



AC's TECH / AMIGA

For The Commodore

Volume 3 Number 3
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- Programming the Amiga in Assembly Language: Making Waves
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REXX *Rainbow Library* S E R I E S

The REXX RAINBOW LIBRARY SERIES is a complete product line of support libraries designed specifically for use with ARExx. Each volume in the Series contains functions dedicated to a specific subject. The first volume in the series is the Stem/Array functions. It provides over 100 functions to manipulate single dimension arrays, which simplify ARExx arrays, Compound Symbols, Pointers and Subscripts. The functions include string manipulation, mathematical and scientific calculations and file access. Also included is the AssgnArrayO function which assigns/retrieves arrays from/to other ARExx programs. With this function you can build your own single or multiple dimension array functions. Tutorials and examples are used throughout the manual. The REXX RAINBOW LIBRARY SERIES requires ARExx and works with or without REXX PLUS.

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```
printf("Hello");
```

```
print "Hello"
```

```
JSR printMsg
```

```
say "Hello"
```

```
writeln("Hello")
```

Whatever language you speak, AC's TECH provides a platform for both gaining insight and sharing information on its most innovative implementation for the Amiga. Why not see if your latest programming endeavor can help a fellow Amiga user expand upon his or her vocabulary? To be considered for publication in AC's TECH, submit your technically oriented article (both hard copy & disk) to:

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Correspondence

The following letter is from Paul Castonguay. It answers some questions raised by readers regarding AmigaBASIC subprograms.

AmigaBASIC SUBPROGRAMS

In all fairness to the folks at Microsoft, I would like to point out an inaccurate statement you (Paul Castonguay) keep making in your articles. In them you state that an AmigaBASIC SUBPROGRAM cannot invoke another SUBPROGRAM. I don't know where you got this idea, but it is not true. It does seem to be a widely held myth, however, I've seen this statement in print before. AmigaBASIC does have its shortcomings, of course, but to be fair about it, this isn't one of them.

Mr. Probst, Columbia, MD

You're right, I think. Yes, an AmigaBASIC SUBPROGRAM invoking another SUBPROGRAM does seem to work, and yes, it is a widely held myth. I did some research and uncovered the following on page 442 of "Advanced AmigaBASIC", by Tom R. Halfhill & Charles Brannon, COMPUTE! Publications, 1986, which may have led me astray:

"There are a few disadvantages of subprograms. ... They can't be nested, and one subprogram can't call another subprogram."

Since I was an early user of the Amiga, I suspect that I had the misfortune of reading that before I thought of trying it on my own. That's too bad. I have published many a program that would have been better written if only I had known that I could do this. Indeed, I even curtailed the publishing of articles about general purpose libraries of SUBPROGRAMS simply because I thought that they could not be invoked reliably from anywhere in a program.

I tested your correction and found it to work, as you have reported. The only operational restriction I could find was that no SUBPROGRAM could be invoked twice, either by itself recursively, or by another through some recursive connection of SUBPROGRAMS.

At the same time, I checked my AmigaBASIC manuals but nowhere is it explicitly stated that a SUBPROGRAM really can invoke another, although the implication is strong that it can. Is that enough to openly say that it can be done reliably? Has this been thoroughly tested? It's too bad that Microsoft does not continue to support the language, otherwise we could all find out for sure. It's possible that there are limitations to this. For example, many early versions of

BASIC allowed only a limited number of levels of SUBROUTINE or SUBPROGRAM calls, some as little as eight.

Since you have pointed this out I will no longer make the claim that an AmigaBASIC SUBPROGRAM cannot invoke another SUBPROGRAM. However, neither will I say that you can, at least not until I find out for sure how reliable it is to do so.

Thank you for the correction. Alas, it may be too late anyway, since AmigaBASIC is no longer bundled with the Amiga. It is unfortunate that over the years no Amiga users have chosen to write an article to clear up this popular misconception about AmigaBASIC.

—Paul Castonguay

The following is a correction to the listing in Bill Neill's Assembly Language & Computer Simulations article, AC TECH 3.2.

```

;LISTING
equates:
depth          = 4
jan2           = $1
mousebuttons  = $8
borderless    = $800
vw.screen     = $2e
vw.rport      = $32
tw.screen     = $1e
customscreen  = $f
activate      = $1000
rmb           = $10000
public        = $1
chip          = $0
fast         = $4
clear        = $10000

offsets:
jmac
openlibrary   = -552
closelibrary  = -414
allocmem     = -198
freemem      = -210
forbid       = -132
permit       = -138
intuition

;no registers used
;no registers used
```

```

openecrwn = -196
closecrwn = -84
openwindw = -204
closewindw = -72
viewportaddress = -200 ;a0=window
;graphics
setdrow = -254
loadrgb4 = -192 ;a0=vp.a1=colortable,d0=#pens
setapen = -242
writepixel = -224

```

```

sum equi d7
across equi d8
down equi d5
tb equi d4
aa equi d3
len = 32*1 ;try 32*5 (or AMIGA 3000)
lenm1 = len-1
mianm1 = -1*lenm1
lenm2 = len-2
soff = (220-len)/2 ;to center display
yoif = (200-len)/2 ;to center display
lenp1 = len+1
lenm3 = len-3
mian = -1*len
byte = (yoif*220+soff)/8 ;byte containing yoif/soff
wpl = len/32-1 ;long words in line
byteoff = 3*soff/8 ;offset to next line
size = len*len ;array size
;k1 equi 2 ;default
;k2 equi 3 ;default
;qu equi 5 ;default

```

macros:

```

syslib macro ;(routine)
move.l #,a0
;sr (l(a0))
endm

```

```

openlib macro ;(name,location,BEQ if 0)
lea v1,a1
moveq #0,d0
syslib openlibrary
move.l d0,v2
beq v3
endm

```

```

initlib macro ;(routine)
move.l initbase,a0
;sr (l(a0))
endm

```

```

openscreen macro ;(parameters,screen,BEQ=0)
lea v1,a0
initlib openscreen
move.l d0,v2
beq v3
endm

```

```

openwindow macro ;(parameters>window,BEQ=0)
lea v1,a0
move.l screen,sw.screen(a0)
initlib openwindow
move.l d0,v2
beq v3
endm

```

```

gfxlib macro ;(routine)
move.l gfxbase,a0
;sr (l(a0))
endm

```

```

test macro ;(top,left,right,bottom)
beq.a healthy,#
cpl.b #0,d0
bcs.b l1,# ;branch if lower
moveq #0,d0
bra testdone,#
healthy:#

```

```

moveq.b #1,aa ;always at least 1
moveq.b #0,bb ;start bb at 0
h1:#

```

```

move.b (l(a4),d1 ;row() 'above' value
beq.a h2,# ;branch if 0
cpl.b #50,d1 ;is it 50?
beq.a h1a,#
addq.b #1,aa ;if not, increase aa
bra.b h2,#

```

```

h1a:#
addq.b #1,bb ;increase bb
h2:#

```

```

move.b (2(a4),d1 ;'left' neighbor value
beq.a h3,#
cpl.b #50,d1
beq.a h3a,#
addq.b #1,aa
bra.s h3,#

```

```

h3a:#
addq.b #1,bb
h3:#

```

```

move.b (3(a4),d1 ;'right' neighbor value
beq.a h4,#
cpl.b #50,d1
beq.a h4a,#
addq.b #1,aa
bra.s h4,#

```

```

h4a:#
addq.b #1,bb
h4:#

```

```

move.b (4(a4),d1 ;'bottom' neighbor value
beq.a h5,#
cpl.b #50,d1
beq.a h5a,#
addq.b #1,aa
bra.s h5,#

```

```

h5a:#
addq.b #1,bb
h5:#

```

```

moveq #0,d1
move.b k1,d1
divs d1,aa ;aa=aa/k1
moveq #0,d1

```

```

move.b k2,d1
divs d1,bb ;bb=bb/k2
add.b bb,aa ;aa=aa+bb

```

```

move.b aa,d0 ;row generation value
bra.s testdone,#
l1:#

```

(continued to page 58)

REXX Rainbow Library

Volume of Stem/Array Functions

by Merrill Callaway

The REXX Rainbow Library Series marks a new and useful effort by the Dineen Edwards Group, who brought us the REXXPlus Compiler. This new series of ARexx-specific libraries is arguably more important than the REXXPlus Compiler in the scheme of things, but the REXXPlus Compiler adds an interesting connection to the Rainbow Libraries. As you may know, if you program an application that uses functions from a shared library, and attempt to export or distribute it to an Amiga that lacks that library, then it will not run. The other computer must have the library aboard. In the case of freely distributable libraries, such as Willy Langeveld's `rexarplib.library`, you simply send along a copy of the library. But Dineen Edwards is commercial, and you cannot distribute any of the Rainbow Libraries without a license. However, because of the compiler options in REXXPlus, you may "build in" the functions from a Rainbow library at compile time and the compiled product will be distributable without further license, and the library need not be present on the other system. Dineen Edwards has changed their policy and absorbed the former \$10 licensing fee for distribution of REXXPlus compiled programs into the price of the REXXPlus Compiler. A complete set of routines and libraries are included in the Rainbow Library Disk for REXXPlus (RP) support. I did not compile the examples given here because of a problem in my compiler that was not fixed in time. By the time you read this, there will be a newer version of REXXPlus. I found a glitch in a pre-release Stem/Array Function, and Mark Edwards of Dineen Edwards called in my fix data (a CLIZAP program comes on disk) within eight hours. That's service! The Stem/Array Functions worked very well.

Adding Stem/Array Library to ARexx Library List

The first of the Rainbow Library Series volumes contains 107 array functions, much like those in the standard ARexx function set, except that these functions act on one or two single-dimensional arrays, and usually output to a third "answer" array. To add the Stem/Array (SA) library to your ARexx library list, from a Shell prompt>

```
HELLO ADDARRAY.LIBRARY 2 -10 0
```

where the library name is case sensitive and the keywords are "priority," "offset," and "version" respectively. Inside an ARexx program the following code accomplishes the same thing:

```
CALL ADDLIB("ADDARRAY.LIBRARY",2,-10,0)
```

Syntax

The SA functions share a similar syntax. If there is a similar ARexx function, the SA name is a composite of the regular ARexx function name with "array" concatenated to it. For example the ARexx function LASTPOS() becomes LASTPOSarray(). SA functions that don't share a corresponding regular ARexx function have an intuitive name such as ADDarray() which ADDs two single-dimensional arrays

```
/* just feedback */
numA=5
start=1
numADDarray(ANS,numA,numB,5,1)
say %
/*
** say % returns 5 for the number of compound symbol tokens
assigned.
** These lines also have correct syntax:
** @ADDarray(ANS,numA,numB,count,start)
** @ADDarray(ANS,numA,numB,5,1)
** CALL ADDarray(ANS,numA,numB,...)
** @ADDarray(ANS,numA,numB)
** The above say six return the same values as they depend on what
was
** VALUE of numA,1 and numB,1 are, although they are 0 in syntax.
*/
```

Syntax Conventions

The answer array, if we were to put in a DO loop to write it to the console would have elements 1 through 5 added from the two arrays. If one of the elements is uninitialized, then it is set equal to 0 in a numeric array function or the null string "" in a string array function. This is normally OK, but you will get an error if you use the DIVIDEarray() function and try to divide by either 0 or a compound symbol token that is not initialized. Another convention is that if the COUNT is left off, then the COUNT=MAX(numA,0,numB,0) in the case of two input arrays present, or just the 0th element of numA, if

A complete set of routines and libraries are included in the Rainbow Library Disk for RexxPlus support.

together. The arguments, separated by commas, to the SA functions have a family resemblance, too. The "answer" array always comes first, the actual argument being the STEM, or name for the answer array. If you leave off the period (.) at the end of the STEM, SA will add one for you. In general all arrays are named by their stems, the name of the array with exactly one period at the end. For purposes of explanation, we will call the answer array's stem ANS, but of course you may name it anything. As soon as nodes index an array, the stem.nodeA.nodeB.nodeC, etc. becomes a compound symbol token in ARexx-speak. There are up to two INPUT arrays which here we will call numA, and numB, (even though they can be string arrays as well—of course they may be any stem name at all in your program). The general pattern of argument syntax is ANS,numA,numB, but there are some exceptions. In general, the last two arguments are the COUNT and the START numbers. COUNT and START are optional and there are conventions followed if we omit them, as we'll see later. Assume we have two arrays numA, and numB, and we want to add them element by element, starting at element 2 and adding 5 elements in a row and assign the results of the addition into an array called ANS, then the ADDarray() function in a program would look like this:

only one is present. If either numA,0 or numB,0 (if numB, is present as an argument) is uninitialized then COUNT=0 is assigned. If numA,0 or numB,0 is assigned to a non-numeric value, then a numeric conversion error results. If the start argument is omitted, then START=1 becomes the convention. I think there ought to be a convention to take care of division by zero in the case of an uninitialized compound symbol token in numB, as the manual states that making an uninitialized compound symbol 0 was to avoid numeric errors! Only if you actually go and put in a 0 into numB, should there be a numeric error.

A Syntax Exception

One major syntax exception is ASSIGNarray() which is the most powerful function of the lot. Plain ARexx does not allow you to pass intact arrays to an exterior ARexx program from a main program, nor does it allow you to get an array back to the calling program from the subprogram. The only way to pass an intact array in ARexx is to an INTERIOR function, called a PROCEDURE. Here, you may pass the STEM, and the COUNT as arguments, and the entire array will go over. With ASSIGNarray(), you may not only obtain intact arrays from the calling program inside an EXTERIOR function program, you can obtain whole arrays from the program that called the program that called the one you are in! ASSIGNarray() lets you specify how many levels if any you wish to go back to obtain its values! This argument is called NEST LEVEL (NL). Instead of calling it the input stem or array,

the SA manual calls it the VALUE stem. The output array is called the ASSIGN stem by SA. I prefer to think FROM the value array TO the assign array. In FROM and TO terms, the argument syntax is

```
ASSIGNArray(TO_NL, TO_Start, FROM_Start, FROM_NL, Count, Start)
DAT *
```

Any function may be CALLED to discard the return value. Here the function returns the number of compound symbols it assigned in the simple symbol, m. Count and Start may be omitted and the syntax will follow the above cited conventions. The Nest_Level (NL) follows this convention: 0 means THIS program; 1 means ONE program back (the one that called this one); 2 means the program which called the one which called this one; etc. Entire arrays may be assigned by ASSIGNArray() within the same program (both TO_NL=0 and FROM_NL=0), or more commonly, you will code two calls to ASSIGNArray(), one to GET the array from a calling program and another to PUT the processed array back to the calling program. The example program, SANodupes.rexx calls a sort routine, SASort.rexx which uses ASSIGNArray() to get the array LIST from the calling program, sort this array, and then put the sorted array back to SANodupes.rexx by using another ASSIGNArray() with the four TO and FROM arguments, reversed. The original STEM, COUNT, and START are passed to the external function, SASort.rexx in the normal way as arguments.

The second example shows SAtester.rexx, a program to try out the functions and study the way the arrays are processed. It uses an INTERPRET instruction as a basis for testing the functions which are built up via the powerful string handling ARExx exhibits. Ironically the INTERPRET instruction cannot be compiled with RexxPlus successfully, as it is too self referential for cost effective system requirements. SAtester.rexx will work very well with the resident process, rexxmast, however. You will need the Rainbow Stem/Array Library to run these.

I look forward to the other Rainbow Series Libraries, as they will undoubtedly enrich my ARExx capabilities. If you plan to distribute programs using the Rainbow Series, I'd suggest buying the RexxPlus Compiler, as that is the most economical way to export these functions without further licensing.

SAnodupes.rexx

```
/*
** SAnodupes.rexx
** SASort.rexx uses Rainbow Series Stem/Array
** This pgn calls the sort routine SASort.rexx as an
** exterior
** function, where the array here is assigned there via
** AssignArray().
** The returned value is the number of words sorted. The
** external
** function program alters the values of the array from
** this
** program, so that the final array written at the end of
```

```
this program
** is the sorted array EVEN THOUGH it is the *SAME* ARRAY!
** copyright 1992, 1993 by Merrill Callaway
*/
```

```
SAY 'Input filename and path.'
PULL infile
CALL TIME('R')
rcode=20
IF OPEN('textfile'.infile,'READ') THEN DO
  rcode=0

  /* initialize an entire array with one line! */
  listed=0

  m=1
  i=1
  DO WHILE -EOF('textfile')
    line.i=READLN('textfile')

    IF line.i ~<= '' THEN DO
      j=1
      DO WHILE line.j ~<= ''
        PARSE VAR line.i word.i.j line.i
        word=word.i.j
        /* NOTE! You cannot use an array as a SCODE! */
        /* Get rid of punctuation at end and beginning
        of words. */
        DO FOREVER
          IF DATATYPE(word,'N') THEN LEAVE
          IF -DATATYPE(RIGHT(word,1),MIXED) THEN DO
            IF LENGTH(word)>1 THEN
              word=LEFT(word,LENGTH(word)-1)
            ELSE LEAVE
          END
          IF -DATATYPE(LEFT(word,1),MIXED) THEN DO
            IF LENGTH(word)>1 THEN
              word=RIGHT(word,LENGTH(word)-1)
            ELSE LEAVE
          END
          IF
            DATATYPE(LEFT(word,1),MIXED) < DATATYPE(RIGHT(word,1),MIXED),
            THEN LEAVE
            IF LENGTH(word)=0 THEN LEAVE
          END
          /* end punctuation removal */

          IF word='' THEN ITERATE

          /* testing of "random access" array */
          IF listed.word THEN ITERATE
          listed.word=1 /* boolean 'yes' */
          list.m=word
          m=m+1
          j=j+1
        END
      END
      i=i+1
    END
  END
  i=i-1
  IF line.i = '' THEN i=i-1
  END
ELSE SAY 'Could not open your file!'

/* Adjust the count. */
mm=1
```

```

/* Call the exterior function program. */
k=ASort(list,,m,1)
SAY k 'entries sorted.'

/* Write the sorted array to the console. */
DO j=1 TO k
  SAY list,j
END

/* For time comparisons of this ppg with others. */
SAY 'Elapsed time in 'TIME('E')' seconds.'

