKE 839,246:REM SEND
  RUN BACK TO SCREEN
200 PRINT
201 PRINT T;" = 153 IN ";Z;" ITERATIONS"
202 Z=0:SUM=0:C=0:B=0
205 PRINT :PRINT
210 RETURN

```

Some where along the way, it was pointed out that $5! + 4! + 3! + 2! + 1! = 153$. The symbol ! stands for factorial, which represents the product of all the numbers descending from the given number to 1 (ex. $5*4*3*2*1=120$). The sum of the factorials from 5! to 1! is equal to $120 + 24 + 6 + 1 = 153$. Interesting, isn't it ? Perhaps, but nothing to write home about.

Some one else came along and pointed out the number 153 is equal to the sum of all the numbers between 1 and 17 (a triangular number).

The number 153 is also mentioned in the bible. In John (21:11), Jesus and his disciples went fishing on the Sea of Tiberias. When they hauled in the catch, your guessed it, 153 fish !

Did John know of the peculiarities of the number 153 when he wrote the gospels ? Most of the time the bible uses round numbers like 100 or 1000, so if you see a number like 153, you can be sure it has some special significance. Remember, these people didn't have computers, so the solution must be simple.

What about the computer age ? How does the number 153 fit in ? Well, if we take the ASCII sum of the individual digits, we get $49 + 53 + 51$ which, believe it or not, equals 153.

If anyone knows any other facts concerning the number 153, I would appreciate your sharing them with me.

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Escher Sketch Pad

Edward H. Carlson

The computer is a splendid toy for the mind. Play is nature's classroom, teaching adult and child alike about the possible and the impossible in this amazing universe we skate through. I hope you will join me over the next months in playing with the computer and the ideas that it can model for us.

This month we sketch some intriguing doodles. In later columns I will model the population explosion of castaways on a desert isle, help you invent planets in alternate solar systems, analyze the concepts that underlie management games—*M.U.L.E.* and *Hammurabi*, for example—relating them to economics, and help you build many other computer toys. Please write to me at *Creative Computing* if you have ideas you would like to contribute.

Escher and the Arabs

Among the many fascinating drawings of Maurits Cornelis Escher are some that tile all space with interlocking figures—angels and devils, birds and fish, horsemen, lizards, and various grotesque monsters. The figures not only fill plane space, leaving no gaps and by repetition extend to infinity, but often are related to one another by certain rotation and reflection symmetries.

Islamic artists (forbidden to represent life forms in their art) created many such tilings with purely geometric forms of intricate design. Escher in his travels studied the Arabic decorations of the Alhambra palace in Granada, Spain (the palace in which Isabella and Ferdinand met with Columbus and approved his plan to sail west to the Indies).

Grab pencil and paper and try to sketch a simple Escher-like drawing—maybe a side view of a cat standing with all four feet showing and legs intertwining with those of another cat, upside down and facing the other way. You find yourself struggling to interlock the figures properly. Now load the program in Listing 1 and draw on the screen. Auto-

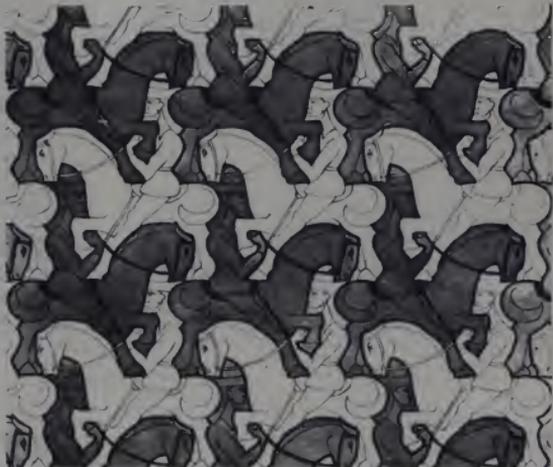


Figure 1. Escher's "horseman."

matically the figures related by symmetry to the one you are drawing appear on the screen so you can detect any gaps and overlaps immediately. Unless you are somewhat artistic and very patient, you may not produce a satisfactory Escher-like interlocking drawing at all.

OK then, dream you are the architect for a Moorish sultan's harem, and design intricate tile patterns of high symmetry. In either case, borrow or buy a book of Escher's work and analyze the drawings in light of what the computer program shows you about symmetry in the tiling task.

Staring at the Harem Floor

The theory of tiling (tessellation) needs only a few concepts.