EXIT roode

```

SAsort.rexx

```

/*
** SAsort.rexx
** An external function which may be called from any
** program with a list in array form, the stem, the
** count,
** and the start are passed as arguments. Picked up by
** this
** program, and by means of AssignArray() array substituted
** into an array to be sorted. At finish, the array is
** assigned
** back to the one from which it came.
*****
** YOU MUST HAVE Rainbow Series Stem/Array
** rexxarray.library
** TO USE THIS PROGRAM! It is available from: Dineen
** Edwards Group.
** (11) 352-4288 OR this ppg must have been compiled by
** RexxPlus.
** This program copyright 1992, 1993 by Merrill Callaway
**/

/* Load the rexxarray.library */

IF -SHOW('L', 'rexxarray.library') THEN DO,
CALL ADDLIB('rexxarray.library',0,-30,0)
IF -SHOW('L', 'rexxarray.library') THEN DO
  SAY 'rexxarray.library failed to open.'
  EXIT 5
  ENDD
END

/* The Shell Sort Feed the array to Shell Sort directly:
*/

/* get the name of the stem, the count m, and the start
value */
PARSE ARG stem,m,start

/* guarantee list. is uninitialized if compiled with
RexxPlus */
DROP list.

```

```

/*
** Call Rainbow Stem/Array Library AssignArray() function
** Assigns stem from the calling program at level l next
to list. stem
** in this program level 0 (for m count starting at start.
** Syntax for AssignArray(): Assign TO and Assign FROM;
** (TO_LEVEL, TO_STEM, FROM_STEM, FROM_LEVEL, COUNT, START)
** 0 means THIS PGM; 1 means ONE LEVEL UP of calling pgma.
**/

CALL AssignArray(0,list..stem,l,m,start)

listlength = m

span = 1
DO WHILE (span < listlength); span = span * 2; END
DO WHILE (span > 1)
  span = span % 2
  numpairs = listlength - span
  DO node = 1 TO numpairs
    nextnode = node + span
    IF list.node > list.nextnode THEN
      DO
        store = list.nextnode
        list.nextnode = list.node
        DO bubpos = node-span TO 1 BY -span WHILE (store
< list.bubpos)
          nextnode = bubpos + span
          list.nextnode = list.bubpos
          ENDD bubpos
        bubpos = bubpos + span
        list.bubpos = store
        ENDD
      ENDD node
    ENDD
  /* the end of the shell sort of the words */

/* Assign TO stem there (1), FROM list. here (0), for
listlength,start */

CALL AssignArray(1,stem,list..0,listlength,start)

EXIT listlength /* entire exterior function returns how
many words sorted */

```

SAtester.rexx

```

/* SAtester.rexx to test the S/A functions */
SIGNAL ON BREAK_C
START:
SAY 'CTRL-C to quit.'
SAY 'Enter a line of separate numbers as Array A'
SAY '[Rtn] for a default Array A.'
PULL lineA

IF lineA = '' THEN lineA='2 5 8 10 0,5'
SAY 'Array A is'
SAY lineA

```

```

SAY 'Enter a line of separate numbers as Array B.'
SAY '(Rtn) for a default Array B.'
PULL lineB

IF lineB = '' THEN lineB='1 5 4 5 0 1'
SAY 'Array B is'
SAY lineB

i=0
DO WHILE lineA << ''
  PARSE VAR lineA numA.i lineA
  i=i+1
END

j=0
DO WHILE lineB << ''
  PARSE VAR lineB numB.j lineB
  j=j+1
END

w=MAX(i-1,j-1)

SAY 'Enter Stem/Array function name you wish to test. NO
1)'
PULL saf
funname=saf
saf=saf'|'
SAY 'Enter number of arguments.'
PULL numarg

SAY 'Use numA & numB as INPUT array names.'
SAY
DO a=1 TO numarg
  ending=''
  rtn='(Rtn)='
  SELECT
    WHEN a=1 THEN ending='AND'
    WHEN a=2 THEN ending='numA'
    WHEN a=3 THEN ending='numB'
    OTHERWISE rtn=''
  END

  SAY 'Enter argument No. 'a rtn|ending
  PARSE UPPER PULL argument.a','
  IF argument.a<>' THEN argument.a=ending
  IF a<numarg THEN saf=saf|(argument.a','
    ELSE saf=saf|(argument.a'|'
  SAY saf
END

SAY
SAY 'OK to interpret? N=exit.'
PULL ok

IF ok<'N' THEN EXIT 5
saf='n='saf

INTERPRET saf

SAY n' array elements processed.'
nat=numarg-1

```

```

strt=argument,numarg
count=argument.nat
IF -DATATYPE(count,'W') THEN count=MAX(numA,0,numB,0)
IF -DATATYPE(strt,'W') THEN strt=1

SAY 'Count='count
SAY 'Start='strt

IF funname<'ASSIGNARRAY' THEN DO
  ans=argument.1|'|'
  SAY 'Answer_Stem. is 'argument.1
  END
  ELSE DO
    ans=argument.2|'|'
    SAY 'Assign_Stem. is 'argument.2
  END

SAY saf
SAY funname 'answer table for' ans
DO k=0 TO w
  SAY ans|'|k'='VALUE(ans|'|k)' numA,'k'='numA.k
  'numB,'k'='numB.k
  END

DROP numA.
DROP numB.
DROP ans

```

```

SIGNAL START
END

```



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Programming the Amiga

ANOTHER SIMULATION

In this article I'll show you another computer simulation using the Amiga. You see this simulation in action whenever you drop a stone in the water, watch a heart-beat, or stir your coffee. The effect produced is wave action—waves that move out from the disturbance and interact with whatever they touch. These waves could be electrical impulses along heart muscles, rust spreading on metal, or simply ripples in a pond. Using a principle developed by John J. Tyson of V.P.I. we'll simulate wave motion in an excitable media; water is not an excitable media, but nerve cell membranes and oxidation are. Excitable media keeps sending out waves over relatively long distances.

Whatever media we use, it will be described as being in an excitation state (U) or a recovery state (V). The U state will only have two values - 0 (unexcited cell) or 1 (excited cell). The recovery state V will range from 0 to V_{MAX} which throughout these examples will always be 100. In simple terms, consider one cell in the media; at any given time it has a U and V value. To determine its values for the next generation look first at its U value. When $U=1$, V increases by a fixed amount called GUP ; when V reaches V_{MAX} , U becomes 0. If U is initially 0, V will decrease by an amount called $GDOWN$ until it reaches 0. When both U and V are 0, the media is stable.

If these were the only variables, a media would quickly settle down to its stable state and wave motion would cease. We can add other variables however, that will simulate specific reactions and produce more realistic demonstrations. First we'll let a cell be partially affected by cells around it; these cells are called the neighborhood. If we go out a distance of R (generally $R=3$) in all directions from a given cell then our neighborhood consists of 49 cells in a square centered over a given cell; if $R=2$ the neighborhood is 25 cells. The size of any neighborhood is $(2R+1)(2R+1)$.

The variable V_{EXC} will represent a sufficiently recovered state. An unexcited cell ($U=0$) can become excited ($U=1$) at the next generation if V is between 0 and V_{EXC} and the number of excited cells in a neighborhood (E) exceeds a variable K_{EXC} . The variable V_{REC} represents a

Making
waves

b y W i l l i a m P. N e e

sufficiently unexcited V state. An excited cell ($U=1$) can become unexcited ($U=0$) at the next generation if V is between V_{REC} and V_{MAX} and the number of unexcited cells in the neighborhood (EE) exceeds a variable K_{REC} . For all other cases we'll only add GUP or subtract $GDOWN$ from V depending on the U value. Also, if $V=V_{MAX}$ then an excited cell ($U=1$) will automatically become unexcited ($U=0$).

GUP, GDOWN

GUP and $GDOWN$ depend on the local kinetics of the excitable media. These values may represent the oxidation of iron, diffusion in a membrane, etc. While their values could be obtained from a chemistry book, we'll be more interested in programming the simulation and experimenting with different values. To summarize the rules at this point:

```
IF U=0
  IF V<VREC THEN NEWV=V-GDOWN;IF NEWV<0 THEN NEWV=0;NEWU=1;LOOP
  COMPUTE THE NEIGHBORHOOD OF EXCITED CELLS (E)
  * IF E<KREC THEN NEWU=1;NEWV=V;LOOP
  IF E<KREC THEN NEWV=V-GDOWN;IF NEWV<0 THEN NEWV=0;NEWU=1;LOOP
IF U=1
  IF V<VREC THEN NEWV=V-GUP;IF NEWV<0 THEN NEWV=0;NEWU=1;LOOP
  * IF V<VMAX THEN NEWU=0;NEWV=V;LOOP
  COMPUTE THE NUMBER OF UNEXCITED CELLS (EE)
  * IF EE<KREC THEN NEWU=0;NEWV=V;LOOP
  IF EE<KREC THEN NEWV=V-GUP;IF NEWV<0 THEN NEWV=0;NEWU=1
*CHANGE IN U STATUS
```

in

Assembly Language

Notice that there is only one way an unexcited cell state can go from 0 to 1, but there are two ways an excited cell state may become unexcited. This process gradually dampens the initial disturbance smoothing things out just as in real life.

Initial values of U and V are stored in two separate arrays; new U and V values will be stored in two more arrays. After all the new values for each cell have been computed, they are transferred back to the original array. The display is colored using the U values of 0 or 1 for each cell and point on the screen.

If you wrote the program at this point there would be two problems. First, the waves don't appear to be waves; they're more like large blobs and most of them don't interact. It's not too realistic and definitely not interesting to watch. The second problem is speed—or rather the lack of it. Computing that neighborhood of 49 squares takes too long and slows everything down especially on the Amiga 500. And if we use a larger neighborhood, say R=6, that's 169 cells to evaluate!

BETTER K VALUES

Let's correct the first problem by making a refinement to the K values. As an unexcited cell's V values get closer to 0 it takes fewer and fewer neighbors to change its U state to 1. Conversely, as an excited cell's V values get closer to VMAX it takes more neighbors to change

its V state to 0. We'll reflect this by spreading the K values out in arrays as V ranges from 0 to VMAX based on the formulas:

$$KREC(V) = KREC + (R/28 + 1) - KREC + V/VREC$$

$$KEXC(V) = KREC + (R/28 + 1) - KREC + (VMAX - V) / (VMAX - VREC)$$

Now the E value will be compared to KEXC(V) and EE will be compared to KREC(V). Remember that VMAX=100. Let's look at some actual values. One example in the listing is:

$$R=3; VREC=70; VREC=65; Q29=20; Q200W=5; KREC=5; KEXC=1; VMAX=100$$

Using the above formulas as V ranges from 0 to VMAX, KEXC(V) would range from 1 to 31; KREC(V) ranges from 53 to 5.

A QUICKER ARRAY

We could still check all 49 squares in the neighborhood to compute the E or EE value, but there is a quicker way. This new way, however, requires a fifth array called SQUARES. Any point in this array, say SQUARES(I,J), equals the corresponding U value $U(I,J) + SQUARES(I-1,J) + SQUARES(I,J-1) - SQUARES(I-1,J-1)$. This array must be recomputed at the start of each generation.

The sum of the neighborhood around a cell can be computed using only four values from SQUARE. E at location (X,Y) is equal to

$$SQUARES(X+R,Y+R) + SQUARES(X-R,Y+R-1) + SQUARES(X-R-1,Y+R) + SQUARES(X+R,Y-R-1)$$

Now the number of steps required to compute E is not dependant on R. The extra time required to fill the initial SQUARES array is much less than the time saved in computing E with four steps versus computing E with 49 steps.

The demo for the program fills the left-half of a square with excitable media (U=1); the right-half is unexcited (U=0) and all V values are 0. Waves will begin to come out from the excited portion of the media and as time progresses they will begin to interact with themselves, collide, and form new waves or spirals. Use the initial values given and then try some of the ones at the end of the program.

THE LISTING

Let's look at the machine language program (Listing 1) in detail. After the usual equates and offsets the variables SUM, TESTV, and E are equated to specific data registers. Notice that SUM and TESTV are both equated to register d7, as long as these variables are not used

together they can be referenced using the same register. After defining the variable LEN other variables are computed based on LEN. N1 through N4 are the four locations in array SQUARES used to compute the neighborhood E value. There are several macros that make the program easier to write and read. Since the DEPTH for the program is 1, we only need one bitplane location. The routine MEMORY reserves space for arrays U, UU, V, VV, and SQUARES.

Next the values for the KEXC array are computed. The array address is in a1, R1-KEXC in d1, and the counter V in d0. Multiply d1*d0 then divide by VEXC; add KEXC to the result and store the result at location a1+d0. Increase d0 until it reaches VMAX (100). The array for KREC is computed in the same manner. The array address is in a2, R1-KREC in d1, and the counter V in d0. Subtract V from VMAX and multiply the result by d1; divide this result by VMAX-VREC then add KREC. Store this at location a2+d0. Keep doing this until V reaches VMAX. DEMO2 fills the left side of array U and UU with 1 to represent the excited state of the media. Each array value set to 1 is also colored on the screen.

The main part of the program is next. CONTINUE fills in array SQUARES at location (L,I) in U and SQUARES. The value at U is

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added to the value just to the left in SQUARES (-1(a5)), just above (-LEN(a5)), and subtracted from the value to the left and above (-LENP1(a5)). This continues until the whole array is filled. Figure out the initial value for yourself for this array and it becomes more clear as to how it works when you compute neighborhood values. The values get large enough that they could be stored in a word array, but since we're only using their difference, we can get by with a byte array.

TESTING THE CELLS

The TEST routine has to start at (R+1,R+1) in all the arrays since two of the locations used in SQUARES are -R-1 away from the current cell. The current V value is put in NEWVV and saved in TESTV; the current U value is stored in U. If the current U is 1, branch to TEST1. If it is 0, however, first compare TESTV to VEXC. If it's lower, branch to TEST0A. If not, compute the neighborhood using N1+N2-N3-N4 in array SQUARES. Compare this value with the corresponding value in the KEXC array; if it's less or the same, branch to TEST0A else change UU to 1.

TEST0A subtracts GDOWN from TESTV. If there is a carry, the result went below 0 so replace TESTV with 0. Store TESTV in VV.

TEST1 follows the same general procedure. Compare TESTV to VREC; if it's lower or the same, branch to TEST1A. If not, compare TESTV to VMAX (100). If they're equal, branch to TEST1B. If not, first compute the neighborhood E value using N1+N2-N3-N4 in array SQUARES. Since this time we want the number of unexecuted cells, subtract the E value from RR. Compare this to the corresponding value in array KREC; if it's greater, branch to TEST1B.

TEST1A adds GUP to TESTV. Compare the result with VMAX; if it's greater, make the result VMAX. Store TESTV in array VV. TEST1B reverses the U value to 0 and stores this in array UU.

When an entire row in an array has been computed you have to jump 2R+1 (R0) to the next location since the row steps R away from the end and starts at R+1. After the entire array has been checked the new LU and VV values are switched back to U and V while the corresponding SQUARES locations are cleared in preparation for refilling them. The PSET routine takes the value of each UU (either 0 or 1) and rotates it into d3; when d3 is filled it's poked into the proper screen location. When a row has been displayed the next row is drawn 32-bits at a time through the length of the array. When you press the LMB the program terminates else it reverts back to CONTINUE and re-starts by filling the array SQUARES.

Type or copy this program from the magazine disk as RECOVERY.ASM. Use the enclosed A68K to assemble it by typing A68K RECOVERY.ASM; then use BLINK to link the program by typing BLINK RECOVERY.O. Run the program as RECOVERY. I usually run this program from RAM, since the disk drives sometimes have a tendency to keep running while the program is running. There are alternate values you can try at the end of the listing. If you want to experiment with your own values, be sure to meet the following requirements:

```
0 = VREC = VREC + 100
```

```
0 = 20000 + 000 = VREC
0 = KEXC = KEXC + 3(20+1)
KEXC(0) = 255 = KEXC(100) = 255
```

The last two requirements are artificial restrictions since I'm using only byte arrays and values can't exceed 255. I've included CHART1 recapping the test rules depending on the U value.

CHANGES

Some changes you might want to try with this program are to assign different lengths and widths making a rectangle instead of a square (use LENX and LENY). Or color the V values instead of the U values; this will require that you expand the PSET routine for up to 5-bitplanes. Finally, you might want the program to accept the variables from CLI or "read" the DATA lines at the end of the program.

Listing

```

:LISTING1
equates:
depth = $1
jan2 = $1
mousebuttons = $8
keyless = $800
screen = $2e
width = $33
motion = $1e
customscreen = $f
activate = $1000
rmb = $0000
public = $1
chip = $2
fast = $4
clear = $10000

offsets:
jexec
openlibrary = -552
closelibrary = -414
allocmem = -198
freemem = -210
forbid = -132 ;no registers used
permit = -138 ;no registers used
:intuition
openScreen = -198
closeScreen = -66
openWindow = -204
closeWindow = -72
viewportAddress = -100 ;a0=window
:graphics
setdred = -354
loadrgb4 = -192 ;a0=vp, a1=colortable, d0=#pens
setapen = -342

```



```

writepixel = -324

sum      equi d7
testv   equi d7
s        equi d4
acrnse   equi d8
down     equi d5
len      = 32*3          ;try 32*4 for AMIGA 3000
lenml    = len-1
mlenml   = -1*lenml
lenml2   = len-2
xoff     = (320-len)/2   ;to center display
yoff     = (200-len)/2   ;to center display
lenpl    = len+1
mlenpl   = -1*lenpl
lenml    = len-1
mlen     = -1*len
byte     = (yoff*320+xoff)/8 ;byte containing yoff
wpl      = len/32-1      ;long words per line
byteoff  = 2*xoff/8      ;offset to next byte
size     = len*len       ;array size
r        = 3
rpl      = r+1
n1       = r*lenpl
n2       = (r-1)*mlenpl
n3       = r*lenml-1
n4       = -1*(r-1)*len+r
r0       = 2*r+1
r1       = r*12*r-1
r2       = 12*r-1*(2*r+1)
vmax     = 100
vrec     = 70
vexc     = 65
gup      = 30
gdown    = 5
krec     = 5
kexc     = 1

macro:
syslib macro          ;(routine)
  movea.l 4,a6
  jar     \1(a6)
  endm

openlib macro         ;(Name, location, BEQ if 0)
  lea     \1,a1
  moveq   #0,d0
  syslib  openlibrary
  move.l  d0,\2
  beq     \3
  endm

inllib macro         ;(routine)
  movea.l intbase,a6
  jar     \1(a6)
  endm

openscreen macro     ;(parameters, screen, BEQ=0)
  lea     \1,a0
  inllib  openscreen
  move.l  d0,\2
  beq     \3
  endm

```

```

openwindow macro     ;(parameters, window, BEQ=0)
  lea     \1,a0
  move.l  screen,nw.screen(a0)
  inllib  openwindow
  move.l  d0,\2
  beq     \3
  endm

gfxlib macro         ;(routine)
  movea.l gfxbase,a6
  jar     \1(a6)
  endm

pset macro
  move.l  rp,a1
  move.w  across,d0
  add.w   #xoff,d0      ;center across
  move.w  down,d1
  add.w   #yoff,d1      ;center down
  ext.l   d0
  ext.l   d1
  gfxlib  writepixel
  endm

color macro
  move.l  rp,a1
  gfxlib  setopen
  endm

array macro         ;(address, BEQ=0)
  move.l  #size,d0
  move.l  #510004,d1
  inllib allocmem
  move.l  d0,\1
  lea     \2
  endm

free macro          ;(array name)
  move.l  #0,d0
  movea.l \1,a1
  syslib  freeam
  endm

everpc macro
  ds.w   0
  endm

start:
  move.l  sp,stack
open_lib:
  openlib intuition,intbase,dope
  openlib graphics,gfxbase,close_int

set_up:
take_screen:
  openscreen myscreen,screen,close_libs
  openwindow mywindow>window,close_screen
  move.l  d0,a0
  movea.l vw.rport(a0),a1
  move.l  a1,rp
  movea.l window,a0
  inllib viewportaddress
  move.l  d0,vp      ;viewport address

```

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```

movea.l rp,a1
move.l #iam2,d0
qfplib setdrnd
get_bit_planes:
movea.l rp,a1
movea.l #a1,a1
lea bpl,a0
move.l #a1,(a0) ;bitplane addresses
syslib forbid
memory:
array u,close_window
array uu,close_outu
array v,close_outuv
array vv,close_outv
array squares,close_outvv

lea akexc,a1
moveq #0,d0
moveq #0,d1
moveq #0,d2
ll move.b #r1,d1
sub.b #kexc,d1
mulu.w d0,d1
move.b #vexc,d1
divu.w d2,d1
add.b #kexc,d1
move.b d1,0(a1,d0)
    
```

```

addq.w #1,d0
cmp.b #vmax,d0
bts.s ll

lea akrec,a2
moveq #0,d0
moveq #0,d1
moveq #0,d2
ll move.b #r1,d1
sub.b #krec,d1
move.b #vmax,d2
sub.b d0,d2
mulu.w d1,d2
move.b #vmax,d1
sub.b #vrec,d1
divu.w d1,d2
add.b #krec,d2
move.b d2,0(a2,d0)
addq.w #1,d0
cmp.b #vmax,d0
bts.s ll

demo1:
movea.l u,a4
movea.l uu,a5
moveq #0,down
demo2:
moveq #0,across
demo3:
move.b #1,(a4)+
move.b #1,(a5)+
movnq #1,d0
color
set
addq.w #1,across
addq.w #len/2,across
bne.s demo3
lea #len/2(a4),a4
lea #len/2(a5),a5
addq.w #1,d0
cmp.w #len,down
bne.s demo2

continue:
movea.l u,a1
lea lenpl(a1),a1
movea.l #squares,a1
lea lenpl(a1),a1
moveq #1,down
contf:
moveq #1,across
contl:
move.b (a1)+,sum
add.b -1(a1),sum
add.b -len(a1),sum
sub.b -lenpl(a1),sum
move.b sum,(a5)+
addq.w #1,across
cmp.w #len,across
bne.s contf
lea l(a1),a1
lea l(a5),a5
addq.w #1,down
    
```

```

cmp.w #len,down
bra.s cont2

test:
move.l v,a1
lea rpl*lenpl(a1),a1
move.l v2,a2
lea rpl*lenpl(a2),a2
move.l v,a3
lea rpl*lenpl(a3),a3
move.l v4,a4
lea rpl*lenpl(a4),a4
move.l squares,a5
lea rpl*lenpl(a5),a5
moveq #rpl,down
t2
moveq #rpl,across
t1
move.b (a1)+,testv
move.b testv,(a4)
move.b (a1)+,(a2)
bra.s test1

test0
lea ahexr,a6
cmp.b #vmax,testv
bcc.s test0a
move.b n1(a5),e
add.b n2(a5),e
sub.b n3(a5),e
sub.b n4(a5),e
cmp.b 0(a6),testv,e
bix.s test0a
move.b #1,(a2)
bra.s loopy

test0a
sub.b #gdown,testv
bcc.s test0a1
moveq.d #0,testv

test0a1
move.b testv,(a4)
bra.s loopy

test1:
lea ahexr,a6
cmp.b #vmax,testv
bix.s test1a
cmp.b #vmax,testv
beq.s test1b
move.b n1(a5),e
add.b n2(a5),e
sub.b n3(a5),e
sub.b n4(a5),e
move.b hex,d0
sub.b e,d0
cmp.b 0(a6),testv,d0
bix.s test1b

test1a
add.b #gup,testv
bcc.s test1a0 ;greater than 255
cmp.b #vmax,testv
bix.s test1a1

test1a0
move.b #vmax,testv

```

```

test1a1
move.b testv,(a4)
bra.s loopy

test1b
move.d #0,(a2)
loopy
lea (a2),a2
lea 1(a4),a4
lea 1(a5),a5
addq.w #1,across
cmp.w #len-r,across
bra.s t1
lea r0(a1),a1
lea r0(a2),a2
lea r0(a3),a3
lea r0(a4),a4
lea r0(a5),a5
addq.w #1,down
cmp.w #len-r,down
bra.s t2

switch:
move.l v,a1
move.l m,a2
move.l v,a3
move.l v4,a4
move.l squares,a5
move.w #len1,down
a2
move.w #len1,across
a1
move.b (a4)+,(a1)+
move.b (a2)+,(a1)+
move.b #0,(a1)+
dbf across,a1
dbr down,a2

move.l r0,a5
move.l rpl,a1
lea byteoff(a1),a1
move.l #len,down

qp1
moveq #rpl,across ;length/32-1
qp4
moveq #15,d0 ;fill all 32 bits
qp3
move.b (a5)+,sum
arr.b #1,sum ;1st color bit to x
rovl.l #1,d3 ;and to d1
dbf d2,qp3 ;do 32 times
move.l d3,(a1)+ ;all 1st color bits
dbf across,qp4
lea byteoff(a1),a1
dbr down,qp5

loop:
test #6,b0e001 ;pressed LMB?
bne continue ;branch if not

vysib: permit
close_rvm:
free squares
close_sutvv:
free v4

```

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MOVING?