An outline, called the *unit cell*, must fill the plane when you lay copies of it side by side—no gaps, no overlaps, and all cells oriented the same way. That is, you slide one cell (without letting it twist) by its own length to get a neighboring cell. Such a sliding is called a *translation*.

"But" you say, "how about the common bathroom tile of octagons and squares—two dissimilar shapes that together tile the plane?" All such composite outlines as well as irregular outlines like Escher's "horseman" (Figure 1) can be included by adding inner structure to the basic outlines: parallelogram, rectangle, square, and hexagon.

The cells rarely show up in the final drawing explicitly. To detect a cell you

most reconstruct it by marking repeated elements with a dot and then joining the dots by lines. For example, dot the tip of the front hoof of every white horse in the Horsemen drawing. The infinite set of dots you get is called the *lattice*. Now connect four adjacent dots and you will see the rectangular unit cell. The cell for a given drawing is unique in size and shape, but not in location. If you choose to dot the chin of each black warrior you would get the same set of rectangular cells, but displaced from the "hoof" cells.

Added to the lattice of cells are three kinds of symmetry elements: rotations, reflections, and glides. The requirement that no overlaps or gaps be present in the tiling of the plane can be satisfied in exactly 17 combinations of cell shape and symmetry elements. These are called the 17 plane space groups, and each is named with a special symbol (see lines 2316 through 2348 of Listing 1). In these symbols, p stands for primitive cell (having lattice points at the corners of the cells only) and c for centered, having also a lattice point in the center of each cell. The numbers stand for n-fold rotation axes, m for mirror planes, and g for glide planes.

N-fold axes of rotation are important in many of Escher's drawings. Only values of n = 2, 3, 4, 6 are allowed by mathematical consistency with the tiling idea. (N = 1 means no rotations at all.) By a "two-fold axis" we mean this: Taking an axis perpendicular to the paper, you rotate the drawing by one half turn. The whole plane of figures will rotate into coincidence with itself.

A two-fold axis does not impose any conditions on the cell shape, but a four-fold axis can be present only when the cell is a square, and then only at the corners or center of the square. Likewise, a three-fold or six-fold axis requires the cell be hexagonal in shape.

Look for reflection planes in Escher's drawings. Holding a pocket mirror perpendicular to the page and moving it around, you may find a spot where the reflection in the mirror exactly matches the part of the drawing you see if you remove the mirror. If so, draw a line along the base of the mirror and you have marked a reflection plane. Planes tiled with oblique cells (non-rectangular parallelograms) cannot have reflection planes.

You can also detect the presence of reflection planes by just eyeballing the drawing. A symmetric figure, such as the front view of a soldier standing at atten-

tion, has a reflection plane (line, really) as the midline from head to toe. Non-symmetric figures that occur in pairs related like the right and left hand of a glove have a reflection plane half way between them if the line joining equivalent points (tip of each thumb) is perpendicular to the reflection plane. (If not, you

have a glide plane.)

Glide planes are a combination of reflection and translation that have no counterpart in everyday life. The horseman drawing of Escher shows the presence of a glide plane in this way: Each horseman is a mirror image in form (related as right glove to left glove) of one facing the other way (of opposite color) but is not correctly placed to be a mirror image. In fact, each horseman is a mirror image "glided" by a half cell height from the mirror position.

Escher colored his tile prints so the viewer could distinguish each figure from its neighbors. Ignore the colors when saying that one figure reflects, rotates, translates, or glides into another.

More about cell shapes: Symmetry does not restrict the proportions of

Glide planes are a combination of reflection and translation that have no counterpart in everyday life.

Listing 1. Escher Sketch Pad.

```

1  @GOTO 2000; ***** ESCHER SKETCH PAD *****
2  REM file name:ESCHER          disk name:CC
100  REM ***** main loop *****
120  ON B @GSUB 410,420,430,440,450,460,470,480,490,500,510,520,530,540,550,560
,570
130  @GSUB 200                      REM user draws
140  @GOTO 120                      REM plot points
200  REM ***** get dot for screen *****
205  IX=X:Y=Y
210  CHS=INKEY; IF CHS="" THEN 210    REM get keyboard command
211  IF CHS="O" THEN WIDTH @OEND    REM restore screen and
212  IF CHS="I" THEN 249            REM toggle to other draw modes
220  IF CHS="L" THEN Y=Y-1:IF Y<-A2 THEN Y=Y+A    REM up, don't go off screen
221  IF CHS="H" THEN Y=Y+1:IF Y>=A2 THEN Y=Y-A    REM down
222  IF CHS="J" THEN X=X-1:IF X<-B2 THEN X=X+B    REM left
223  IF CHS="K" THEN X=X+1:IF X>=B2 THEN X=X-B    REM right
240  IF M<3 THEN RETURN           REM plot or erase all sym dots
241  PBET (X1=X+2, Y1=Y+2), @PBET (X=X+2, Y=Y+2):@GOTO 200 REM erase old, move new dot
249  LOCATE 2,2                   REM move cursor to upper left
250  M=M+1:IF M<3 THEN M=1        REM toggle to other draw modes
251  IF M=1 THEN E=3:PRINT "DRAW":RETURN    REM draw mode
252  IF M=2 THEN E=0:PRINT "ERASE":RETURN   REM erase mode
253  IF M=3 THEN PRINT "MOVE":@GOTO 200    REM move mode
350  REM ***** print dot in all cells *****
352  PBET (X1=X+2, Y1=Y+2),E
354  X2=X+@2  :IF X<0 THEN X2=X+@2    REM put original dot on screen
356  PBET (X2=X+2, Y1=Y+2),E         REM put left dot on screen
358  X3=X+@2+@C:IF X<0 THEN X3=X+3+@C
360  Y2=Y+@2  :IF Y<0 THEN Y2=Y+@2+@C:IF X3>=2*@C
362  PBET (X3=X+2, Y2=Y+2),E         REM put upper left dot on screen
364  X4=X+@C
366  Y2=Y+@2  :IF Y<0 THEN Y2=Y+@2+@C:IF X4=X+2*@C
368  PBET (X4=X+2, Y2=Y+2),E:RETURN    REM put upper center dot on screen
410  REM ***** no symmetry *****
411  X=X  : Y=Y  : @GSUB 350:RETURN     REM plot original points
420  REM ***** two-fold axis *****
421  X=X  : Y=Y  : @GSUB 350          REM plot original points
424  X=X-X  : Y=Y-Y  : @GSUB 350:RETURN REM 2-fold rotation
430  REM ***** reflection plane *****
431  X=X  : Y=Y  : @GSUB 350          REM plot original points
435  : Y=Y-Y  : @GSUB 350:RETURN     REM reflection
440  REM ***** glide plane *****
441  X=X  : Y=Y  : @GSUB 350          REM plot original points
442  X=X+A4:Y=Y-Y  : @GSUB 350:RETURN REM glide plane
448  REM ***** centered cell *****
451  X=X  : Y=Y  : @GSUB 430          REM reflection plane
450  REM ***** reflection and glide *****
452  X=X+A4:Y=Y-Y+@H4: @GSUB 430    REM restore X,Y and return
456  X=X  : Y=Y  : Y=Y-YT            REM reflection
460  REM ***** 2 reflection planes *****
461  : @GSUB 420                      REM glide plane implied
462  X=X-X  : Y=Y-Y  : @GSUB 350    REM first reflection
465  X=X-X  : Y=Y-Y  : @GSUB 350:RETURN REM second reflection
470  REM ***** reflection and glide *****
471  : @GSUB 420                      REM two fold axis implied
472  X=X-X  : Y=Y-Y+@H4: @GSUB 350  REM reflection
478  X=X-X  : Y=Y-Y+@H4: @GSUB 350:RETURN REM glide
481  : @GSUB 420                      REM two fold axis implied
482  X=X-X+A4:Y=Y-Y+@H4: @GSUB 350  REM first glide
    