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```
close_outvr:
  free v
close_outaut:
  free ua
close_outur:
  free u
close_window:
  move.l window,a0
  intlib closewindow
close_screen:
  move.l screen,a0
  intlib closescreen
close_libs:
  move.l glibbase,a1
  syscall closelibrary
close_int:
  move.l intbase,a1
  syscall closelibrary
done:
  move.l stack,sp
  rta

  everpc

stack dc.l 0
glibbase dc.l 0
intbase dc.l 0
screen dc.l 0
window dc.l 0
```

```
fp dc.l 0
vp dc.l 0
w dc.l 0
ui dc.l 0
v dc.l 0
vv dc.l 0
square dc.l 0
bp1 dc.l 0
bp2 dc.l 0
bp3 dc.l 0
bp4 dc.l 0
bp5 dc.l 0
ahorr: ds.b 102
  everpc
akrrc: ds.b 102
  everpc

graphics dc.b 'graphics.library',0
  everpc
intuition dc.b 'intuition.library',0
  everpc

myscreen:
  dc.w 0,0,320,200,depth
  dc.b 0,1
  dc.w 0
  dc.w customscreen
  dc.l 0,0,0,0
  everpc
mywindow:
  dc.w 0,0,320,200
  dc.b 0,1
  dc.l mousebuttons
  dc.l borderless|activate|mb
  dc.l 0,0
  dc.l 0
  dc.w 0,0,0
  dc.w customscreen
  everpc
data:
  dc.b '3,70,0,20,5,5,1'
  everpc
  dc.b '3,85,80,24,19,7,5'
  everpc
  dc.b '6,92,71,15,5,33,0'
  and
```



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*W*hat is morphing exactly? Why is it so popular, right now? Is it that complicated? How can it be implemented? Which are the best techniques, and why? Why do they usually require so much user intervention? In this article, we're going to try to answer these questions and make you see morphing as a technical matter, instead of an unexplainable magical effect. Well, let's say that the results may look magical sometimes, but the technique surely is not.

You won't find the word morphing in any dictionary, as it has been just recently created to describe a new special effect that you should have seen a couple of times by now. The word comes from a better-sounding, shorter term of the more complicated synonym *metamorphosis*, which is simply a change of shape, structure, or substance of something into another. This kind of transformation is many times a desirable special effect, especially in the entertainment and advertising industries. You have probably seen many metamorphoses in movies and commercials, even before computer based morphing techniques showed up. Conventional horror movies, for instance, are filled with transformations, which have been traditionally created using a couple of elementary techniques, such as rudimentary scene cuts, mechanical models that can change their appearance, and cross-dissolves.

*All you ever
wanted to
know about
morphing**

by

Bruno Costa & Lucia Darsa



**but were afraid to ask...*

Cross-dissolve has been, by far, the most-used method to create metamorphoses, probably because of its inherent simplicity and the acceptable end results. Since the initial and final subjects in a transformation usually differ significantly, some dolls representing in-between steps in the transformation have to be created. The cross-dissolve is then performed between each pair of successive dolls, which must be positioned so that they match reasonably well. The obvious problem with this technique is that the dolls never match perfectly, and that the transformation looks as though it is "broken" into many smaller transformations, from each doll to the next. Besides, the creation of convincing in-between dolls may be a hard job, although we are often surprised by what special effects technicians can do.

effective than a completely synthetical 3-D metamorphosis sequence. Obviously, these cross-dissolves can also be created with computers instead of optical techniques and lenses. At first, there is no good reason to do that, since optical cross-dissolves are perfectly effective, but computers are able to do much more than lenses—including simulating them!—so they might present a solution to the alignment problems that plain cross-dissolves have. It is not hard to realize that a much better effect can be created if the images to be transformed are geometrically aligned before doing the cross-dissolve, so that the transition is smooth and fluid. This artificial alignment between the images is basically the only (but great) difference between a traditional cross-dissolve and the so-called morphing effect.



1a
1b, page 19

Different approaches, based on computer graphics, can be used to simulate metamorphosis-like effects. Two 3-D models, if they have a similar structure (same number of vertices, etc.), can be trivially transformed into each other by interpolating the position of corresponding points (see the "Interpolation" box). With extra effort, some objects with highly differing structures can also be transformed. However, even with the corresponding interpolation of surface characteristics like color and texture, the final quality of a 3-D object metamorphosis will depend on the accuracy of the models and the realism of the rendering. For real world objects such as live beings—typical metamorphosis subjects—convincing modeling and rendering are currently impractical, if not impossible.

When carefully designed, a basic cross-dissolve, even if the intermediate steps do not match perfectly, is usually much more

It was not until recently that the researchers working for top computer graphics companies found out that such techniques could be used to create much better metamorphoses using computers and digital images. The *bat* of this effect was seen in the movie *Willow*, where a goat turns into many different animals and then finally into a sorceress. Since then, morphing has been significantly improved, and used in many different movies, sometimes in unsuspecting places. In *Indiana Jones and the Last Crusade*, for instance, traditional techniques were used to create parts of the transformation where the villain ages rapidly until death, and morphing was used to join the different transformation segments smoothly. Morphing has also been used explicitly in the anthological clip *Black or White*, one of the best

examples of high quality morphing of moving subjects, and in *Terminator 2*, for most of the transformations of the shape-shifting creature into human beings. Morphing is now such an important tool in the special effects industry that most movies with a reasonable budget for this area sports at least one morphing sequence, and this includes productions like *The Abyss*, *Star Trek VI*, *Freddy's Dead*, *The Final Nightmare*, *Bram Stoker's Dracula*, and so on.

Now, with the availability of capable morphing software for the Amiga, you should expect to see morphing incorporated into the toolbox of lower budget special effects producers. Even though some of these packages do not have the features that are needed to create truly professional results (features which we're going to detail later), it is possible to use most of them to create simple metamorphoses, suitable for TV commercials and low-budget TV productions. More complex packages, if used with high quality display hardware like a film recorder, can be used to produce quite affordable but convincing special effects for movies.

Morph = Warp + Dissolve

We'll now see, through a simple example, how the alignment of the main image features before doing a cross-dissolve can produce much better results than cross-dissolve alone. Figures 1a and 1b show two digitized images, in their original, undeformed state. Let's call Figure 1a the FROM image and 1b the TO image. Figure 1c is a 50% cross-dissolve between 1a and 1b. Notice how awful the result can be if the eyes, nose, and mouth do not match: it definitely doesn't look like an intermediate step of a metamorphosis.

What if we try to move the woman's eyes a bit apart, or move the feline's mouth up so that it matches the woman's mouth? By pushing or pulling the images here and there, just as if they were made of rubber, we can deform (or warp) them somehow, so that their eyes, nose and mouth match. Figures 1d and 1e are deformed versions of Figures 1a and 1b. Note how the main features, like the mouth, are now at the same approximate position and shape in both pictures. Figure 1f shows a similar 50% cross-dissolve of Figures 1d and 1e, and now the results are a lot better (the quality of the morphing can be enhanced even further with the use of advanced techniques that we'll explain later). You might notice that although the deformed images usually look somewhat weird and artificial, their combinations produce creatures that are very authentic and believable, almost lifelike.

Obtaining this kind of alignment is not so straightforward, as it requires that the main features of both images are identified and then correlated, so that an arbitrary warping of the images can be done. Although the identification of the main features could be done by an edge-detection algorithm, for instance, there is no known way to automatically correlate corresponding features in both images. Presently, all this work must be done by the animator who operates the software.

There are a couple of different ways of specifying these features, but the important point is that the animator's work must give enough information for a particular warping algorithm to align the features. Once such a warping algorithm is used, the cross-dissolve is simply a pixel-by-pixel weighted average of the two deformed images.

Interpolation

You'll find the word interpolation many times when working with morphing. In fact, we could say that plain morphing is just a sequence of interpolations (two complex shape interpolations followed by one color interpolation, plus interpolations in time for animation morphing).

An interpolation is simply a combination of two values, with the quantity of both controlled by a single parameter. This parameter can be given as a percentage: 0% means just the first value, 100% means just the second value, and in-between percentages represent values between the first and the second. The simplest type of interpolation is the linear interpolation, which is simply a weighted average between the two values, with the weight as the parameter. A linear interpolation between 20 and 50 is represented in the table below for some particular percentages (of course there are infinitely many).

You are not restricted to linear interpolations, though, there are many ways of going from one value to the other. In general, an interpolation will be a weighted average between the two values, where the weight is a function of the percentage.



1e

A simple fact that is sometimes confusing is that morphing is an operation performed on two different images and that warping operates on a single image. In fact, two warps are necessary to create a morph: each of the two images to be morphed is warped independently, and then the results are combined with a cross-dissolve. As mentioned before, when you are creating a morph, you'll want to warp each of the images so that its features match those of the other. To do that, of course, you'll have to know where the features of both images are, so the warps are not fully independent in fact. The whole morphing process is depicted in the small diagram in Figure 1.

Animation Morphing

When it comes to morphing, the word "animation" can appear in two different contexts: either describing the output of a morphing software or its input. We've already seen how an image representing one of the intermediate steps between two other images is created. It is easy to see that there are infinitely many steps between two images, ranging from steps which are "almost" the first image to steps which are "almost" the second. We like to identify each of these steps through a percentage, so that 0% would be exactly the first image and a 100% would be the second one. Any percentage can be used, and of course we can vary this value continuously from 0 to 100, so that a coherent sequence of images (an animation!) is produced. This is not what is called animation morphing, though; it's simply an animation created from two still images.

An animation morphing is created between two moving subjects, instead of two static images. This is the same as saying that two animations are used as input to the morphing software. The difference from still animation morphing is striking: it brings a whole new level of realism in the results. There is no better example of this than the *Black or White* video, where people dance and sing while morphing takes place.

Do not be fooled that animation morphing is easy to do: it takes a good deal of work to find (or create) two animations that match reasonably well, so that a convincing morph can be created. This difficulty is the reason why there are so few examples of animation morphing, even in movies with a reasonable budget. In some of those productions it is even possible to see a moving subject stop, metamorphose, and then continue its movement, just to be able to use a simpler still morph instead of a full animation morph. In the multi-million-dollar movie industry, things like these might bring a saving of some hundred thousand dollars! Technically speaking, both kinds of morphing have similar complexities, but animation morphing requires a lot of extra effort from the animator.

You shouldn't be surprised to know that an animation morph isn't much more than a combination of many still morphs. As mentioned before, two animations are used as input to the morph, both with the same number of frames n . Between each pair of corresponding still frames from the two animations, it would be possible to create an entire still morph with n frames, which are



1c

depicted in the figure as empty rectangles. Of all these m 's possible frames, we pick up just the n highlighted ones to be rendered and placed in the final output animation, and, believe us, it works! The reason for that is simple: for each successive frame, we morph a bit toward the TO animation and move a bit toward the end of the animations. Note also that we start from the first frame of the FROM animation, and end precisely at the last frame of the TO animation. It is a simple concept, but it takes a while before you get used to it.

Warping Algorithms

Since cross-dissolve is so simple, it is the warping phase that will determine the speed, quality, and even the user-interface of a morphing software. There are basically two techniques for specifying the important features of an image, and thus, how it will be warped.

The first technique to appear was based on control points placed over each important feature of the image. Each of these control points has a corresponding one which can be moved to show the deformation of the region of the image that surrounds that control point. When used for morphing, these corresponding control points are placed over the other image to specify the corresponding features. Since each feature is usually much larger than a single point, many points must be placed over each feature to produce acceptable results.

The other technique is based on two regular meshes. The first is

adjusted so that it follows the overall shape of the underlying image, and the second is a deformed version of the first. Both meshes have exactly the same structure and number of points. The meshes can be formed either by straight lines connecting each of the adjacent mesh points, or by any smooth spline curve (see the "Splines" box) passing over each line or column of points. When used for morphing, the second mesh is adjusted so that it follows the shape of the other image, and corresponding points of the two meshes are placed over corresponding features.

Once the animator has placed the "feature indicators," either single points or a mesh, over each image, a suitable algorithm must be used to compute the deformation. The algorithm used when features are specified by single points is relatively simple to implement. Basically, a triangulation, or a set of triangles, connecting all the control points in the deformed position is automatically created by the program. For each pixel in the output image, we must find which is the triangle that covers it. We then look at the original triangle (formed by the same three vertices in their undeformed position, in that case A, B and C), and find the position (p) in this triangle where our pixel would be. The color of the original image at this position will be the color of the output pixel. The entire procedure is repeated for each pixel in the output image.

Although the algorithm above is easy to implement and relatively efficient, the quality of the results is not what one would call profes-

sional. If you use too few triangles for a given image, discontinuities of the deformation will be noticed exactly along the edges of the triangles. Of course there are workarounds that try to smooth the deformation around the triangle edges, at the cost of speed. Note, however, that since the triangles are arbitrarily created by the algorithm, the position of the edges is unpredictable, and it may change suddenly during a continuous morph. If you have access to a program that uses point-based techniques, you can easily check the existence of these discontinuities—they will be noticeable if you try to warp a large checkerboard pattern. All these problems will be solved by an appropriate implementation of a smooth spline-mesh warping algorithm.

Spline Mesh Warping

The implementation of a spline-based warping technique that we present here is considerably more complex than the point based one, but it has many advantages. First, it is naturally continuous and smooth, providing for much more fluid and spontaneous deformations, specially for living subjects. Second, it is an efficient implementation that works in two passes, facilitating anti-aliasing, and it takes advantage of the memory organization of conventional computers. Besides, although the algorithm itself is more complex, the required data structures for a full implementation are simpler and easier to deal with.

The efficiency of the algorithm is mostly due to its two-pass nature: it can be performed in two independent passes, one horizontal, that produces an intermediate image, and one vertical, that uses the intermediate image to produce the final output. This brings the

problem of deforming a 2-D image down to the simpler problem of deforming many 1-D scanlines, greatly reducing the required calculations. Let's see how this can be done.

The horizontal pass of the algorithm starts by creating an intermediate mesh I that includes just the horizontal displacements from the source mesh S to the destination mesh D , that is, each point in I has the same x coordinate of the corresponding point in D , and the y coordinate of the point in S . Each column of S and I is then fitted with an interpolating spline—we call SS the set of vertical splines in S , and IS the set of vertical splines in I . Each horizontal scanline is intercepted independently with SS and IS . The x coordinates of the interceptions with IS and the x coordinates of the interceptions with SS are then fitted with a new interpolating spline, which gives a smooth relation, called the scanline mapping function, between each pixel in the output and the pixels in the corresponding input scanline. For each pixel of each horizontal scanline of the intermediate image, it is now easy to use this mapping function to determine which pixels of the input image influence this output pixel. The color of pixel p will then be either the color of a , that of b , or an average of the two to obtain an anti-aliasing effect. In general, anti-aliasing here is as simple as computing an average of the pixels that affect a particular output pixel, assigning higher weights for the pixels that have greater influence, a in this case.

You should note at this point that there are two ways to apply a mapping function to an image: direct and inverse mapping. In the first case, the function is applied to each pixel in the input image to find its

Splines

Splines are curves that are defined by a small set of control points, and a (usually complex) formula that takes these points as arguments. With the use of this formula, it becomes possible to know all the infinitely many points that make up the curve without having to store all of them. A spline will usually pass on, or near, each of its control points, and the splines that pass exactly over each of the control points are called *interpolating splines*.

There are many different kinds of splines, each of them defined by a certain formula: Natural Splines, Beta Splines, B-Splines, NURBS, etc. You can find the formulas and explanations for most of them, and some other, in good introductory computer graphics books like the second edition of "Computer Graphics: Principles and Practice" by J. Foley, A. van Dam, S. Feiner and J. Hughes.

location in the output. Inverse mapping, on the other hand, applies the inverse function to each pixel in the output to determine which input pixels contribute to it. Inverse mapping is generally preferred since it assures that every output pixel is calculated and that no work is wasted computing unnecessary pixels, as opposed to direct mapping.

The vertical pass uses the intermediate mesh and the intermediate image as input to produce the final output; the source mesh and the source image are not used. It is completely analogous to the first pass, with the rows of I and D fitted by horizontal splines, and the mapping functions computed for each vertical scanline. Note that the intermediate image may be distorted to such an extent that there is not enough information to compute a correct vertical pass, but this rarely happens, unless there are very large rotations in the two meshes, but this is usually nonsense for morphing.

It may seem complicated to implement such an algorithm, but once you have the routines to manipulate the kind of spline that you chose, it is not that hard. Obviously, this is just the basic warping algorithm, it needs a bit of extra work if you want it to do morphing. For this, it would need to warp two different images according to their respective meshes, and then create a cross-dissolve between the results, an average between each pair of corresponding pixels. By the way, the images must have exactly the same dimensions for this to be possible!

Progress Control

An important feature missing from the above discussion is the detailed control of the progress of the transformation. There are two

different things going on in a morph, the warping and the cross-dissolve—OK, we know you know that by now—so you should be able to control the progress of each of them independently. At a certain point in an animation, for instance, you might want to have the result almost fully warped to the end shape, but with the colors of the starting image still visible. You can also have no warping at all, keeping it at zero, and let just the cross-dissolve take place, or vice-versa. In more conventional morphs, you'll want both of them to take place, but at different rates, usually starting with pure warping and letting the cross-dissolve in just at a later stage. The progress of each of the two can be precisely described by two functions, which we like to call shape mixer and color mixer, that control how much of the FROM and the TO images will show up in the output, or the mix between the two.

Even more important than the overall control of the color and the shape progresses is the ability to define them precisely at specific regions of the image. This is achieved through the use of local mixers. These mixers are created and manipulated just like the global ones, but they can be associated with particular control points in the mesh, and their action is restricted to the region that surrounds them. Of course you can have all kinds of mixers working at the same time, with global ones controlling the rates for most places, and local ones providing distinctive rates for some special parts of the image. The ability to do this is an absolute requisite to obtain professional results like those you see in the movies and TV commercials.



11



1d

Conclusion

You would be surprised to know that the code directly devoted to morphing in a serious morphing package will hardly take up more than 15% of the total. Video professionals require much more from the morphing software they are going to use, like a friendly user-interface, many types of image conversion routines, dithering, anti-aliasing, alpha-channels, high-quality output, multi-format image loading and saving, and an efficient and system-compliant implementation. They also need support for creating complex animations easily, and automatically recording them to video tape. In this article, we were not worried about how all of this can be done—after all, it doesn't have much to do with morphing itself.

Considering the availability of morphing packages for the Amiga, you might ask yourself why you would worry about trying to implement the algorithms we've described here. Implementing something is always an excellent challenge, and these algorithms are quite interesting; you can learn a lot from them. And much more important than that, understanding how morphing works inside will surely help you to use it much better from the outside. If you wish, you can try the demo version of *Visionaire* included in the AC's TECH disk, which will let you experiment with many of the ideas and the algorithms presented here, including spline meshes and all kinds of mixers. We hope to have helped to make some concepts which seemed alien to you become friendly and natural.

Bruno Costa and Lucia Darsa are computer engineers working with computer graphics at Rio de Janeiro, Brazil. They are the authors of *Visionaire*, the morphing software from Impulse, Inc.

A demo of an earlier version of *Visionaire* is included on the AC's TECH disk.

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Fall River, MA 02722



Have Your Own Custom 3-D Graphics Package: Part I

by Laura M. Morrisson

Commercial 3-D graphics packages do photorealism superbly well, but is that all there is? If you have ever wished for something more, or just something different, from 3-D graphics, here is your chance. The programs described in this article provide the necessary 3-D graphics functions and a point of departure for your own custom code.

I developed these programs to accept 3-D trees and other plant objects produced using iterated functions systems. (See Volume 3, Number 1 of this journal for my article on "Make Your Own 3-D Vegetation Objects.") The IFS vegetation objects are defined by sets of points whereas commercial programs require objects defined by polygonal faces.

Besides accepting objects defined by sets of points, the programs described here provide some extra benefits not available with commercial graphics packages. The rendering algorithm is a Z-buffer algorithm, which is much faster than ray tracing. The code is designed to work on parts of the scene independently, so the number of objects and intricacy of composition is unlimited. The guiding metaphor is not Photography but Fine Arts, implying much greater artist's interference in rendering. You can use the programs as they are, or customize the algorithms and compile custom variations.

Part I of this article describes the Z-buffer rendering algorithm for objects defined by points and gives a z-buffer rendering program. Part I includes programs for generating boxes, shadows, and patterned grounds. It also includes several support programs for handling point-defined objects, such as changing position, manually adding points, and combining picture elements.

All the lighting algorithm code is postponed until Part II, which will explain the derivation of a lighting algorithm, and a fine arts theory of coloring for Amiga 3-D graphics.

World Space: Points and Perspective

The context of these programs is a world space with left-handed real number coordinates. A frame in the world space where $z=0$, $0 \leq x < \text{WIDTH}$, and $0 \leq y < \text{HEIGHT}$ provides a grid of $\text{HEIGHT} \times \text{WIDTH}$ integer positions. The frame is not the same as the Amiga screen. See Illustration I.1(a). The programs use floating point numbers for calculation, integers for saving, and only translate to Amiga screen pixel coordinates for plotting.

Objects and lights can be anywhere in the world space. No view volume or clipping is necessary. Points that do not have projections on the frame are simply ignored when time comes to plot the Amiga screen.

The eye, which defines the point of view, must be between the frame and the objects it is viewing as shown in Illustration I.1 (a). The frame is analogous to the retina of the eye. This eye position gives more natural vision than having the frame between the eye and the object. When the frame is between the eye and the object, the object appears smaller the nearer it is to the eye, just the opposite from natural vision, and, as the distance

between the eye and the object increases, the object increases in size toward orthogonal projection. When the eye is between the frame and the object, however, the object looms larger as the object comes nearer to the eye, and diminishes as it recedes, as in natural vision. More dramatic images are possible with the eye between the frame and the image.

The distance between eye and frame is not fixed. The relative proportions of the distances between eye and frame, and between eye and object will influence the image. When the eye is about half-way between object and frame the object's image will be about the same size as the object. If an object's image is larger than the object extra points may be needed to insure an opaque image. Notice that, as on the retina, an image is upside down and right-left reversed on the frame.

Objects consist of points which are stored as four 16-bit integers: color register number, x coordinate, y coordinate, and z coordinate. For easy handling they are best stored in numbered files of, say, 4000 points each. FPS vegetation objects will typically have from 10 to 30 such files.

Part I includes programs for generating boxes, shadows, and patterned grounds.

An object's points are independent. They have no order and are not linked. Objects can be combined by adding files of their points, or, parts of an object can be processed separately and differently by splitting the object's files into sub-sets of points.

Objects defined by points are easy to work with. Algorithms for such objects appear to be much simpler than algorithms involving polygonal faces.

The Two-Point Form

The two-point form of the equation of a line in space is useful for 3-D graphics having point primitives. A line in space is determined by two points, P1 and P2, on the line. Any other point, P, is on the line if the coordinates of P satisfy the equations:

$$(x-x1)/(x2-x1) = (y-y1)/(y2-y1) = (z-z1)/(z2-z1)$$

Point P(x,y,z) is on the line through P1(x1,y1,z1) and P2(x2,y2,z2) if these relations hold.

These are versatile and powerful equations worth the effort necessary to become familiar with them. They provide solutions to many 3-D graphics problems. Illustrations 1.1 and 1.2 show some of the useful points and lines. Most of the algorithms for the programs given in this article exploit the two-point form of the line in space. (Detailed

discussions of relationships of lines in space can be found in Analytic Geometry texts.)

The 3-D graphics described in this article uses a Z-buffer rendering algorithm instead of ray tracing. A Z-buffer algorithm renders a scene by keeping track, in a 'z-buffer,' of the z value associated with each point (x,y) plotted, and, when another point comes along having a smaller z-value, replacing the previously plotted point and its z value. The algorithm automatically sorts out which object is in front of which.

The z-buffer algorithm described here uses the equation of a line through two points in space to calculate which points the eye sees. Illustration 1.1 (a) depicts, in side view, the lines of interest relating the object, the frame, and the eye. For simplicity the object is shown solid but is to be considered a cluster of points. The eye is between the object and the frame. The lines suggest how the image gets inverted onto the frame. When the line through a point of the object, and the eye, intersects the frame the object is visible if not blocked by a nearer object. The equations give the point of intersection, and, with transformation, the image of the object's point on the Amiga screen.

Equations for the z-buffer rendering algorithm can be derived from the two-point equations as follows. Points on the frame have z = 0 (by definition of the frame) so the expression involving z becomes a constant:

```
Let k1 = Pobj((Zobj),Yobj,Zobj) and
    k2 = Peye((Zeye),Yeye,Zeye), and
    P = Pframe(Xframe,Yframe,Zframe)
Then (z-k1)/(k2-k1) = -(k2)/(Zeye-Zobj) = k1
```

Equating each of the other two terms to k1 yields equations for x and y, where x and y are on the plane z=0, that is, the frame.

$$\begin{aligned} x &= k1*(x2-k1) + k1 = k1 + k1*(Zeye-Zobj) + k2 \\ y &= k1*(y2-y1) + y1 = Yf + k1*(Yeye-Zobj) + Zobj \\ z &= 0 = Zf \end{aligned}$$

The line through the eye and the object's point might not intersect the frame if the object is too low, too high, or too far left or right. If $0 <= x < WIDTH$ and $0 <= y < HEIGHT$ then the point's projection falls within the frame and has a representation where the line intersects the frame. Finally, Pframe has a corresponding pixel, Pscr(Xscr,Yscr,Zscr), on the Amiga screen. Pframe can be transformed into Pscr with the equations:

$$\begin{aligned} Xscr &= WIDTH - Xframe \\ Yscr &= HEIGHT - (HEIGHT-Yframe) \end{aligned}$$

The z value = Zobj. Note that the z-buffer holds a record for each screen pixel of the z value associated with that pixel.

The algorithm for calculating the shadow of an object on the ground also uses the two-point form of the equations of a line in space to find points of the shadow object. Illustration 1.1 (b) shows the relevant points and lines. The points are:

$$\begin{aligned} P1 &= P11x(X11x,Y11x,Z11x) \\ P2 &= P20(X20,Y20,Z20) \\ P &= Pshad(Xshad,Yshad,Zshad) \end{aligned}$$

Since the shadow is on the ground, Yshad = 0 and the expression:

$$\begin{aligned} (z-y1)/(y2-y1) &= (Zshad-Y11x)/(Y20-Y11x) + k1 \\ x &= k2*(x2-k1) + k1 = Zshad + k2*(X20-Y11x) + X11x \\ z &= 0 = Zshad \\ x &= k2*(X2-Y11x) + X11x = Zshad + k2*(X20-Y11x) + X11x \end{aligned}$$

The line is from the light through an object point. The point where this line intersects the ground becomes a point of the shadow, Pshad(Xshad,0,Zshad). Note that the shadow is a object, a set of points.

Shadows cast on one object by another are likely to be ugly, garble the form, and are rarely used by fine artists, so no cast shadow algorithm has been implemented for this article. You can, however, create cast shadows by first creating the shadow of an object on the floor and then projecting this shadow object, considered as a floor "pattern," onto the far side of the to-be-shadowed object.

The algorithm for rendering floor, or ground, points also uses the two-point form of the equations of a line in space. However, because the ground, or floor, can have infinitely many points the algorithm works backward from those for other objects. Instead of picking a point on the floor and checking to see if it is visible the algorithm picks a point on the frame and checks to see if it should reflect a floor point. This avoids having to calculate non visible points. See illustration 1,2(a) The algorithm constructs a line through a point on the frame and the eye, and sees where it would intersect the floor. The points are:

```
P1 = Pframe(Xframe, Yframe, Zframe) = Pframe(col, row, 0)
P2 = Peye(Xeye, Yeye, Zeye)
0 = Pline(X1r, Y1r, Z1r) = Pline(X2r, 0, Z2r)
```

For a given row and column on the frame we wish to calculate whether it should reflect a floor point.

Since Y1r = 0:

```
(y-y1)/(y2-y1) = - row/(Yeye-row) = X1 Also since Zframe = 0:
(x-x1)/(x2-x1) = X1r/Zeye + X1
X1r = X1*Zeye and X1r = X1*(Zeye-col) = col
```

The point (X1r,0,Z1r) can be used to determine what color Pframe(col,row,0) should be. The determination could involve examining the floor pattern and the effect of light at that floor point.

The Code

Most functions have a separate program to make it easier to customize and re-compile the code. Some objects, however, have too many points to write out. For example, a floor. The floor program given below generates a floor point, places it, rotates it, colors it, lights it and renders it all without the point ever leaving temporary storage. Cubes or boxes also have large numbers of points. To avoid repeatedly handling the object's files, the 'cuber' program generates, colors, positions and lights the cube, point by point. The cuber program could be extended to generate the cube's shadow, and render both cube and shadow. You can use the programs as separate functions, writing out the sets of points between each operation, and using scripts to orchestrate production, or you can string the code of different functions together and compile special purpose programs for each class of object you use.

To get help on running a program, type its name at the CLI prompt. The program will write instructions to the screen on how it is to be run. Some programs use scripts either to copy all necessary files to ram: or to process a numbered sequence of object's points files. Scripts are give in Table 1.2. Some programs require a parameter file. Example 'params' files are given in Table 1.1

Following are a brief descriptions of the programs. Further comments are in the listings.

Zbuffer, Listing 1, reads files of object's points and plots appropriate points on the Amiga screen. Zbuffer gets the eye coordinates and the maximum z distance from an ASCII parameter file, which you can prepare and/or edit using 'ed.' Zbuffer's parameter file is called 'zparams.' Note that you can keep a copy of the parameter's definitions and input format at the end of the 'params' file.

Zbuffer produces two types of files, one with a 'rend' suffix and others with a 'zbuf' suffix. The first is the rendered screen image, the others are lists of z values for non-zero screen points. The 'zbuf' file has the same format as an object's point file but the contents are completely different. The 'zbuf' file record refers to the Amiga screen. It consists of four 16-bit integers: the pixel color, screen column, screen row, and associated z value.

Zbuffer accepts an indeterminate number of miscellaneous named object files. This facility together with 'compzbufs' program, which merges two or more 'zbuf' files, allows the user to build up a virtually unlimited number of objects in limited storage.

For processing speed zbuffer.script copies all the files zbuffer will need to RAM: (where you have placed the files of object's points).

Use the programs as they are
or customize the algorithms
and compile
custom variations.

Zbuffer requires a list of input files on the command line. Note that you can continue the list past the end of the line if you do not hit return. To run Zbuffer on three files, for example, type at the CLI prompt:

```
zbuffer <filenamex> <filenamed> <filenamed> 9999
```

The file '9999' is an 'end-of-files' file. When zbuffer tries to process 9999, it recognizes that it is finished. The 9999 file should contain one set of dummy values.

Zbuffer, as do all of the programs described in this article, writes a record of its activity and run parameters to a 'Run_Notes' file on disk.

Compzbufs, Listing 2, reads two or more 'zbuf' files and combines these into one new 'rend' file and new, composite, 'zbuf' files. To run compzbufs, at the CLI prompt, type:

```
compzbufs <'zbuf' filen> <'zbuf' filen> ... 9999
```

You can also use compzbufs to view 'zbuf' files. Compzbufs script copies necessary files to ram: Compzbufs does not require a parameter file.

Shadowgen, Listing 3, reads an object's points and given a light

position, calculates the points of the plane $y=0$ that fall in shadow. It writes these points to files of a new shadow object. Note that the shadow is an object. Since the ground is frequently patterned the program also calculates the shadow color according to the floor pattern.

Shadowgen requires a pattern repeat image. How the repeat is used is described in the discussion of 'floor', Listing 4, the program that generates a patterned ground.

Shadowgen requires a parameter file called 'slparams' containing the light position, and the width and height of the pattern repeat. The parameter file also contains 16 numbers which specify color register re-mapping, if any. The numbers zero to 15 will leave the color registers unchanged. If, for example, position three in the list, which corresponds to color register two, contains the digit '9' then the program will color any point having color identity '3' with the color in register '9'. This is handy for changing the colors of the repeat image.

Zfloor, Listing 4, generates and renders a patterned ground. The familiar checkered ground of cyberspace has become a bit boring. That is unfortunate because patterned grounds provide powerful 3-D visual

**The code
is designed to work
on parts of the scene inde-
pendently.**

clues. So this floor program allows you to create elaborate floor patterns instead of the simple checkers. Elaborate patterns can have surprising rendered images so a little experimentation will repay your effort. For example, one pattern I found looks exactly like patio carpeting, another looks like breeze ripples on a lake, another suggests cyberspace flying-saucer hangers!

Zfloor gets the pattern color of a floor point by the point's position on the pattern repeat, modula the repeat's width and depth. See Illustration 1.2(b). You can make the image of a pattern repeat in a point program. The program looks for the repeat in the upper left corner of the image.

As the program creates a virtual patterned ground, it produces the zbuffer rendering of how the floor would look from the given point of view in all directions and to the horizon. This is a special way of dealing with a high object, in this case the ground far and wide, without ever writing its points to files. Since a ground will even so have a large number (perhaps 30 or more) of 'zbuf' files the program does not produce them automatically. You must key 'x' during the run to get 'zbuf' files. Since, however, you can use the 'rend' file directly in your final image you will seldom need the 'zbuf' files for a floor.

The rendered floor's 'zbuf' files can be composed with 'zbuf' files of objects using compzbufs as described above, to make up the final

rendering. Alternatively, the rendered ground image could be 'pasted' behind the rendered objects using the backer program, Listing 7.

Besides requiring the pattern image, zfloor program requires a parameter file, 'lparams,' containing light position, eye position, pattern repeat width and height, and 'yon,' the maximum z distance.

Illustration 1.3 shows the rendered ground for the repeat shown in Illustration 1.2. The ground in the illustration is lighted, but since lighting requires a long explanation, the code for lighting the floor is not included in Listing 4. It will be given in Part II of this article. Meanwhile you can use the program to try out different patterned grounds.

Cuber, Listing 5, generates rectangular boxes. It reads height, width, and depth, row and column increments, color and offsets, from a parameter file and generates points of a hollow box. Since boxes of any size at all have large numbers of points cuber, as well as generating points, places and lights (the lighting code will be given in Part II) the box to avoid handling files of points. You may want to expand the code to generate the box's patterned shadow, and then render both box and shadow. A point can then go from generation through rendering without ever leaving temporary storage. That is how I generated the boxes of Illustration 1.3, which shows three boxes floating in space with shadows on a patterned ground.

To run cuber, type at the CLI prompt:

```
cuber <output box-object's name>
```

For many boxes their points as projected unto the frame are not dense enough to produce a solid looking image. You can get around this by generating points for a box, say, twice as large as you want, then just before lighting the points, scale the box's dimensions down to half. This will increase the density of points.

Placer, Listing 6, positions objects within a scene. It reads a point, scale, rotates, translates, then writes the revised point to a new file.

Explanations of the transformations are not given here. My article, "Make Your Own 3-D Vegetation Objects," in Volume 3, Number 1 of this journal, gives detailed explanations of the code for scaling, translation, and rotation.

Placer rotation do not include correction for non-square pixel distortion because different resolutions, different monitors, and different printers, will require different correction amounts. Correction code is described in my article, "Transformer" in Volume 3, Number 1 of this journal. To get the inches/pixel of your particular resolution-monitor-printer setup draw an image of a one pixel frame in a paint program, print it, and measure the resulting width and height. Divide these by the corresponding pixel counts.

To run placer, copy the files of object's points to ram, then use the 'placer script.' Type at the CLI prompt:

```
Revoke placer.script <objectname>
```

Backer, Listing 7, reads a backdrop image and pastes it behind rendered objects. The backdrop fills only pixels of the foreground having color register zero. The backdrop image could be a rendered ground or even a partially rendered scene. Or, the backdrop image could be a flat backdrop picture. A common old Fine Arts technique was to paste a distance scene behind a 3-D foreground, with no middle ground. The backdrop blue for Illustration 1.3, 'Floating Cubes,' was pasted behind the rendered patterned floor. Purists who object to

superimposition of rendered parts of an image can, of course, compose the entire image from 'zbuf' files. Superposition, however, saves a great amount of work and even makes feasible effects that would otherwise require prohibitive amounts of storage. A combination of means works best. Where image elements intermingle their 'zbuf' files can be combined using compabufs and then non-intermingled elements added behind by pasting.

Addpoints, Listing 8, reads object's points, plots them on the screen, then accepts user mouse-clicks indicating points to be added to the object. Although it would be possible to build an entire object using addpoints, the program is meant to be used for editing objects. For example, a few points might need to be added to fill a hole. Or, a few points added with addpoints can indicate the beginning and end of a line whose points can then be written into the ASCII points file using 'ed'. Addpoints can also be helpful in adding sub-objects when building complex objects. It will record your click of the center point coordinates of the to-be-added sub-objects. The added points file, called '-inputfilename.ap' is written to ram. To run addpoints, type at the CLI prompt:

```
addpoints object-filename
```

Addpoints requires a parameter file called 'adparams' containing the color register to be assigned the added points. Addpoints has an x-y screen and a z-y screen which give a side and front view for positioning points. You will need a top view, of the x-z plane, to position points on a shadow object, which lies in the y = 0 plane. Rather than elaborate the algorithm you can make, by a few small changes, a special version of Addpoints, which has a x-z plane and an x-y plane.

Tutorial

Follow these activities to get started running these programs. First to make a cube, use 'ed' to make up a parameter file called 'cuparams' or copy the 'cuparams' file from Table 1. Try the values:

```
100 2 0.8 0.4 0.0 260 100 560
1 8 8 100 800 360 1.0 1.0 1.0
```

Reading from left to right, top to bottom, the cube is to have side length of 100 pixels. The increment of two means only every other line will be included, it will not be opaque. It will be rotated 0.8 radians about the x-axis and 0.4 radians about the y-axis. Its center is (260,100,560). The top and bottom will have the color in register 3, front and back will have the color in register 6, and left and right side will have color in register 9. The light is at (100,800,360). (Although the cuber program doesn't have its lighter algorithm so it won't light the cube keep the parameter format intact and all ready to add the lighter code fragment to be given in Part II) All the sides will be the same length as given in the first parameter. These definitions and input format are always available in the program listing and you can keep a copy on the parameter file itself below the values. Put the 'cuparams' file in the same directory as cuber. At the CLI prompt type:

```
cuber cube
```

When 'cuber' is finished it will have written to ram: four files called cube1, cube2, cube3, and cube4.

Leave the four files in ram. Make a 'rbparams' file with the parameter values:240 200 430 1800 which will give an eye position =

(240,200,430) and will cut the ground off at z = 1800.

Next type at the CLI prompt:

```
Execute zbuffer.script zbuffer
```

The script will copy everything you need for a zbuffer run to ram: and will change directory to ram: It will report "Ready to run zbuffer" At the CLI prompt type:

```
zbuffer mycube cube1 cube2 cube3 cube4 9999
```

where 'mycube' is the name of the output rendering and zbuffer files, and '9999' is an end-of-files file.

When zbuffer is finished you will find a file called 'mycuberend' in ram. There will also be one or more files 'mycubezbuf1', 'mycubezbuf2', etc.

To save the rendered image convert it to ILM format and write it to disk. At the CLI prompt type:

```
raw2ilbm mycuberend -d1:mycuberend.pir hi 4
```

The rendering algorithm is a Z-buffer algorithm, which is much faster than ray tracing.

Copy the 'zbuf' files to another disk so you can combine them with other 'zbuf' files later.

Next, make a shadow for the cube. Shadowgen will make a patterned shadow in case the shadow falls on a patterned floor. Although we will feed shadowgen a pattern image we will trick the program into giving a shadow of color register 15. Make up a 'shparams' file with the following parameter values.