```

rectangular or oblique cells, nor the angle in oblique cells. In fact, a rectangular or oblique cell could "accidentally" be square in shape. Each cell contains an integer number of complete figures. (A figure often extends outside the boundaries of the cell. If so, there must be an equivalent part extending into the cell from one corresponding figure in another cell.)

The Dancing Dots

The program is written in BASIC on an IBM PC. I have been careful to keep the program as free as possible from special features of the IBM, and hope you can adapt it easily to your computer. Apple and Commodore machines, and Atari and Radio Shack machines using Microsoft Basic, can accept this program with only a few lines changed. I have kept the program simple. It uses the medium resolution black and white screen, and the I, J, K, and L keys to move the cursor for drawing. You may want to use color, low or high resolution, arrow cursor keys, or other special features of your own machine.

Lines 400 to 599 of the program are its geometrical heart and can be moved unchanged to any computer. Each of the 17 space groups is generated by a few lines of code giving the x and y coordinates of all equivalent points in a given cell.

In lines 350 to 399, the dots are written on the screen for four complete cells. One cell has its upper left lattice point in the center of the drawing, and from this point you move the dot that draws the figure. For other computers, you may need to change the PSET command to a PLOT or use a LOCATE or similar manner of putting a dot or character on a specified part of the screen.

Lines 200 to 299 let the program user move the dots around on the screen, and erase dots. These lines can in principle be moved to any other computer, but some changes may have to be made, such as changing the INKEY\$ construction of the IBM to a GET or INPUT.

For low symmetry cases, the program is moderately fast. You can input about five points per second. But when you are drawing high symmetry diagrams in which the computer must compute the location of up to 48 points for each point you input, and place them on the screen, the pace slows to about one point per second.

Enjoy the program. May all your figures interlock, on the screen and as you skate through life. ■

```

480 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The **ATARI** Resource

AUGUST 1983

VOLUME 2, NUMBER 5

■ GRAPHICS

■ Atari Signs
Alan Alda

■ 3-D Fuji

■ Datasoft's
Pat Ketcham

■ Escher Sketcher

■ 'Maze Maniac'
Game



Escher

Isometric illusions anoiulli oittemoal

Sketcher

by BENJAMIN BARTELS

The artistic illusions of M.C. Escher are familiar to many. Birds change to fish, water runs uphill, and men climb stairs that seem to be descending. His techniques inspired me to design a program that creates similar isometric improbabilities.

My Escher Sketcher is an isometric sketch pad that uses the joystick to draw boxes and lines in isometric view. When the joystick is moved in the typical four directions, cubes will be drawn on a two-dimensional plane. When the fire button is pressed, the joystick stacks cubes above or below the main plane, giving an illusion of depth. A variety of colors for the blocks is possible, and a "line" mode is included to embellish your designs.

This program uses GTIA Graphics Mode 10. If you do not have a GTIA chip in your ATARI, you will need to install one in order to use this program.

At the start of the program you will be prompted for background color, cursor color, and two different color combinations. The combinations are for the two cube shapes which you can draw; box 1 and box 2. Colors correspond to Table 9.3 on page 50 of your ATARI BASIC Reference Manual. If you press [RETURN] at these prompts, the program will use a set of default colors.