```
100 800 360
0 15 15 15 15 15 15 15 15 15 15 15 15 15 15 15
140 140
```

The parameters show the light at the same place as for the cube above. Light at (100,800,360). The string of 16 numbers map every color on the input pattern except black into color register 15. The width and height of the pattern repeat will be 168 since we will use the pattern image on disk. It has width and height of 168 pixels.

At the CLI prompt type:

```
Execute shadow.script shadowgen
```

This will copy everything you need to ram: and change directory to ram. When it is finished copying it will print:



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"Ready to run shadows"

At the CLI prompt type:

```
shadows cubeshad pattern.pic cube1 cube2 cube3 9999
```

Do not hit return until after you type '9999'

This will produce several files called 'cubeshad1', 'cubeshad2' ... etc. in ram. Run zbuffer on them as above. Use the same 'zparams' file.

And so on. You will be able to continue on your own. To find out what is needed on the command line, type the name of the program at the CLI prompt.

Try using 'compzbufs' to combine the shadow and cube 'zbuf' files. Save the rendered cube + shadow image. Make a plain floor of color in register 13. Use backer to put the floor image behind the cube + shadow image. Try out 'zfloor' on some of your own patterns which you can make in a paint program. Be sure to keep a note of the width and depth of you pattern repeats.

Biographical Sketch

Laura M. Morrison has a master's degree in mathematics from New York University, NY. She has worked as an Operations Research Analyst designing applications software for Esso R&E, Union Carbide and Eastern Airlines.

Ms Morrison studied painting at the Art Student's League in New York and the Academie Julian in Paris.

Listing 1

```
/* zbuffer.c Listing 1
Reads lighted and positioned object's points,
a color map and a point of view.
Renders the object accordingly.
Produces 'zbuf' and 'rend' files.
Copyright 1993 by Laura M. Morrison */
#include "stdio.h"
#include "libraries/dosextens.h"
#include "intuition/intuition.h"
#include "intuition/intuitionbase.h"
#include "exec/exec.h"
#include "math.h"
#define COLORBIT 32
#define DEPTH 31
#define WIDTH 640L
#define HEIGHT 400L
#define MAXPOINTS 4000L
extern struct Window *w;
extern struct RastPort *rp;
extern struct Screen *OpenScreen();
struct FileHandle *Open();
USHORT cmap[16];
SHORT *cols;
struct NewScreen newscre = {
    0, 0, 640, 400, 4, 0, 1,
```

```
MINES, FACE,
CUSTOMSCREEN, CUSTOMBITMAP,
NULL, NULL,
NULL, NULL,
};
struct Screen *scr;
struct NewWindow nw = {
    420, 70, 210, 50, 0, 1,
    CLOSEWINDOW | VANILLAKEY,
    WINDOWCLOSE | ACTIVATE | BORDERLESS | WINDOWBAG,
    NULL, NULL,
    "idemp",
    NULL, NULL,
    0, 0, 100, 50,
    CUSTOMSCREEN
};
struct Window *w;
struct BitMap *bitm;
struct RastPort *rp;
struct ViewPort *vp;
struct IntuitionBase *IntuitionBase;
struct GfxBase *GfxBase;
static WORD *aptr(400);
WORD *rouptr;
WORD *buf;
static float xl, xs, ys, zs, xe, ye, ze;
static float xs, ys, zs, xv, yv, zv;
static float xaf, yaf, zaf, inside;
char outfile[120];
char infile[120];
char str[120];
main(argc, argv)
int argc;
char *argv[];
{
    LONG ofh, afh, bfh, cfh, pfh;
    struct IntuiMessage *mess;
    LONG class;
    ULONG code;
    int row, col, cc, i, j, k;
    int count, count2, dif, number, yon;
    float xscal, yscal, zscal;
    int xeye, yeye, zeye, xobj, yobj, zobj;
    int xscr, yscr, zscr;
    int xoff, yoff, zoff, xwid, ywid, zwid;
    int dn = 999;
    WORD ryal, oldval;
    LONG planesize, bufsiz, nb = 0;
    LONG nt, colorsiz;
    FILE *fopen(), *wp, *sp, *lp, *pp;
    colorsiz = COLORBIT;
    count2 = 0;
    IntuitionBase = (struct IntuitionBase *)
        OpenLibrary("intuition.library", 0);
    if (IntuitionBase == NULL)
    {
        printf("Couldn't open Intuition library\n");
        exit(1);
    }
    GfxBase = (struct GfxBase *)
        OpenLibrary("graphics.library", 0);
    if (GfxBase == NULL)
    {
        printf("Couldn't open Graphics library\n");
        exit(2);
    }
    if (argc < 3)
```

```

{
printf(" Need name of output file and \n");
printf(" one or more object's points files, \n");
printf(" and an 'eof' file called '9999' \n");
exit(1);
}
if ((pp = fopen("zparams", "r")) == NULL)
{
printf(" Need a 'zparams' file with eye position. \n");
exit(4);
}
fscanf(pp, "%d %d %d %d", &xe, &yeye, &ze, &yobj);
fclose(pp);
printf("\n\n\n\n\n\n\n\n\n");
printf(" *");
printf("RENDER AN OBJECT/OBJECTS \n");
printf(" *");
printf(" from a Point of View \n\n");
printf(" *");
printf("Copyright 1993 by Laura M. Morrison \n");
printf("\n\n\n\n\n\n\n\n\n");
/* set up storage for the z-value of each point
on the screen. */
for (i = 0; i < HEIGHT; i++)
{
bufsize = 2*WIDTH;
zptr[i] = (WORD *)
AllocMem(bufsize, MEMF_FAST|MEMF_CLEAR);
if (zptr[i] == NULL)
{
printf("No memory for zbuffer row %d, \n", i);
goto quit;
}
}
/* set all the z values to the maximum */
for (i = 0; i < HEIGHT; i++)
{
rowptr = zptr[i];
for (j = 0; j < WIDTH; j++)
{
*(rowptr++) = yobj;
}
}
/* Set up a CustomBitMap and open a screen
to receive the rendered image. */

bitm = (struct BitMap *) AllocMem
(sizeof(struct BitMap), MEMF_CHIP);
if (bitm == NULL)
{
printf("Couldn't allocate bmap struct \n");
goto quit;
}
InitBitMap(bitm, DEPTH, WIDTH, HEIGHT);
planesize = (LONG) (WIDTH/H)*HEIGHT;
for (i = 0; i < DEPTH; i++)
{
bitm->Planes[i] = (PLANEPTR)
AllocRaster(WIDTH, HEIGHT);
if (bitm->Planes[i] == NULL)
{
printf("bitmap planes were null \n");
goto quit;
}
BitClear(bitm->Planes[i], planesize, 1);
}
newscr.CustomBitMap = bitm;

```

```

scr = (struct Screen *) OpenScreen(&newschr);
if (scr == NULL)
{
printf("scr was null \n");
goto quit;
}
rp = &scr->RastPort;
vp = &scr->ViewPort;
nw.Screen = scr;
w = OpenWindow(&rw);
if (w == NULL) goto quit;
/* Read in a special palette file called 'pal'. */
pfh = Open("pal", MODE_OLDFILE);
if (pfh != NULL)
{
cols = &cmmap[0];
nb = Read(pfh, cols, colorsize);
Close(pfh);
LoadRGB4(vp, cmmap, 16);
}
SetRast(rp, 0);
number = 1;
nextfile:
number++;
printf(" *");
printf("Now processing file %s \n", argv[number]);
dif = strcmp(argv[number], "9999");
if (dif == 0)
{
goto finish;
}
strcpy(infile, argv[number]);
zp = fopen(infile, "r");
if (zp == NULL)
{
goto nextfile;
}
readobj:
fscanf(zp, "%d %d %d %d \n",
&cc, &xobj, &yobj, &zobj);
if (cc == 13)
{
fclose(zp);
goto nextfile;
}
count++;
xe = (float)xeye;
ye = (float)yeye;
ze = (float)ze;
so = (float)zobj;
xo = (float)xobj;
yo = (float)yobj;
if ( (zo-ze) != 0 )
{
kl = -ze/(zo-ze);
xsf = kl*(xo-xe) + xe;
ysf = kl*(yo-ye) + ye;
zsf = 0.0;
xwid = WIDTH - (int)xsf;
ywld = HEIGHT - (int)ysf;
xscr = xwid;
yscr = HEIGHT - ywld;
if ( (xscr > 0) && (xscr < WIDTH)
&& (yscr > 0) && (yscr < HEIGHT) )
{
rowptr = zptr[yscr];
oldval = *(rowptr + xscr);

```

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```

if(zob) < oldval)
{
    rowptr=zptr[yacr];
    *(rowptr + xscr) = zob);
    SetAPen(rp,cc);
    WritePixel(rp,xscr,yacr);
}
}
/* end of eye inside object */
while(mess=(struct IntuiMessage *)
    GetMsg(W->UserPort)) != NULL)
{
    class = mess->Class;
    code = mess->Code;
    ReplyMsg(mess);
    if (class == CLOSEWINDOW) goto finish;
    if ((class == VANILLAREY) && (code == 'q'))
        goto quit;
}
goto readmore;
finish:
if(w)
{
    CloseWindow(w);
    w = NULL;
}
ScreenToBack(scr);
printf("\n\n\n Finished ... \n\n");
printf("      \n");
printf(" Writing output files to ram: ... \n");
strcpy(outfile,"ram");
strcat(outfile,argv[1]);
strcat(outfile,".rend");
ofh = Open(outfile,MODE_NEWFILE);
if (ofh != NULL)
{
    for ( i=0; i < DEPTH; i++)
    {
        nb = Write(ofh,bitm->Planes[i],planesize);
    }
    cols = swap[0];
    nb = Write(ofh,cols,colsize);
    Close(ofh);
}
number = 1;
count2 = 0;
itoa(number, str);
strcpy(outfile,"ram");
strcat(outfile,argv[1]);
strcat(outfile,".sbuf");
strcat(outfile,str);
wp = fopen(outfile,"w");
/* Save z values as this may not be the final
rendering of the entire picture. z values may
be needed to make a composite of two partial
renderings. */
for(row = 0; row < HEIGHT; row++)
{
    for(col = 0; col < WIDTH; col++)
    {
        rowptr = zptr[row];
        cc = HeadPixel(rp,col,row);
        zval = *(rowptr + col);
        if (cc != 0)
        {
            fprintf(wp," %d %d %d %d\n",cc,col,row,zval);

```

```

count2++;
/* When output file gets large close it and
open another. */
if(count2 > MAXPOINTS)
{
    fprintf(wp," %d %d %d %d\n",
        dn,dn,dn,dn);
    fclose(wp);
    count2=0;
    number++;
    itoa(number, str);
    strcpy(outfile,"ram");
    strcat(outfile,argv[1]);
    strcat(outfile,".sbuf");
    strcat(outfile,str);
    wp = fopen(outfile,"w");
}
}
fprintf(wp," %d %d %d %d\n",dn,dn,dn,dn);
fclose(wp);
quit:
if (w) CloseWindow(w);
if (scr)
{
    CloseScreen(scr);
    for ( i = 0; i < DEPTH; i++)
    {
        if (bitm->Planes[i] > 0)
        {
            FreeRaster(bitm->Planes[i],WIDTH,HEIGHT);
        }
    }
    if (bitm) FreeMem(bitm,sizeof(struct BitMap));
    planesize = 3*WIDTH;
    for ( i = 0; i < HEIGHT; i++)
    {
        if (scr[i])
        {
            FreeMem(scr[i],bufsize);
        }
    }
    fp = fopen("dl:fun_Notes","a");
    if (fp != NULL)
    {
        fprintf(fp,"\n\n %s %s \n", argv[0],argv[1]);
        fprintf(fp," %d %d %d %d\n",xyye,yeye,zeye,yoni);
        fclose(fp);
    }
    if (IntuitionBase) CloseLibrary(IntuitionBase);
    if (GfxBase) CloseLibrary(GfxBase);
} /* end of main */
/* itoa is from Kernighan and Ritchie
C Programming */
itoa(int, str);
char str[11];
int ntr;
{
    int c, j, i, sign;
    if ((sign = ntr) < 0)
        ntr = -ntr;
    i=0;
    do {
        str[i++] = ntr % 10 + '0';

```

```

} while ((int) /= 10) > 0);
if (isign < 0)
    str[i++] = '-';
str[i] = '\0';
for (i = 0, j = strlen(str); i < j; i++, j--)
{
    c = str[i];
    str[i] = str[j];
    str[j] = c;
}
return(0);
}

```

Listing 2

```

/* compobjs.c Listing 2
Combines 'zbuf' files.
Copyright 1993 by Laura M. Morrison */
#include "stdio.h"
#include "libraries/dosextms.h"
#include "intuition/intuition.h"
#include "intuition/intuitionbase.h"
#include "exec/exec.h"
#include "math.h"
#define COLONIZE 32
#define BUFSIZE 32000L
#define DEPTH 4L
#define WIDTH 640L
#define HEIGHT 400L
#define MAXPOINTS 4000L
extern struct FastPart *rp;
extern struct Screen *OpenScreen();
struct FileHandle *Open();
USHORT cmap[16];
USHORT *color;
struct NewScreen newscr = {
    0, 0, 640, 400, 4, 0, 1,
    HINES/LACE,
    CUSTOMSCREEN/CUSTOMBITMAP,
    NULL, NULL,
    NULL, NULL,
};
struct Screen *scr;
struct BitMap *bitm;
struct FastPart *rp;
struct ViewPort *vp;
struct IntuitionBase *IntuitionBase;
struct GfxBase *GfxBase;
static WORD zval, midval;
static WORD *zptr[400];
WORD *rowptr;
WORD *buf;
static int yon, zobj;
char delfile[120];
char outfile[120];
char infile[120];
char str[120];
main(argc, argv)
int argc;
char *argv[];
{
    LONG ofh, pfh;

```

```

int count, row, col, cc, i, j, *z;
int dummy, dif, number, count2;
int xobj, yobj, zobj, xscr, yscr, zscr;
int dn = 999;
LONG planesize, bufsize, nb = 0, nt;
LONG nt, valuesize, success;
FILE *fopen(), *fp, *ap, *lp, *pp, *wp;
colorsize = COLONIZE;
yon = 20000;
if (argc < 3)
{
    printf("Need name of output file, then '\n");
    printf("names of one or more 'zbuf' files,\n");
    printf("then an 'eof' file called '9999'\n");
    exit(10);
}
IntuitionBase = (struct IntuitionBase *)
    OpenLibrary("intuition.library", 0);
if (IntuitionBase == NULL)
{
    printf("Couldn't open Intuition library\n");
    exit(1);
}
GfxBase = (struct GfxBase *)
    OpenLibrary("graphics.library", 0);
if (GfxBase == NULL)
{
    printf("Couldn't open Graphics library\n");
    exit(2);
}
printf("\n\n\n\n\n\n\n\n\n");
printf("      ");
printf("MERGE ZBUFFEN FILES\n");
printf("      ");
printf("Copyright 1993 by Laura M. Morrison\n");
printf("\n\n\n\n\n\n\n\n\n");
bitm = (struct BitMap *)
    AllocMem(sizeof(struct BitMap), MEMF_CHIP);
if (bitm == NULL)
{
    printf("couldn't allocate bitmap struct\n");
    goto finish;
}
InitBitMap(bitm, DEPTH, WIDTH, HEIGHT);
planesize = (LONG) (WIDTH * 8 * HEIGHT);
for (i = 0; i < DEPTH; i++)
{
    bitm->Planes[i] = (PLANEPTH)
        AllocRaster(WIDTH, HEIGHT);
    if (bitm->Planes[i] == NULL)
    {
        printf("bitmap planes were null\n");
        goto finish;
    }
    BltClear(bitm->Planes[i], planesize, 1);
}
newschr.CustomBitMap = bitm;
scr = (struct Screen *) OpenScreen(&newschr);
if (scr == NULL)
{
    printf("scr was null\n");
    goto finish;
}
fp = fopen(argv[1], "r");
vp = &scr->ViewPort;
pfh = Open("pal", MODE_OLDFILE);

```

```

if (pfn != NULL)
{
    cols = &cmmap[0];
    nb = Read(pfn, cols, colorsize);
    Close(pfn);
    LoadRGB4(vp, cmmap, 16);
}
SetRGB4(vp, 0, 0, 0, 0);
SetRast(rp, 0);
/* Set up a buffer to save a z value
for each screen pixel. */
for(i = 0; i < HEIGHT; i++)
{
    bufsize = Z*WIDTH;
    zptrl[i] = (WORD *)AllocMem(bufsize,
                                MEMF_FAST|MEMF_CLEAN);
    if(zptrl[i]==NULL)
    {
        printf("No memory for row %d\n", i);
        goto quit;
    }
}
for(i = 0; i < HEIGHT; i++)
{
    rowptr = zptrl[i];
    for(j = 0; j < WIDTH; j++)
    {
        *(rowptr++) = yon;
    }
}
number = 1;
nextzbuf:
number++;
printf("      ");
printf("Processing file %s \n", argv[number]);
dif = strcmp(argv[number], "9999");
if(dif==0)
{
    goto finish;
}
strcpy(infile, argv[number]);
ap = fopen(infile, "r");
if(ap==NULL)
{
    printf("Couldn't find 'zbuf' %s ... \n");
    goto nextzbuf;
}
readmorea:
fscanf(ap, " %d %d %d %d\n",
        &cc, &col, &row, &zobj);
if(cc > 997)
{
    fclose(ap);
    ap = NULL;
    goto nextzbuf;
}
rowptr = zptrl[row];
oldval = *(rowptr + col);
if(zobj < oldval)
{
    rowptr = zptrl[row];
    *(rowptr + col) = zobj;
    SetAPen(rp, cc);
    WritePixel(rp, col, row);
}
goto readmorea;
finish:

```

```

ScreenToBack(scr);
printf("\n\n      ");
printf("Finished ... writing output files.\n");
printf("\n\n\n\n\n");
strcpy(outfile, "ram:");
strcat(outfile, argv[1]);
strcat(outfile, "end");
ofh = Open(outfile, MODE_NEWFILE);
if (ofh != NULL)
{
    for (i=0; i < DEPTH; i++)
    {
        nb = Write(ofh, bits->Planes[i].planesize);
        cols = &cmmap[0];
        nb = Write(ofh, cols, colorsize);
        Close(ofh);
    }
    number = 1;
    count2 = 0;
    itoa(number, str);
    strcpy(outfile, "ram:");
    strcat(outfile, argv[1]);
    strcat(outfile, "zbuf");
    strcat(outfile, str);
    wp = fopen(outfile, "w");
    printf("      ");
    printf("Writing output file %s \n", outfile);
    for(row = 0; row < HEIGHT; row++)
    {
        for(col = 0; col < WIDTH; col++)
        {
            rowptr = zptrl[row];
            cc = ReadPixel(rp, col, row);
            zval = *(rowptr + col);
            if (cc != 0)
            {
                fprintf(wp, " %d %d %d %d\n", cc, col, row, zval);
                count2++;
            }
            /* when output file gets large close it
            and open another. */
            if (count2 > MAXPOINTS)
            {
                fprintf(wp, " %d %d %d %d\n",
                        dn, dn, dn, dn);
                fclose(wp);
                wp = NULL;
                count2=0;
                number++;
                itoa(number, str);
                strcpy(outfile, "ram:");
                strcat(outfile, argv[1]);
                strcat(outfile, "zbuf");
                strcat(outfile, str);
                wp = fopen(outfile, "w");
                if(wp==NULL)
                {
                    goto quit;
                }
                else
                {
                    printf("      ");
                    printf("Writing output file %s \n",
                            outfile);
                }
            }
        }
    }
} /* start a new file */

```



```

    } /* cc not zero */
}
fprintf(wp, " %d %d %d %d \n", dm, dm, dm, dm);
fclose(wp);
wp = NULL;
quit:
if (lap) fclose(lap);
if (wp) fclose(wp);
if (scr)
{
    CloseScreen(scr);
    for (i = 0; i < DEPTH; i++)
    {
        if (bitm->Planes[i] > 0)
        {
            FreeRaster(bitm->Planes[i], WIDTH, HEIGHT);
        }
    }
    if (bitm) FreeMem(bitm, sizeof(struct BitMap));
}
bufsize = 2*WIDTH;
for(i = 0; i < HEIGHT; i++)
{
    if(zptr[i])
    {
        FreeMem(zptr[i], bufsize);
    }
}
fp = fopen("GfxRun_States", "a");
if (fp != NULL)
{
    fprintf(fp, "\n");
    for(i = 0; i < number; i++)
    {
        fprintf(fp, " %s ", argv[i]);
    }
    fclose(fp);
}
if (IntuitionBase) CloseLibrary(IntuitionBase);
if (GfxBase) CloseLibrary(GfxBase);
} /* end of main */
/* itoa is from Kernighan and Ritchie */
itoa(n, str)
char str[];
int nt;
{
    int c, j, i, sign;
    if ((sign = nt) < 0)
        nt = -nt;
    i=0;
    do {
        str[i++] = nt % 10 + '0';
    } while ((nt /= 10) > 0);
    if (sign < 0)
        str[i++] = '-';
    str[i] = '\0';
    for (i=0, j=strlen(str)-1; i<j; i++, j--)
    {
        c = str[i];
        str[i]=str[j];
        str[j] = c;
    }
    return(0);
}

```

Listing 3

```

/* shadowgen.c: Listing 3.
Generates points for the shadow
on the floor of an input object.
Copyright 1993 by Laura M. Morrison */
#include "stdio.h"
#include "libraries/dosextens.h"
#include "intuition/intuition.h"
#include "intuition/intuitionbase.h"
#include "exec/exec.h"
#include "math.h"
#define COLORSTE 32L
#define DEPTH 4L
#define WIDTH 640L
#define HEIGHT 400L
#define MAXPOINTS 4000L
/* map1[] and map2[] assign color registers to points
given a color id number from one to forty-five. More
explanation in Part II of this article. */
static int map1[] = { 0, 1, 2, 3, 4, 5, 6, 7,
                    8, 9, 10, 11, 12, 13, 14, 15,
                    1, 2, 3, 1, 2, 3, 1, 2, 3, 1, 2, 3,
                    4, 5, 6, 4, 5, 6, 4, 5, 6, 7, 8, 9,
                    7, 8, 9, 10, 11, 12 };
static int map2[] = { 0, 1, 2, 3, 4, 5, 6, 7,
                    8, 9, 10, 11, 12, 13, 14, 15,
                    4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
                    8, 9, 10, 11, 12, 13, 14, 15, 10, 11, 12,
                    14, 15, 13, 14, 15 };
#include "colordi0";
USHORT *i;
extern struct Screen *scr;
struct Screen newscr = {
    0, 640, 400, 0, 1,
    HIBS/LACK,
    CUSTOMSCREEN, 0, 0, BITMAP,
    NULL, /* Converting libm image to raw format */
    NULL, NULL,
};
struct Screen *scr;
SHORT *cols;
extern struct RastPort *rp;
struct FileHandle *Opm();
struct BitMap *bitm;
struct RastPort *rp;
struct ViewPort *vp;
struct IntuitionBase *IntuitionBase;
struct GfxBase *GfxBase;
static int wx, wx, ccc, cpat;
static int xlit, ylit, zlit;
static int row, col, i, j, k;
static int r, count2, number, number2;
static int dn, dazw;
static int cobj, subj, yobj, zobj;
static int cshd, xshd, yshd, rshd;
static char turav[120];
static char infile[120];
static char outfile[120];
static char delfile[120];

```

```

static char str[120];
main(argc, argv)
int argc;
char *argv[];
{
    LONG hfh, pfh;
    int dir, incr, id, row, col, cov;
    int yen, repwidth, repheight;
    int pcol, prow;
    int i, j, sum, rem, colorid;
    FILE *fopen[]; *sp, *pp, *vp, *lp;
    LONG sb, nt, colorsize, planesize;
    colorize = COLORIZE;
    db = 999;
    if (argc > 4)
    {
        printf("Need name of output shadow. %s");
        printf(" and name of floor pattern file.\n");
        printf(" and names of object files. %s");
        printf(" and last, '999', 'eof' file.\n");
        exit(10);
    }
    IntuitionBase = (struct IntuitionBase *)
        OpenLibrary("intuition.library", 0);
    if (IntuitionBase == NULL)
    {
        printf("Couldn't open Intuition library\n");
        exit(10);
    }
    GfxBase = (struct GfxBase *)
        OpenLibrary("graphics.library", 0);
    if (GfxBase == NULL)
    {
        printf("Couldn't open Graphics library\n");
        CloseLibrary(IntuitionBase);
        exit(10);
    }
    if ((fp = fopen("shparams", "r")) == NULL)
    {
        printf("Need a 'shparams' file with:\n");
        printf(" Light positions: xlit, ylit, zlit, %s");
        printf(" Color remaps for 16 registers. %s");
        printf(" Width and height of pattern repeat.\n");
        exit(1);
    }
    fscanf(fp, "%d %d %d %s", &xlit, &ylit, &zlit);
    /* Use numbers 0 through 15 on the parameter file for no
    change of color from input pattern repeat.
    for ii = 0; i < 16; i++)
    {
        fscanf(fp, "%d %s", &dummy);
        colorid[i] = dummy;
    }
    fscanf(fp, "%d %d %s", &repwidth, &repheight);
    fclose(fp);
    printf("\n\n COLOR MAP: ");
    for ii = 0; i < 16; i++)
    {
        dummy = colorid[i];
        printf("%d %s", dummy);
    }
    printf("\n\n\n\n\n\n\n\n");
    printf(" ");
    printf("GENERATE SHADOW OF AN OBJECT\n");
    printf(" ");
    printf("Copyright 1993 by Laura M. Morrison");
}

```

```

printf("\n\n\n\n\n\n\n\n");
Delay(100);
planesize = (LONG) (WIDTH/R)*HEIGHT;
bits = (struct BitMap *)
    AllocMem(sizeof(struct BitMap), MEMF_CHIP);
if (bits == NULL)
{
    printf("No memory for bitmap structure.\n");
    goto quit;
}
InitBitMap(bits, DEPTH, WIDTH, HEIGHT);
for (i=0; i < DEPTH; i++)
{
    bits->Planes[i] = (PLANETYPE)
        AllocRaster(WIDTH, HEIGHT);
    if (bits->Planes[i] == NULL)
    {
        printf("Bitmap planes were null\n");
        goto quit;
    }
    BitClear(bits->Planes[i], planesize);
}
newscr.CustomBitMap = bits;
scr = (struct Screen *) OpenScreen(&newscr);
if (scr == NULL)
{
    printf("scr was null\n");
    goto quit;
}
rp = &scr->RastPort;
vp = &scr->ViewPort;
/* convert the floor pattern to row format */
strcpy(toraw, "lineDraw");
strcat(toraw, argv[2]);
Execute(toraw, 0, 0);
strcpy(infile, argv[2]);
strcat(infile, ".hl4");
/* read in floor pattern */
if (fopen(infile, MODE_OCTFILE);
if (f == NULL)
{
    printf("Can't open image input file\n");
    goto quit;
}
for (i=0; i < DEPTH; i++)
{
    sb = Read(hfh, bits->Planes[i], planesize);
}
cols = &crap[0];
sb = Read(hfh, cols, colorsize);
Close(hfh);
strcpy(idelfile, "delete");
strcat(idelfile, infile);
Execute(idelfile, 0, 0);
Delay(100);
/* Read 'pal' file if available to assign a new palette.
Optional. Program to make 'pal' files will be given in
Part II of this article. */
gfh = Open("pal", MODE_OCTFILE);
if (gfh != NULL)
{
    cols = &crap[0];
    sb = Read(gfh, cols, colorsize);
    Close(gfh);
    LoadRGB4(vp, crap, 16);
}
Delay(100);
}

```

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```

number = 1;
count2=0;
itoa(number, str);
strcpy(outfile, "ram");
strcat(outfile, argv[1]);
strcat(outfile, str);
ScreenToBackscr();
wp = fopen(outfile, "a");
numberin = 2;
nextfile:
numberin++;
dif = strcmp(argv[numberin], "9999");
if (dif == 0)
    goto finish;
strcpy(infile, argv[numberin]);
ap = fopen(infile, "r");
if(ap==0)
    goto nextfile;
printf("Processing file %s\n", argv[numberin]);
readhere:
fscanf(ap, "%d %d %d %d\n",
        &cx, &xobj, &yobj, &zobj);
if(cx > 997)
    fclose(ap);
    goto nextfile;
/* find the shadow of this point */
yshad = 0;
if( (yobj-ylit) != 0)
{
xshad = xlit - ((ylit*yobj)-ylit*xlit)/(yobj-ylit);
zshad = zlit - ((ylit*zobj)-ylit*zlit)/(yobj-ylit);
/* Get the shadow color, even if the shadow falls on a
patterned ground. */
if (xshad < 0)
    {
        wx = -xshad;
        pcol = wx % repwidth;
        pcol = repwidth - pcol;
    }
else if(xshad==0)
    {
        pcol = 0;
    }
else
    {
        pcol = xshad % repwidth;
    }
    prow = zshad % repheight;
    cpnt = headPixel(rp, pcol, prow);
/* Now have the pattern color's register number. */
dummy = color[cpnt];
/* The pattern color may be a mixture. */
sum = prow + pcol;
rem = sum % 2;
if(rem == 1)
    {
        cshad = map[dummy];
    }
else
    {
        cshad = map[dummy];
    }
}

```

```

/* Now have point's object color. */
fprintf(wp, "%d %d %d %d\n",
        cshad, xshad, yshad, zshad);
count2++;
/* Keep the output file under MAXPOINTS size */
if(count2 > MAXPOINTS)
    {
        fprintf(wp, "%d %d %d %d\n", dn, dn, dn, dn);
        fclose(wp);
        count2=0;
        number++;
        itoa(number, str);
        strcpy(outfile, "ram");
        strcat(outfile, argv[1]);
        strcat(outfile, str);
        wp = fopen(outfile, "a");
        Delay(10);
        printf(" ... Writing file %d\n", number);
    }
/* end of shad calc */
goto readnext;
finish:
fp = fopen("dfi:Run_Notex", "a");
if (fp != NULL)
    {
        fprintf(fp, "\n\n %s %s %s\n",
                argv[0], argv[1], argv[2]);
        fprintf(fp, "light = (%d,%d,%d) ", xlit, ylit, zlit);
        fflush(fp);
        fprintf(wp, "%d %d %d %d\n", dn, dn, dn, dn);
        fclose(fp);
    }
quit:
scr =
    {
        int i = 0; i < DEPTH; i++)
        {
            if (bits->planes[i] == 0)
                FreeMem(bits->planes[i], WIDTH, HEIGHT);
        }
        if (bits) FreeMem(bits, sizeof(struct BitMap));
    }
if (IntuitionBase) CloseLibrary(IntuitionBase);
if (GfxBase) CloseLibrary(GfxBase);
} /* end of main */
/* this is from Kernighan and Ritchie */
itoa(int, str);
char str[];
int nt;

int c, j, i, sign;
if ((i = sign = nt) < 0)
    nt = -nt;
i=0;
do {
    str[i++] = nt % 10 + '0';
} while ((nt /= 10) > 0);
if (sign < 0)
    str[i++] = '-';
str[i] = '\0';
for (i=0, j=strlen(str)-1; i<j; i++, j--)
    {

```

```

c = str[i];
str[i]=str[i+1];
str[i+1] = c;
}
return 0;
}

```

Listing 4

```

/* rfloor.c Listing 4
Reads floor pattern, generates points for fall floor,
lights points, renders floor. Note: This version does
not include the lighting code which will be given in Part
II of this article.
Copyright 1993 by Laura M. Morrison */
#include "stdio.h"
#include "libraries/dosextern.h"
#include "intuition/intuition.h"
#include "intuition/intuitionbase.h"
#include "exec/exec.h"
#include "math.h"
#define COLGNSZ 32L
#define DEPTH 4L
#define WIDTH 640L
#define HEIGHT 400L
#define MAXPOINTS 4000L
/* Zone[] will be needed for the lighting code
to be added in Part II. */
static float zone[] = { 0.0,
0.02618, 0.05236, 0.07854, 0.10472, 0.13090,
0.15708, 0.18326, 0.20944, 0.23562, 0.26180,
0.28798, 0.31416, 0.34034, 0.36652, 0.39270,

0.41888, 0.44506, 0.47124, 0.49742, 0.52360,
0.54978, 0.57596, 0.60214, 0.62832, 0.65450,
0.68068, 0.70686, 0.73304, 0.75922, 0.78540,

0.81158, 0.83776, 0.86394, 0.89012, 0.91630,
0.94248, 0.96866, 0.99484, 1.02102, 1.04720,
1.07338, 1.09956, 1.12574, 1.15192, 1.17810,
1.20428, 1.23046, 1.25664, 1.28282, 1.30900,

1.33518, 1.36136, 1.38754, 1.41372, 1.43990,
1.46608, 1.49226, 1.51844, 1.54462, 1.57080 };
/* "maps" let you change color register numbers */
static int map1[] = { 0, 1, 2, 3, 4, 5, 6, 7,
8, 9, 10, 11, 12, 13, 14, 15,
1, 2, 3, 1, 2, 3, 1, 2, 3,
4, 5, 6, 4, 5, 6, 4, 5, 6,
7, 8, 9, 7, 8, 9, 10, 11, 12 };
static int map2[] = { 0, 1, 2, 3, 4, 5, 6, 7,
8, 9, 10, 11, 12, 13, 14, 15,
4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,
7, 8, 9, 10, 11, 12, 13, 14, 15,
10, 11, 12, 13, 14, 15, 13, 14, 15 };
static int colid[16];
USHORT cmap[16];
extern struct Window *w;
extern struct Screen *scr;
extern struct Screen *scr2;
/* Set up one input and one output screen. */
struct NewScreen newscre = {
0.0,640,400,4,0,1,

```

```

HIRES)LACE,
CUSTOMSCREEN(CUSTOMBITMAP,
NULL, "Converting ilbm image to raw... ",
NULL,NULL,
};
struct Screen *scr;
struct NewWindow nw = {
420,30,210,50,0,1,
CLOSEWINDOW|VANILLAKEY,
WINDOWCLOSE|ACTIVATE|ORDERLESS|WINDOWMAG,
NULL, NULL,
"icomp",
NULL, NULL,
0.0,100,50,
CUSTOMSCREEN
};
struct Window *w;
struct NewScreen newscre2 = {
0.0,640,400,4,0,1,
HIRES)LACE,
CUSTOMSCREEN(CUSTOMBITMAP,
NULL,NULL,
NULL,NULL,
};
struct Screen *scr2;
SHORT *colo;
extern struct RastPort *rp;
extern struct RastPort *rp2;
struct FileHandle *Open();
struct BitMap *bitc;
struct BitMap *bitm;
struct RastPort *rp;
struct RastPort *rp2;
struct ViewPort *vp;
struct ViewPort *vp2;
struct IntuitionBase *IntuitionBase;
struct GfxBase *GfxBase;
struct WORD *rptr(400);
struct *cmap;
static int *map;
static int *ki, *k, *xlr, *yfir, *zlf;
static float *rowf, *yeyef, *seyef, *rowf, *colf;
static int *xlr, *zlf, *xlr, *wz, *wz;
static int *cc, *rpat, *cob;
static int *mbj, *ybj, *mbj;

```



The complete set of listings and source code, along with the illustrations and tables mentioned in the article can be found on the AC TECH disk.

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StateMachine

by J.T. Steichen

StateMachine is intended to allow an Amiga programmer to create finite state machines with a graphical user interface, rather than generate the program by hand. StateMachine does not generate the action functions associated with the finite state machine. This is up to the user of StateMachine.

A state machine is a program that executes a given function (the action) when a given input is supplied (the state), then it moves to another state (the next state) and waits for more input. This input is supplied by a user-supplied function that essentially is a lexical analyzer-generator (scanner). A 'scanner' takes an input file and breaks it up into lexemes (i.e., keywords, whitespace, punctuation, etc). Based on the type of lexeme, it returns a value to the finite state machine, which in this case, is called the State. The state machine generated uses re-directed I/O for input, therefore, usage of your state machine program will be:

```
your_statemachine <input_definition_file> <output_source_file>
```

NOTE: you decide if the output is redirected by how you define your output functions!

In a way, your computer itself is a large state machine, with instructions serving as lexemes, execution of the instructions serving as actions, and the operating system determining what the next state of the PC is!

So when exactly would a programmer use a finite state machine instead of something straightforward, like a large case statement or a series of if-then-else constructs? For those of you who have examined a simple Microsoft Windows 3.x program, you will notice that all data communications between the operating system and a windows application is done via messages. Hundreds of them! Every WinMain() function has to have a large case statement (or call a function that does) in order to cover every message that the program will respond to. Even for simple programs, this case statement can be quite large!

Intuition also uses messages, sent to the IDCMPort attached to all open windows.

Fortunately, Intuition has fewer messages to contend with, so it's much easier to use case statements for deciding what the user is doing with the GUI. Unfortunately, the IDCMP message values are not in a linear sequence! This rules out using finite state machines for the GUI decoding (IDCMP message values are powers of two. This means a finite state machine might have a very large (2^{32}) next-state,action matrix with very few used elements. This is known as a sparse matrix).

If IDCMP message values were linear, this is how a IDCMP message decoder could be constructed using a finite state machine:

FROM TYPICAL IDCMP MESSAGE LOOP:

```

while (looping == TRUE)
{
  if (lmessage = (struct IntuiMessage *)
      GetMsg( my_window->device )) == NULL)
  {
    (void) Wait( 1L == my_window->msg_flags );
    continue;
  }
  mclass = lmessage->Class;
  mcode = lmessage->Code;
  (void) ReplyMsg( lmessage );
  switch (mclass)
  {
    case MESSAGEWINDOW:
      DecodeMouseEvent( mcode );
      break;
    case MESSAGE:
      DecodeMouseEvent( MESSAGE mcode );
      break;
    case GADGETUP:
      DecodeGadgetSelection( mcode );
      break;
    case MESSAGE:
      UpdateGraphics();
      break;
  }
}

```

```

case MESSAGEWINDOW:
  UpdateGraphics();
  break;
case MESSAGE:
  /* CheckMouseEvent() if there is one */
  DoMouseEvent();
  looping = FALSE;
default:
  break;
}

```

CHANGED INTO A FINITE STATE MACHINE:

```

while (looping == TRUE)
{
  if (lmessage = (struct IntuiMessage *)
      GetMsg( my_window->device )) == NULL)
  {
    (void) Wait( 1L == my_window->msg_flags );
    continue;
  }
  State = lmessage->Class;
  mcode = lmessage->Code;
  (void) ReplyMsg( lmessage );
  (*IDCMP_FunctionTable[ mcode ])( State );
  looping = (*IDCMP_FunctionTable[ mcode ])( State );
}

```

As you can see, the code is much simpler, but much harder to trace and debug!

The places a programmer might find uses for finite state machines are file translators, interpreters, or compilers. This means that you could create a programming language of your own, for example, a simple interpreted language that uses Amiga graphics functions to draw shapes, etc. This is precisely what I have chosen for my example—take a look at Example.fsm, which reads simple graphic instructions from an input file and executes them. Example recognizes the following instructions:

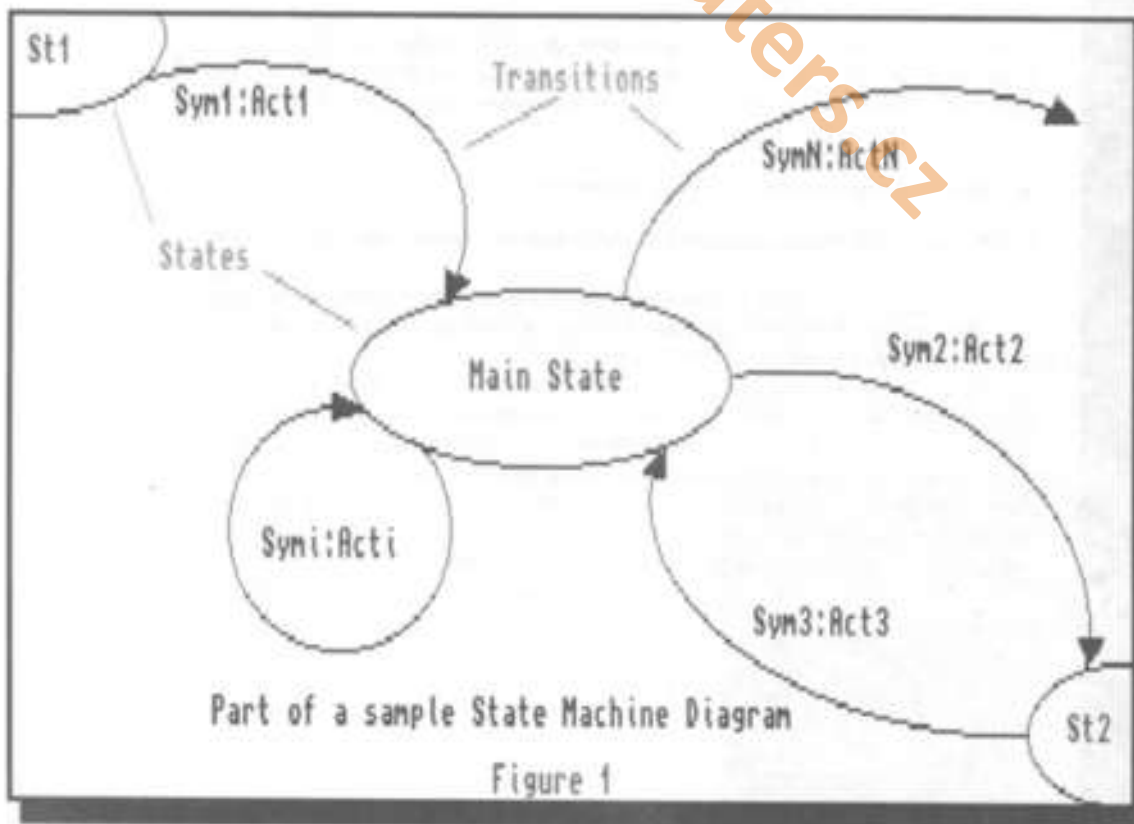


Table 1

Done, Cleanup, Begin, OpenGraph, Error, RptErr,	Begin, Ignore, DefMove, Ignore, Begin, Ignore,	Begin, Ignore, DefDraw, Ignore, Begin, Ignore,	Begin, OpenGraph, DefColor, Ignore
Error, RptErr, Error, RptErr, DefColor, StowNum,	DefColor, Ignore, Error, RptErr, DefColor, Ignore,	Begin, ChgColor, Error, RptErr, DefColor, Ignore,	Error, RptErr, Error, RptErr,
Error, RptErr, Error, RptErr, DefMove, StowNum,	DefMove, Ignore, Error, RptErr, DefMove, Ignore,	Begin, MoveFunc, Error, RptErr, Begin, Ignore,	Error, RptErr, Error, RptErr,
Error, RptErr, Error, RptErr, DefDraw, StowNum,	DefDraw, Ignore, Error, RptErr, DefDraw, Ignore,	Begin, DrawFunc, Error, RptErr, Begin, Ignore,	Error, RptErr, Error, RptErr,
Done, Cleanup, Begin, OpenGraph, Error, RptErr,	Begin, Ignore, DefMove, Ignore, Begin, Ignore,	Begin, Ignore, DefDraw, Ignore, Begin, Ignore,	Begin, OpenGraph, DefColor, Ignore,
Done, Cleanup, Error, RptErr, Done, Cleanup,	Done, Cleanup, Error, RptErr, Done, Cleanup,	Done, Cleanup, Error, RptErr, Done, Cleanup,	Error, RptErr, Error, RptErr,

```

LORR);
COLOR begt, redd, green, black);
NOTE 18, 19);
DRAW 18, 19);
    
```

The first thing a programmer has to figure out is what lexemes the scanner must recognize and return to the finite state machine. For the example, the scanner must recognize:

```

numbers, commas, semicolons, whitespace, newlines, "LORR", "COLOR",
"MOVE", "DRAW" and EOF.
    