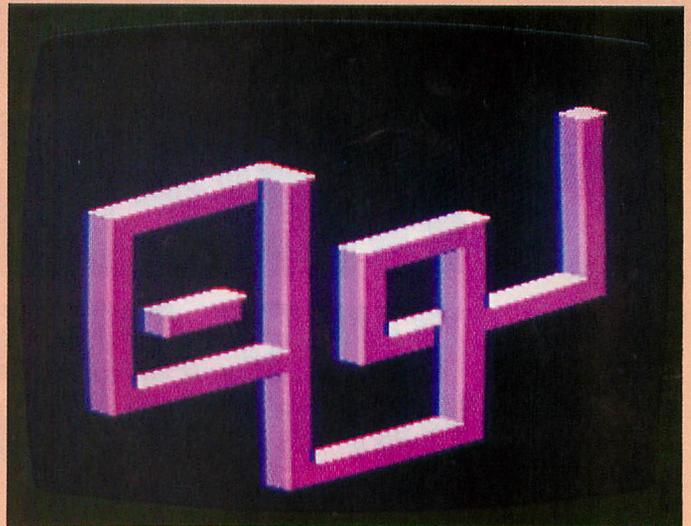
When you have selected all your colors, press [START] to begin drawing. At this point, you will see a flashing cursor which you can move about the screen without drawing. To draw a line with this cursor, push [SELECT]. To move the cursor without drawing, push [SELECT] again.

The [START] button toggles between drawing boxes and moving the cursor. You can use [SELECT] in Box Draw Mode to change the selection of the next box to be drawn between box 1 and box 2.

In either mode, you can use the [OPTION] key to erase the screen and start over.

PROGRAM BREAKDOWN

- 10-95 Opening program housekeeping.
- 100-190 User message and screen preparation.
- 200-290 Position cursor.
- 300-390 Main program loop.



- 400-430 Change box colors — note toggle feature.
- 900-990 Prepare to draw box by setting X and Y coordinates.
- 1000-1990 Draw top of box.
- 1199-1150 Subroutines to draw figure.
- 2000-2990 Draw left side.
- 3000-3990 Draw right side.

```
10 REM *** PRE-SELECT ***
15 DIM CLLR(2,3),D(4)
20 GRAPHICS 0:SETCOLOR 2,0,0:? "ISO-SK
ETCH by BENJAMIN BARTELS"
30 ? : ? " COLOR (0-15), LUM (0-14)" : ? : ? "
INPUT BACKGROUND COLOR AND LUM."
32 TRAP 35:BAK=0:INPUT I,J:BAK=I*16+J
35 ? "INPUT CURSOR COLOR AND LUM.":TRA
P 40:CSSR=15:INPUT I,J:CSSR=I*16+J
40 ? : ? "BOX #1":? "INPUT TOP COLOR AN
D LUM.":TRAP 50:CLLR(1,1)=6:INPUT I,J:
CLLR(1,1)=I*16+J
50 ? "INPUT RIGHT COLOR AND LUM.":TRAP
60:CLLR(1,2)=4:INPUT I,J:CLLR(1,2)=I*
16+J
```

continued on page 98

ESCHER SKETCHER *continued from page 55*

```
60 ? "INPUT LEFT COLOR AND LUM.":TRAP
70:CLLR(1,3)=2:INPUT I,J:CLLR(1,3)=I*1
6+J
70 ? :? "BOX #2"
80 ? "INPUT TOP COLOR AND LUM.":TRAP 9
0:CLLR(2,1)=236:INPUT I,J:CLLR(2,1)=I*
16+J
90 ? "INPUT RIGHT COLOR AND LUM.":TRAP
95:CLLR(2,2)=134:INPUT I,J:CLLR(2,2)=
I*16+J
95 ? "INPUT LEFT COLOR AND LUM.":TRAP
100:CLLR(2,3)=66:INPUT I,J:CLLR(2,3)=I
*16+J
100 REM *** START POSITION ***
110 ? "START=TOGGLES BETWEEN POSITION
ING":? "CURSOR AND DRAWING BOXES"
120 ? "SELECT=TOGGLES BETWEEN BOX #1 A
ND":? "BOX #2"
130 ? "OPTION=CLEARS SCREEN"
140 ? :? "PRESS START TO BEGIN"
142 IF PEEK(53279)=7 THEN 142
160 X=40:Y=96:GRAPHICS 10:CBX=0
170 POKE 705,CLLR(1,1):POKE 706,CLLR(1
,2):POKE 707,CLLR(1,3)
172 POKE 708,CLLR(2,1):POKE 709,CLLR(2
,2):POKE 710,CLLR(2,3)
174 POKE 704,BAK:POKE 711,CSSR
200 REM *** POSITION CURSOR ***
205 IF PEEK(53279)<>7 THEN 205
207 D(4)=0:D(3)=0:D(2)=0:D(1)=5:L=0
210 LOCATE X,Y,I
220 COLOR 0:PLOT X,Y:GOSUB 240
225 IF PEEK(53279)=5 THEN GOSUB 280
227 IF PEEK(53279)=3 THEN 160
230 COLOR 7:PLOT X,Y:GOSUB 250:GOTO 22
0
240 IF PEEK(53279)=6 THEN POP :COLOR I
:PLOT X,Y:POKE 764,255:GOTO 1000
245 RETURN
250 ST=STICK(0):IF ST=15 OR ST=10 OR S
T=9 OR ST=5 OR ST=6 THEN RETURN
260 J=STRIG(0):IF L=0 THEN COLOR I:PLO
T X,Y
262 IF (ST=13 AND J=1) OR ST=7 THEN X=
X+1
263 IF (ST=14 AND J=1) OR ST=11 THEN X
=X-1
264 IF ST=14 OR ST=7 THEN Y=Y-1
265 IF ST=13 OR ST=11 THEN Y=Y+1
267 X=X+(X=-1)-(X=80):Y=Y+(Y=-1)-(Y=19
2):POKE 77,0
270 LOCATE X,Y,I:RETURN
280 L=1-L
285 IF PEEK(53279)<>7 THEN 285
290 RETURN
300 REM *** MAIN LOOP ***
310 ST=STICK(0):IF ST=14 OR ST=7 OR ST
=13 OR ST=11 THEN 900
320 IF PEEK(53279)=3 THEN 160
330 IF PEEK(53279)=5 THEN 400
335 IF PEEK(53279)=6 THEN 200
340 GOTO 300
400 REM *** CHANGE BOX COLORS ***
410 CBX=1-CBX
420 IF PEEK(53279)<>7 THEN 420
430 GOTO 300
900 REM *** DRAW BOX ***
910 D(4)=D(3):D(3)=D(2):D(2)=D(1)
920 D(1)=1*(ST=14)+2*(ST=7)+3*(ST=13)+
4*(ST=11)
922 IF ST=14 AND STRIG(0)=0 THEN D(1)=
5
925 IF ST=13 AND STRIG(0)=0 THEN D(1)=
6
930 X=X+3*(D(1)=3 OR D(1)=2)-3*(D(1)=1
OR D(1)=4):Y=Y+3*(D(1)=3 OR D(1)=4)-3