```

Next, the programmer must decide what to do when the scanner returns a given lexeme. These are the action functions that will be placed into the action, next-state table. Some actions are always going to be needed, these are:

```

state(), ignore(), error();
    
```

The following actions are added to Example:

```

DrawNum, DrawFunc, MoveFunc, OpenGraph, ChgColor and Cleanup as well as RptErr
and Ignore.
    
```

Start up the StateMachine program and wait for the Transition Editor to complete initializing. Select Add from the Actions menu and enter the following actions into the requester by typing the string into the string gadget and pressing the Add button gadget:

```

Ignore, RptErr, StowNum, DrawFunc, MoveFunc, OpenGraph, ChgColor, and Cleanup.
    
```

After all strings show up in the list gadget, click on the 'Done Adding' button. Once you are back in the Transition Editor, select Add from the Symbols menu. Enter the following strings into the string gadget in the same manner as you used for the Actions:

```

RedFile, WhiteSpace, Semicolon, White, Green, Move, Draw, Color, Number,
Comma, EndLine.
    
```

NOTE: These are entered in this order since the generated finite state machine expects to see the values as the scanner defines them. Only the Symbols and NextState, Actions entries are order-dependent.

Return to the Transition Editor and select Add from the States menu. Enter the following state names into the requester in the same manner as used on the Actions and Symbols:

```

Begin, DefColor, DefMove, DefDraw, Error, and Done.
    
```

Return to the Transition Editor and get ready to do the major task of entering in the NextState, Actions

name pairs. This can be done by first double-clicking on the State name and then double-clicking on the Action name that you want to appear in the list. StateMachine doesn't care how many newlines are in the NextState,Actions list, so space them so that you can read them (See Table 1).

After all NextState,Actions are entered into the list gadget, we are ready to enter the prologue and code sections of the Example state machine. Press the 'Goto Prolog Editor' Gadget and wait for the prolog editor. Enter the following:

```
#include <stdio.h>
#include <string.h>
#include <stdbool.h>
#include <graphics/gtututilib.h>
void ignore(); /* Your compiler will complain if
```

these are not here: */

```
void getErr();
void getState();
void getState();
void MoveFast();
void OpenDialog();
void ChgColor();
void CleanUp();
```

NOTE: All code is already typed in Example.fsm and Example.c

Finally, we are ready for the Code Editor. Press the 'Goto Code Editor' button. Enter the following C source code into the list gadget:

```
extern char *lstr; /* defined in the caller */
int linesout = 0; /* used for error reporting */
void ignore();
```

```
{
if (!strcmp(lstr, "GO"))
linesout++;
return;
}
```

```
{
void getErr();

fprintf(stderr, "ERROR in input stream:\n");
fprintf(stderr, "Found on line %d\n", linesout);
return;

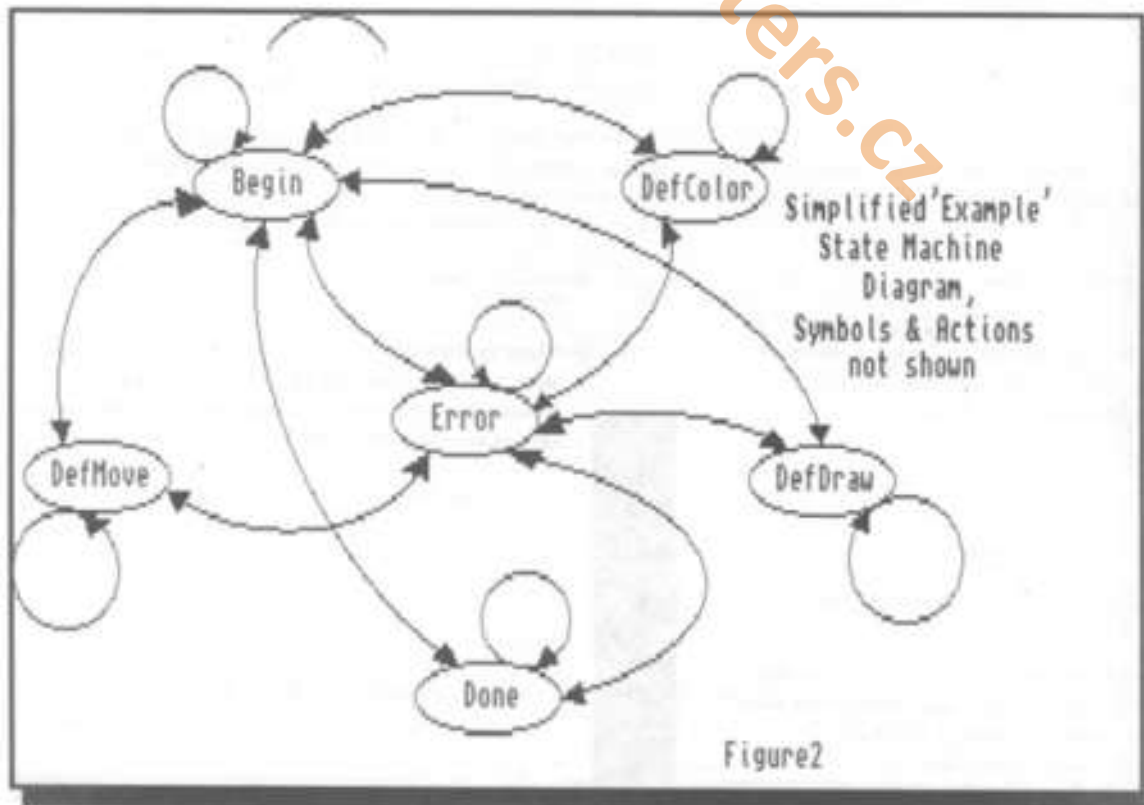
struct DefScreen ds = {
2, 2, 440, 300, 8, DEFV, DEFV, WARS, CUSTOMSCREEN,
NULL, (BYTE *) "StateMachine Example:", NULL, NULL
};

struct DefWindow dw = {
0, 0, 440, 300, DEFV, DEFV, CLOSINGDOWN,
WINDOWCLOSE | ACTIVATE | SMART_REFRESH,
NULL, NULL, (BYTE *) "StateMachine Example:",
NULL, NULL, 20, 20, 440, 300, CUSTOMSCREEN
};

extern struct Initialization *initlibbase;
struct GState gsbase;
struct Window *example_window = NULL;
struct Screen *example_screen = NULL;
void OpenDialog();

if (strcmp(lstr, "CORE") == 0)
{
no-ViewWdbe = 0;
no-Depth = 0;
no-Width = 300;
no-Height = 200;
no-Width = 300; /* Make window larger also! */
no-Height = 200;
no-maxWidth = 300;
no-maxHeight = 300;
}

if (!initlibbase = (struct Initialization *)
OpenLibrary("intutilib.library", 0) == NULL)
return;
if (!gsbase = (struct GState *)
OpenLibrary("graphics.library", 0) == NULL)
{
CloseLibrary(initlibbase);
return;
}
if (!example_screen = (struct Screen *) OpenScreen(lstr) == NULL)
{
CloseLibrary(gsbase);
CloseLibrary(initlibbase);
}
```




```

    return;
}

sw_Screen = example_screen;
IF ( !example_window = (struct Window *) OpenWindow( andbit () == NULL)
{
    CloseScreen( example_screen );
    CloseLibrary( statebase );
    CloseLibrary( intaltimbase );
    return;
}
return;
}

int main() = 1, -1, -1, -1, -1, 0 );
void DrawFunc() /* Atom numbers for DrawFunc, MoveFunc and
ObjColor */

return int win( char * );
for index = 0;
while ( !done[ index ] );
index++;
done[ index ] = atoi( idstr );
return;

void DrawFunc()
IF ( !example_window != NULL)
Draw( example_window->port, done[0], done[1] );
done[0] = done[1] = -1;
return;

void MoveFunc()
IF ( !example_window != NULL)
Move( example_window->port, done[0], done[1] );
done[0] = done[1] = -1;
return;

void ObjColor()
return struct Viewport *ViewPortAddress( struct Window * );
IF ( !example_window != NULL)
{
    SetRGB( ViewPortAddress( example_window ), done[0], done[1],
done[2], done[3] );
    SetApen( example_window->port, done[0] );
}
done[0] = done[1] = done[2] = done[3] = -1;
return;
}

#define TRUE
#define FALSE
#endif

void Cleanup()
int
Checking = TRUE;
ulong
class = 0;
struct IntuiMessage *message = NULL;
char
all[256], *title = ambl[0];

IF ( !example_window == NULL)
goto SkipLoop;
strcpy( title, sw_title );
strcat( title, " Click on close window gadget to EXIT" );
setWindowTitles( example_window, title, NULL );

while (Checking == TRUE)
{
    IF ( !message = (struct IntuiMessage *)
GetMsg( example_window->port )) == NULL)
    {
        (void) Wait( 1L ); // example_window->port->wp_right );
        continue;
    }
    class = message->class;
    (void) ReplyMsg( message );
    switch( class )
    {
        case CHILDWINDOW:
            Checking = FALSE;
            break;
        default:
            break;
    }
}

SkipLoop:
    IF ( !example_window != NULL)
    CloseWindow( example_window

```

```

IF ( !example_screen != NULL)
CloseScreen( example_screen );
IF ( !statebase != NULL)
CloseLibrary( statebase );
IF ( !intaltimbase != NULL)
CloseLibrary( intaltimbase );
return;
}

```

Now, return to the Transition Editor by pressing the 'Done Editing' gadget. Select Save As from the Project menu and save your new state machine source code. Finally, select 'Generate FSM' from the Project menu. This will turn your definition file into C-source code that can be compiled into an executable program, once it is linked with the scanner. That's all there is to producing finite state machines!

NOTES:

The files included with StateMachine are as follows:

- FSM_Aux - Do NOT change the name of this file!
- StateMachine.lff - Title screen, Do NOT change the name of this file!
- StateMachine - The executable program, Do NOT change the name of this program!
- StateMachine.info - Do NOT change the name of this file!
- C-FSMGen - The Finite State Machine generator program, Do NOT change the name of this program! It can be placed in any directory you wish as long as the ToolTypes in the icon are changed to reflect its location. Change CmdDirectory=C: to wherever you locate FSMGen.
- FSMTest - A test input file.
- FSMTest.IdealOutput - what FSMGen should produce from FSMTest!
- FSM_Manual - Description of gadgets and menus in StateMachine.
- SMArticle - Description of what StateMachine does, along with a tutorial.
- Makefile.SMake file for the Lattice C compiler to work on Example.
- Example.fsm - tutorial state machine definition file.
- Example.c - the output of FSMGen when Example.fsm is supplied.
- Example.flex - a tutorial state machine scanner definition file.
- ExampleLex.c - the output of FLEx when Example.flex is supplied.
- TestEx.input - input file for checking and debugging Example program.

It is interesting to note that FSMGen is itself a finite state machine. It was generated from a more primitive version of itself!

The StateMachine GUI was created with CanDo V2.0. I recommend CanDo highly since it cuts down on how much C code I have to write in order to make an effective Amiga-based program.

StateMachine was inspired by a couple of articles in the *C User's Journal* entitled:

'Building a Finite State Machine' by R. Ward, *C User's Journal*, February 1989, pgs. 94-99.

'A Finite State Machine Generator' by R. Ward, *C User's Journal*, April 1989, pgs. 101-107.

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Volume 3, Number 3

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To unarchive a file foo.lzh, type *lharc x foo*

For help with lharc, type *lharc ?*

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Unfortunately, the code in the articles didn't work, and since it was intended to be portable, it certainly didn't make use of the Amiga's graphical user interface capabilities. My rewrite of the code from these articles corrects both of these deficiencies. FSMGen, which is based on these articles, was created from a crude working version of the articles' code and a more complex lexical analyzer (the scanner). FSMGen uses a unique syntax of its own for the input definition file, which actually generates the C source code, which is subsequently compiled by you, the user. You don't have to remember what this syntax is, since StateMachine generates the definition file for you. The syntax is similar to what LeX and YACC use for their definition files.

LeX - Lexical analyzer-generator program, a UNIX programming tool. There is a public-domain program called Flex, available on Fred Fish disk #407 that works real well (be sure that the source code skeleton files don't get mixed up with the skeleton files that have to be included in your lexical analyzer, the file names are similar). YACC - Yet Another Compiler Compiler, a UNIX programming tool. There is a public-domain program called Bison, available on a Fred Fish disk also, that does the same thing as YACC.

example.c

```

/* Start of Prologue */

/* FSMGen Source file written by StateMachine */
/* Copyrighted 1992, by J. T. Steichen.  */

/
.....
** USAGE: Example <input_file>
**
** WARNINGS: Since all scanners generated by Flex used
re-directed input.
** This Example program can only be run from
the CLI properly!
** (unless you want to type the input_file by
hand!)
**
** See the MakeFile for info on how to turn Example.fsm
into Example.
**
** See the Article for the syntax that Example expects to
see in the
** input file.
.....

#include <stdio.h>
#include <string.h>
#include <osac/types.h>
#include <intuition/intuitionbase.h>

void Ignore();
void RptErr();
void ShowNum();
void DrawFunc();
void MoveFunc();

```

```

void OpenGraph();
void ChgColor();
void Cleanup();

/* Bottom of Prologue */

/* Start of Transition Table */

struct Transitions {
    int      nextstate;
    void     (*act)(void);
};

/* Defines for Symbol names: */

#define EMPTY      -1
#define EndFile  0
#define WhiteSpace  1
#define SemiColon  2
#define Hifen     3
#define LoRes     4
#define Move_     5
#define Draw_     6
#define Color     7
#define Number    8
#define Comma     9
#define EndLine  10

/* Defines for State names: */

#define Begin     0
#define DefColor  1
#define DefMove  2
#define DefDraw  3
#define Error     4
#define Done     5
#define STOP     5

struct Transitions fsm_table[11][11] = {

/*
EndFile      WhiteSpace      SemiColon
Hifen        LoRes           Move_         Draw_
Color        Number          Comma         EndLine
*/

/* Begin */
Done ,Cleanup, Begin ,Ignore ,Begin ,Ignore ,Begin
,OpenGraph,
Begin ,OpenGraph, DefMove,Ignore ,DefDraw,Ignore ,
DefColor,Ignore ,
Error ,RptErr ,Begin ,Ignore ,Begin ,Ignore ,

/* DefColor */
Error ,RptErr , DefColor,Ignore ,Begin ,ChgColor, Error
,RptErr ,
Error ,RptErr , Error ,RptErr , Error ,RptErr , Error
,RptErr ,
DefColor,ShowNum, DefColor,Ignore , DefColor,Ignore ,

/* DefMove */
Error ,RptErr , DefMove,Ignore ,Begin ,MoveFunc, Error

```

```

, RptErr,
Error ,RptErr, Error ,RptErr, Error ,RptErr, Error
,RptErr,
DefMove, StopRun, DefMove, Ignore, Begin, Ignore,

/* DefDraw */

Error ,RptErr, DefDraw, Ignore, Begin, DrawFunc, Error
,RptErr,
Error ,RptErr, Error ,RptErr, Error ,RptErr, Error
,RptErr,
DefDraw, StopRun, DefDraw, Ignore, Begin, Ignore,

/* Error */

Done ,Cleanup, Begin, Ignore, Begin, Ignore, Begin
,OpenGraph,
Begin ,OpenGraph, DefMove, Ignore, DefDraw, Ignore,
DefColor, Ignore,
Error ,RptErr, Begin, Ignore, Begin, Ignore,

/* Done */

Done ,Cleanup, Done ,Cleanup, Done ,Cleanup, Error
,RptErr,
Error ,RptErr, Error ,RptErr, Error ,RptErr, Error
,RptErr,
Done ,Cleanup, Done ,Cleanup, Done ,Cleanup

}

typedef int FSTYPE;

static int mstate, token;

/* Code for FSM Start_Function() */

FSTYPE main()
{
    mstate = Begin;
    token = EMPTY;

    do {
        token = yylex();
        (*fsm_table[mstate][token]).act();
        mstate = fsm_table[mstate][token];
    } while (mstate != STOP);

    return 0;
}

/* Start of Code Section: */

extern char *idstr;

int linecount = 0;

void Ignore()
{
    if (idstr[0] == '\n')
        linecount++;
    return;
}

void RptErr()

```

```

{
    fprintf(stderr, "ERROR in input stream!\n");
    fprintf(stderr, "Found on line %d\n", linecount);
    return;
}

struct NewScreen ns = {
    0, 0, 640, 300, 4, 0x00, 0x00, HINES, CUSTOMSCREEN,
    NULL, (UBYTE *) "StateMachine Example:", NULL, NULL
};

struct NewWindow nw = {
    0, 0, 640, 300, 0x00, 0x00, CLOSERWINDOW,
    WINDOWCLOSE | ACTIVATE | SMART_REFRESH,
    NULL, NULL, (UBYTE *) "StateMachine Example:",
    NULL, NULL, 20, 20, 640, 300, CUSTOMSCREEN
};

extern struct IntuitionBase *IntuitionBase;
struct GfxBase *GfxBase = NULL;

struct Window *example_window = NULL;
struct Screen *example_screen = NULL;

void OpenGraph()
{
    if (strcmp(idstr, "LORES") == 0)
    {
        ns.ViewModes = 0;
        ns.Depth = 3;
        ns.Width = 320;
        ns.Height = 300;
        nw.Width = 320; /* Make window LORES also! */
        nw.Height = 300;
        nw.Width = 320;
        nw.Height = 300;
    }

    if ((IntuitionBase = (struct IntuitionBase *)
        OpenLibrary("intuition.library",
        0)) == NULL)
        return;
    if ((GfxBase = (struct GfxBase *)
        OpenLibrary("graphics.library", 0))
        == NULL)
    {
        CloseLibrary(IntuitionBase);
        return;
    }
    if ((example_screen = (struct Screen *) OpenScreen(&ns))
        == NULL)
    {
        CloseLibrary(GfxBase);
        CloseLibrary(IntuitionBase);
        return;
    }
    nw.Screen = example_screen;
    if ((example_window = (struct Window *) OpenWindow(&nw))
        == NULL)
    {
        CloseScreen(example_screen);
        CloseLibrary(GfxBase);
        CloseLibrary(IntuitionBase);
        return;
    }
}

```