*(D(1)<3)+10*(D(1)=6)-10*(D(1)=5)
940 IF X<3 THEN X=3
945 IF X>75 THEN X=75
950 IF Y<4 THEN Y=4
955 IF Y>180 THEN Y=180
960 POKE 77,0
1000 REM *** BOX TOP ***
1010 COLOR 1+CBX*3
1020 IF D(1)=6 THEN 2000
1040 IF D(1)=1 AND D(2)=6 THEN GOSUB 1
100:GOTO 2000
1050 IF D(1)=2 AND D(2)=6 THEN GOSUB 1
500:GOTO 2000
1060 GOSUB 1100:GOSUB 1500:GOTO 2000
1100 REM *** LEFT HALF ***
1110 TRAP 1120:PLOT X,Y:DRAWTO X,Y-4
1120 TRAP 1125:PLOT X-1,Y-1:DRAWTO X-1
,Y-3
1125 TRAP 1130:PLOT X-2,Y-2
1130 RETURN
1500 REM *** RIGHT HALF ***
1520 TRAP 1535:PLOT X+1,Y:DRAWTO X+1,Y
-4
1535 TRAP 1540:PLOT X+2,Y-1:DRAWTO X+2
,Y-3
1540 TRAP 1550:PLOT X+3,Y-2
1550 RETURN
2000 REM *** DRAW LEFT SIDE ***
2010 COLOR 2+CBX*3
2020 IF D(1)=2 THEN 3000
2025 IF D(1)=6 AND D(2)=2 THEN GOSUB 2
500:GOSUB 2700:GOTO 3000
2030 IF D(1)>2 THEN GOSUB 2300:GOSUB 2
500:GOSUB 2700:GOTO 3000
2040 IF D(2)=2 THEN GOSUB 2300:GOTO 30
00
2050 IF D(2)=1 AND D(3)=2 AND D(4)=2 T
HEN GOSUB 2300:GOSUB 2500:GOTO 3000
2060 GOSUB 2300:GOSUB 2500:GOSUB 2700:
GOTO 3000
2300 REM *** TOP WEDGE ***
2305 TRAP 2310:PLOT X,Y+1
2310 TRAP 2320:PLOT X-1,Y+1:PLOT X-1,Y
+2
2320 TRAP 2330:PLOT X-1,Y
2330 TRAP 2340:PLOT X-2,Y+1:DRAWTO X-2
,Y-1
2340 TRAP 2350:PLOT X-2,Y+2:DRAWTO X-2
,Y+3
2350 RETURN
2500 REM *** MID WEDGE ***
```

```

2510 TRAP 2520:PLOT X,Y+2:DRAWTO X,Y+7
2520 TRAP 2530:PLOT X-1,Y+3:DRAWTO X-1
,Y+8
2530 TRAP 2540:PLOT X-2,Y+4:DRAWTO X-2
,Y+8
2540 RETURN
2700 REM *** BOTTOM WEDGE ***
2710 TRAP 2720:PLOT X,Y+8:DRAWTO X,Y+1
0
2720 TRAP 2730:PLOT X-1,Y+9
2730 RETURN
3000 REM *** DRAW RIGHT SIDE ***
3010 COLOR 3+CBX*3
3020 IF D(1)=1 THEN 4000
3025 IF D(1)=6 AND D(2)=1 THEN GOSUB 3
500:GOSUB 3700:GOTO 4000
3030 IF D(1)>2 THEN GOSUB 3300:GOSUB 3
500:GOSUB 3700:GOTO 4000
3040 IF D(2)=1 THEN GOSUB 3300:GOTO 40
00
3050 IF D(2)=2 AND D(3)=1 AND D(4)=1 T
HEN GOSUB 3300:GOSUB 3500:GOTO 4000
3060 GOSUB 3300:GOSUB 3500:GOSUB 3700:
GOTO 4000
3300 REM *** TOP WEDGE ***
3305 TRAP 3310:PLOT X+1,Y+1
3310 TRAP 3320:PLOT X+2,Y+1:PLOT X+2,Y
+2
3320 TRAP 3330:PLOT X+2,Y
3330 TRAP 3340:PLOT X+3,Y+1:DRAWTO X+3
,Y-1
3340 TRAP 3350:PLOT X+3,Y+2:DRAWTO X+3

```

```

,Y+3
3350 RETURN
3500 REM *** MID WEDGE ***
3510 TRAP 3520:PLOT X+1,Y+2:DRAWTO X+1
,Y+7
3520 TRAP 3530:PLOT X+2,Y+3:DRAWTO X+2
,Y+8
3530 TRAP 3540:PLOT X+3,Y+4:DRAWTO X+3
,Y+8
3540 RETURN
3700 REM *** BOTTOM WEDGE ***
3710 TRAP 3720:PLOT X+1,Y+8:DRAWTO X+1
,Y+10
3720 TRAP 3730:PLOT X+2,Y+9
3730 RETURN
4000 GOTO 300

```

TYPO TABLE

Variable checksum = 173371

Line num range	Code	Length
10 - 50	FQ	565
60 - 110	JB	560
120 - 207	ZZ	559
210 - 264	ML	470
265 - 340	RA	391
400 - 930	VE	642
940 - 1100	SV	387
1110 - 2020	HJ	385
2025 - 2330	GY	507
2340 - 3000	JI	384
3010 - 3320	MG	513
3330 - 3730	SJ	444
4000 - 4000	MD	13



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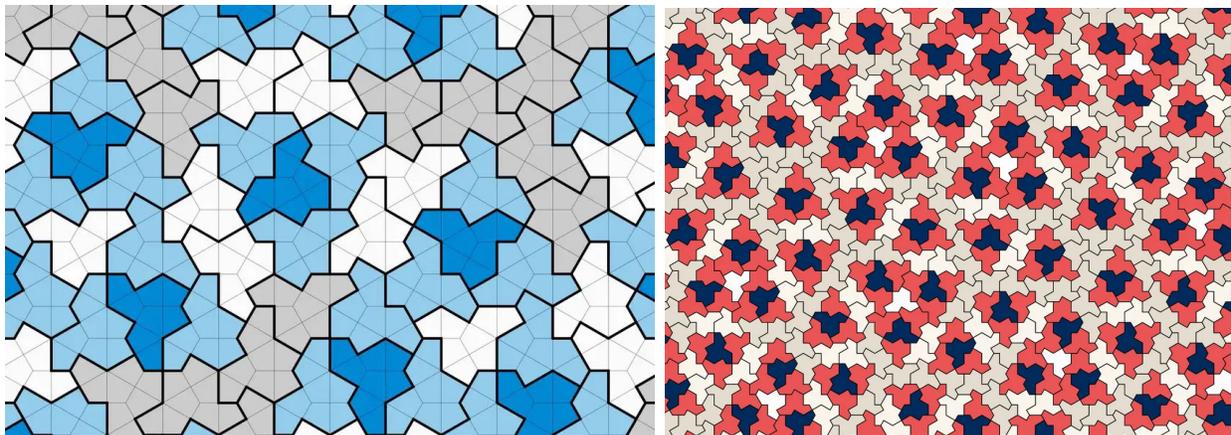
Nonperiodic Tiling

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(January 27, 2024)

The article “Escher Sketch” [1] considered only periodic tilings of a plane with a single type of tile.¹ Already in 1976, Penrose had demonstrated nonperiodic tilings, based on 2 different tiles [2, 3, 4]. Recently, nonperiodic tilings with only a single (14-sided) tile have been demonstrated [5, 6].



References

- [1] K. McDonald, *Escher Sketch*, JACG Newsletter 4(11), 18 (1985), <http://kirkmcd.princeton.edu/examples/escher.pdf>
- [2] R. Penrose, *Set of Tiles for Covering a Surface*, US Patent 4,133,152 (filed Jan. 24, 1976), http://kirkmcd.princeton.edu/examples/patents/penrose_us4133152_76_tiles.pdf
- [3] R. Penrose, *Pentaplexity*, Eureka No. 39, 16 (1978), http://kirkmcd.princeton.edu/examples/mechanics/penrose_eureka_39-apr_16_78.pdf
- [4] R. Penrose, *Pentaplexity*, Math. Intell. 2 32 (1979), http://kirkmcd.princeton.edu/examples/mechanics/penrose_mi_2_32_79.pdf
- [5] D. Smith *et al.*, *An aperiodic monotile* (May 2023), <https://arxiv.org/abs/2303.10798>
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¹Of course, each tile can be partitioned into many subtiles. Several of the illustrations of the 17 basic types of periodic tilings in [1] were shown with 2 subtiles.