```

return;
}

int main() = { -1, -1, -1, -1, -1, 0 };

void StdFunc()
{
extern int atoi(char *);

int index = 0;

while (nums[index] == 0)
index++;
nums[index] = atoi(str);
return;
}

void DrawFunc()
{
if (example_window != NULL)
Draw(example_window->WPort, nums[0], nums[1]);
nums[0] = nums[1] = -1;
return;
}

void MoveFunc()
{
if (example_window != NULL)
Move(example_window->WPort, nums[0], nums[1]);
nums[0] = nums[1] = -1;
return;
}

void ChgColor()
{
extern struct ViewPort.*ViewPortAddress; struct Window
* ;

if (example_window != NULL)
{
SetRGB4(ViewPortAddress(example_window), nums[0],
nums[1],
nums[2], nums[3]);
SetXPort(example_window->WPort, nums[0]);
}
nums[0] = nums[1] = nums[2] = nums[3] = -1;
return;
}

#ifdef TRUE
#define TRUE 1
#define FALSE 0
#endif

void Cleanup()
{
int Checking = TRUE;
ULONG class = 0;
struct IntuiMessage *message = NULL;
char null[256], *title = &null[0];

if (example_window == NULL)
goto SkipLoop;
strcpy(title, mw.Title);
strcat(title, " Click on close window gadget to EXIT!");
SetWindowTitles(example_window, title, NULL);
}

```

```

while (Checking == TRUE)
{
if (message = (struct IntuiMessage *)
GetMsg(example_window->UserPort))
== NULL)
{
(void)Wait(1L == example_window->UserPort-
wp_Signit);
continue;
}
class = message->Class;
(void)ReplyMsg(message);
switch(class)
{
case CLOSINGWINDOW:
Checking = FALSE;
break;
default:
break;
}
}

SkipLoop:

if (example_window != NULL) CloseWindow(
example_window);
if (example_screen != NULL) CloseScreen(
example_screen);
if (GfxBase != NULL) CloseLibrary(GfxBase);
if (IntuitionBase != NULL) CloseLibrary(
IntuitionBase);
return;
}
/* End of Code Section! */

```

example.flex

```

%
*****
** Example.flex: The lexical analyzer for the
** StateMachine example
**
** PROGRAM:
**
** MAKE WITH:
**
** Flex -s -p -v -l Example.flex
** Verbose lex.yy.c ExampleLex.c
** %C notatackcheck data-far ignore=108,161
** %directory INCLUDE: ExampleLex.c
**
*****
%
%
#include <string.h>
#include <stdio.h>

#define POP_ 0
#define WHITE 1

```

```

#define SEMICOLON 3
#define HIRES 3
#define LORES 4
#define MOVE 5
#define DRAW 6
#define COLOR 7
#define NUMBER 8
#define COMMA 9
#define EOL 10

char NIL[256], *idstr = &NIL[0];
int i = 0;

#ifdef EXAMPLE_DEBUG

int main(void)
{
    int tokval = 0;

    tokval = yylex();
    while (tokval >= 0)
    {
        switch (tokval)
        {
            case EOL:      fprintf(stderr, "%s", idstr);
                          break;
            case WHITE:   fprintf(stderr, "%s", idstr);
                          break;
            case HIRES:   fprintf(stderr, "%s", idstr);
                          break;
            case LORES:   fprintf(stderr, "%s", idstr);
                          break;
            case EOP_:    fprintf(stderr, "End of
File!\n");
                          return 0;
            case SEMICOLON: fprintf(stderr, "%s", idstr);
                          break;
            case MOVE:   fprintf(stderr, "%s", idstr);
                          break;
            case DRAW:   fprintf(stderr, "%s", idstr);
                          break;
            case COLOR:  fprintf(stderr, "%s", idstr);
                          break;
            case COMMA:  fprintf(stderr, "%s", idstr);
                          break;
            default:     fprintf(stderr, "intokval =
%d\n", tokval);
                          fprintf(stderr, "idstr =
%s\n", idstr);
                          break;
        }
        tokval = yylex();
    }
    return 0;
}

```

```

#endif /* EXAMPLE_DEBUG */

}

}

{ idstr[0] = '\n';
  idstr[1] = '\0';
  return EOL;
}

{ i = 0;
  while (*(yytext + i) == ' ')
  {
      idstr[i] = ' ';
      i++;
  }
  idstr[i] = '\0';
  return WHITE;
}

{ i = 0;
  while (*(yytext + i) == 'r')
  {
      idstr[i] = 'r';
      i++;
  }
  idstr[i] = '\0';
  return WHITE;
}

{ idstr[0] = 'r';
  idstr[1] = '\0';
  return SEMICOLON;
}

{ strcpy(idstr, "HIRES");
  return HIRES;
}

{ strcpy(idstr, "LORES");
  return LORES;
}

{ strcpy(idstr, "MOVE");
  return MOVE;
}

{ strcpy(idstr, "DRAW");
  return DRAW;
}

{ strcpy(idstr, "COLOR");
  return COLOR;
}

{ strcpy(idstr, ",");
  return COMMA;
}

{ sscanf(yytext, "%d", idstr);
  return NUMBER;
}

{ sscanf(yytext, "%s", idstr);
  return NUMBER;
}

{ sscanf(yytext, "%s", idstr);
  return NUMBER;
}

{ return EOP_; }

}

```

(continued on page 62)

Programming in PostScript

PostScript Programming

PostScript is a programming language that is of major importance to virtually every piece of productivity software in existence, yet few programmers know anything about it. To be sure it is not the new challenger to 'C', BASIC or ARexx. Yet PostScript is running on computers around the world that incorporate the very latest of technologies and fastest processors. PostScript came in the back door, and will always stay there since it is the language of printers and graphics. But every major professional-level productivity application has to use PostScript to generate high quality output. The time has come for you to take the plunge. Join me then in this three-part voyage into the world of PostScript.

What is It?

What is PostScript? "The PostScript language is a simple interpretive programming language with powerful graphics capabilities. Its primary application is to describe the appearance of text, graphical shapes, and sampled images on printed or displayed pages." This is the concise definition given in *The PostScript Language Reference Manual* from Adobe Systems Incorporated. So what does that mean in real life? PostScript is a full programming language that is specially designed for describing how a printed page or display will be rendered. When I say full programming language I mean that all the normal operators for math, string manipulation, I/O, and even stack manipulation are present.

But what does describing a page mean? To most programmers, writing the command `lineto(10,20)` means draw a line from the current point to the point at 10,20. The command executes the same way in nearly all circumstances and is essentially the same as the rendering. In PostScript there are similar commands, but the environment is different. When a `lineto` command is given, the only assumption is that relative to the rest of the image a line of some sort will be rendered to some point that is relatively known as 10,20. With PostScript it is assumed that the drawing commands that are originally given will be modified, possibly at several levels before being rendered to some device. That device may be a screen, slide maker, imagesetter, or laser printer. The device may be able to render color, grayscale, or simply black and white. The idea is that the description (the drawing commands) are independent of the file output device.

In fact a `lineto` does not even cause a line to be rendered. Instead it adds a segment to an overall path. A path is a list of the drawing commands that were used to create it. A path then

can be used to draw an outline, fill a shape, clip to a shape, or even be used to place shapes along it. In PostScript, the creation of an object and its rendering are well removed from each other.

Another facet of PostScript that is important to mention is that it is an interpreted language. From a practical standpoint this means that PostScript can be very slow. It also means that PostScript does not really run programs in the traditional sense. Instead the PostScript interpreter accepts commands and executes them. When there are no more commands it waits around. Getting to the end of a list of commands does not cause anything to happen, like a page printing for instance. This works out well because this allows one piece of PostScript code to be included inside another without any changes. As we will see this is a very important feature.

Under the Hood

Now that we know a little about the ideas behind PostScript, let's look at it from a programmer's standpoint. PostScript is a stack-oriented interpreted language not unlike FORTH. This means that as items are sent to the interpreter, they are placed on a stack until they are used. The stacks are Last in First Out (LIFO). When a command is encountered it takes items off the stack and places the results (if any) back on the top of the stack. For instance the 'C' command `x = 4 + 5`, would result in the PostScript code `/x 5 4 add def`. The `/x` places the variable `x`'s name on the stack. The `5` and `4` wait on the stack until the `add` operator replaces them with `9`. Then the `def` operator accepts a value then a name (remember, last in first out) and binds the name to that value. The `def` command does not generate a result so the stack is now back to the state it was before the example.

A look inside the PostScript Language

by Dan Weiss

This stack works much the same as the stack used by high level languages for passing parameters. The differences are that you have no access to the stack pointer, and virtually everything is handled via the stack as opposed to variables. To help out with using the stack, PostScript includes the following stack manipulation commands: pop, exch, dup, copy, index, roll, clear, count, mark, cleartomark, counttomark. These operators all work on the operand stack. The operand stack is the one used in the example, and the one used by most PostScript operators. There are, however, other stacks—the dictionary stack, execution stack, and graphics state stack.

Hello, World

Now that we understand the basics of how PostScript works, let's write the PostScript equivalent of the infamous "Hello, World" program. In PostScript we draw a box.

```
newpath
100 100 moveto
200 100 lineto
200 200 lineto
100 200 lineto
100 100 lineto
stroke
showpage
```

If you have access to a PostScript printer, or a clone like POST, then stop and enter the program. If you did it right you should have generated a square about 1.5" inches from the bottom left corner, and it should be about 1.5" square. For those without printers or POST, the box looks like this. Congratulations, you just wrote your first piece of PostScript software. Let's take a quick look at it.

The first command newpath always needs to be called when there is no existing path. This initializes the current path to be empty. Now that path has been initialized, we have to give a starting point so we send down 100 100 moveto. The lineto commands work pretty much as expected, but remember, they do not cause a line to be drawn, they simply add to the path. When we get back to the starting point the path is complete, but it still needs to be rendered. The stroke command causes the path to be drawn with the current line width, dash pattern, color or gray, miter limit, join, and cap. The stroke operator consumes the path as part of its operation, and initializes the path like the newpath operator does. At this point the stroked path is sitting in the image buffer, but not yet

printed. The final command in our example, showpage, forces the page to be printed.

Congratulations, you've completed your first PostScript program. Now let's go back and improve it. The first thing to do is add commands so that we can set the thickness of the path that strokes the rectangle. The stroke is always centered on the path and is rendered according to the current settings, even if the settings were different when the path was created. The operator that sets line thickness is called setlinewidth. It expects an number that is in decimal points (1/72th of an inch). To set a quarter-inch thick line for the box, we need to add 18 setlinewidth to our code at some point prior to the stroke command. Since the setlinewidth operator does not affect the building of the path, it is customary to place it right before the stroke command. So now our code looks like this:

```
newpath
100 100 moveto
200 100 lineto
200 200 lineto
100 200 lineto
100 100 lineto
18 setlinewidth
stroke
showpage
```

Now when we send the code down to the printer we get a box that looks like this. Notice the cutout in the lower left corner? This results from the way PostScript draws thick lines. In the default mode it starts at the start of the path and stops at the end of the path. Stopping at the end of the path leaves the cutout. We need the stroke to go a little further. The distance is equal to half the thickness of the stroke. But compensating for it in the program would be a nightmare as the distance is different if the lines meet at other than 90 degrees to each other.

But as mentioned before, PostScript is a language designed for graphics. Obviously this is a serious problem, so there is a specific answer, the closepath operator. The closepath operator is used in place of the last lineto. This tells PostScript to connect the current point to the first point and treat the join as if it were just another join in the path. This way the box ends up looking like we expect it no matter how thick the line is.

Next we want to fill the box with gray. Let's take the code we have so far and replace the stroke command with a fill operator. Additionally we will use the setgray operator to set

the level of gray we want. The setgray operator defines white as 1 and black as 0. So a dark gray is any number less than .5 and a light gray is above .5. In effect we are setting the percentage of white in the "ink" we will be using. Adding the setgray operator we have:

```
newpath
100 100 moveto
200 100 lineto
200 200 lineto
100 200 lineto
closepath
18 setlinewidth
.75 setgray
fill
showpage
```

The setlinewidth command does nothing in this case, but doesn't hurt anything so we leave it in. The result of the code is a light gray box.

Now let's tackle the big task, rendering a box with both a stroke and a fill. The simple answer would seem to be to add the stroke command back after the fill command. But if we do that the printer will only image the filled box. This is so because the path that was filled was consumed by the fill operator before the stroke operator could use it. Since there was nothing to stroke, nothing happened. There are two solutions, both of which work. The first is to describe the path again before using the stroke operator; this has the unfortunate side effect of doubling the size of the code. The second answer is to take advantage of the graphics stack. To do this we need two new operators, gsave and grestore. The gsave operator tells PostScript to save a copy of everything about the current graphics state on the graphics stack, except the graphics rendered so far. The current path is one of the things saved, so we can use it twice with the following code:

```
gsave
18 setlinewidth
stroke
grestore
.75 setgray
fill
```

When the grestore operator is executed, the original version of the current path is restored, even though the stroke command consumed it. An important facet of PostScript programming is to make your code as short as possible, and the gsave/grestore combination is a powerful tool in achieving that goal. With the new gsave/grestore code, our project looks like this:

```
newpath
100 100 moveto
200 100 lineto
200 200 lineto
100 200 lineto
```

```
closepath
gsave
18 setlinewidth
stroke
grestore
.75 setgray
fill
showpage
```

But if we swap the order of the fill and stroke, along with their support commands the output is changed.

This points out a very important feature/limitation of PostScript. Once a path has been rendered to the image buffer, it is there to stay. It can not be changed or manipulated in anyway, but it can be overwritten. In this respect PostScript is much like a paint program.

In Comparison to C

Now that we are familiar with the basic operators and have a bit of a feel for how paths and graphics work, let's compare PostScript to 'C'. First off 'C' is a compiled language whereas PostScript is interpreted. The major repercussions of this is that PostScript is slower, but does not need to be compiled. The second difference is that PostScript uses a stack-based system to pass data to all its operators, even procedures. The third difference is that there is no concept of the entire source or object file being located somewhere. While there is looping, there are no labels or goto operators of any sort. A PostScript file is processed as it is received.

Other than these major differences, PostScript has much in common with other high level languages. As mentioned above, PostScript is designed to describe graphics, and that it does do well.

Bigger and Better Things

Back to our sample code. Since we are mimicking the classic "Hello World" program, our code should say "Hello World" also. To do this we need to use some font-related operators. Due to the way PostScript handles fonts, this is likely to be much different that you are use to.

To image text, we must first find, scale, and set a font. The first operator, findfont, accepts the name of a font and tries to find it. If it can, it will place the instructions for the font on the dictionary stack. If it can not find the font, it will place the default font on the stack (usually Courier) and report an error. The instructions that are placed on the font stack are for a one-point (1/72th of an inch) version of the font. Since this is usually too small, we need to enlarge the font with the scalefont operator. The scalefont operator accepts a point size from the operand (main) stack and a font from the dictionary stack, if either is missing an error will occur. The results of the scalefont operator is a scaled version of the font replaces the original one-point version on the dictionary stack. Now we are ready to use the font. Finally we use the setfont operator to pull the scaled font off of the fonts stack and use it as the current font. With the current font set, we can use the show

operator to render some text. The show operator accepts a PostScript string (surrounded by `()`) and does nothing but render the text in the image buffer according to the current settings, much like fill. But wait, where do we want the text to go? Using a moveto we can place the text inside the box. The following is the current code:

```
newpath
100 100 moveto
200 100 lineto
200 200 lineto
100 200 lineto
closepath
gsave
18 setlinewidth
stroke
grestore
.75 setgray
fill
/Helvetica findfont
18 scalefont
setfont
104 143 moveto
0 setgray
(Hello World) show
showpage
```

Notice that we have to use the setgray operator to set the current gray to black. If we don't, the text will render the same gray as the box fill and not be visible.

Take Control

Text and graphics are the heart of what most people need PostScript for, but it's by no means all there is to PostScript. There are also operators that offer a certain amount of control over the execution of the operators. The first is the if operator. Much as you would expect it allows for the conditional execution of code. But we also said that there is no concept of blocks of code floating around, so how does it work? Using curly braces `{}` we can encapsulate a series of operands and operators and pass them as a block to the if operator. If we wanted to write only a line of text when the top of the operand stack is negative, we would write:

```
dup 0 lt {(Negative) show} if
```

Of course we may want to do something else if the number is positive, so we would use the ifelse operator and write the following:

```
dup 0 lt? {(Negative) show} {(Positive) show} ifelse
```

What is happening is that the interpreter treats the code in `{}` as a single object on the operand stack. Essentially it is a black box. When the if or ifelse operator decides which one to execute, it takes the code out of the braces and passes it to the interpreter.

There are also operators for looping—`for`, `repeat`, and `loop`. The `repeat` and `loop` operators are very similar in that they take a procedure, like the `if` operator, and have it executed repeatedly. In the case of `repeat`, a count is passed along with the operator. The `loop` operator executes until an exit operator is used. By comparison, `for` works more like a traditional `for` loop. A starting value, incrementing value and limit value are passed with the procedure. The control value is incremented, placed on the stack, and the code is executed until the limit value is reached. The placing of the current index on the stack is quite useful in many cases. For example, to add all the numbers from one to ten using each operator would take the following code to leave the answer on the stack:

```
0 1 1 10 [add] for
```

```
0 0 10 [exch 1 add dup 3 1 roll add] repeat exch pop
```

```
0 0 [exch 1 add dup dup 10 gt [exit] if 3 1 roll add] loop pop pop
```

This would seem to make a strong case for the `for` operator, but there are times when each operator has its strengths.

Looking back over the article, you can see that PostScript is very different from the programming languages you may be accustomed to. While we have not covered all of the drawing operators, you can also see why PostScript is said to describe a page rather than just drawing one. In the next part of this series we will look at how you can use PostScript with your program by constructing a PostScript header. In the final part of the series we will examine in detail the most widely-used PostScript header, the one for *Adobe Illustrator 88*, and how you can make use of it.

If you would like to know more about PostScript, I would highly recommend that you pick up the *PostScript Language Reference Manual, Second Edition*, and the *PostScript Language Tutorial and Cookbook*. The first book is the definitive specification of the PostScript language and the second is an excellent guide to learning PostScript.



Please write to:
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—Nee Correction continued from page 4

```

moveq.b #1,a4
move.b \1(a4),d1
beq.s 1112\@
add.b d1,d0
cmpi.b #50,d1
beq.s 1112\@
addq.b #1,a4
1112\@
move.b \2(a4),d1
beq.s 1113\@
add.b d1,d0
cmpi.b #50,d1
beq.s 1113\@
addq.b #1,a4
1113\@
move.b \3(a4),d1
beq.s 1114\@
add.b d1,d0
cmpi.b #50,d1
beq.s 1114\@
addq.b #1,a4
1114\@
move.b \4(a4),d1
beq.s 1115\@
add.b d1,d0
cmpi.b #50,d1
beq.s 1115\@
addq.b #1,a4
1115\@
divu aa,d0
cmp.b diff,d0
bgt.s 1116\@
add.b gg,d0
bra.s testdone\@
1116\@
moveq.b #50,d0
bra.s testdone\@
dead\@
moveq #0,d0
testdone\@
move.b d0,(a5)+
endm

pset macro
move.l rp,a1
move.w across,d0
add.w #xoff,d0
move.w down,d1
add.w #yoff,d1
ext.l d0
ext.l d1
gfxlib writepixel
endm

color macro
move.l rp,a1
gfxlib setapen
endm

array macro
move.l #size,d0
move.l #010004,d1
syscall allocmem
move.l d0,l1
beq \2
endm

```

```

everpc macro
ds.w 0
endm

start:
move.l sp,stack
move.l a0/d0,-(sp)
address,length
open_libs:
openlib intuition,intbase,dow
openlib graphics,gfxbase,close_int

set_up:
make_screen:
openscreen syscreen,screen,close_libs
openwindow mywindow>window,close_screen
move.l d0,a0
movea.l ww,rport(a0),a1
move.l a1,rp
movea.l window,a0
intlil viewportaddress
move.l d0,vp
moves.l d0,a0
lea color_table,a1
moveq #16,d0
gfxlib loadrgb4

movea.l rp,a1
move.l #jan2,d2
gfxlib setdrnd
get_bit_planes:
movea.l rp,a1
movea.l 4(a1),a1
lea bp1,a0
move.l 8(a1),(a0)+
move.l 12(a1),(a0)+
move.l 16(a1),(a0)+
move.l 20(a1),(a0)+
move.l 24(a1),(a0)

memory:
array #array1,close_window
move.l d1,a1
array #array2,close_out

randm:
syscall forbid
lea $df000,a5
movea.l rp,a1
movea.l gfxbase,a6
moveq #0,down
r1 move.w 6(a5),d4
moveq #0,across
r2 move.w 6(a5),d3
add.w d1,d4
add.b across,d4
cmpi.b #50,d4
bhi.s r2
move.b d4,d0
move.b d4,sum
cmpi.b #0,d0
beq.s r2color
arr.b #2,d0
addq.b #1,d0
r2color
color
pset
move.b sum,(a4)+
swap d4

```

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```

addq.w %1,across
cmp.w %1en,across
bne.s r1
addq.w %1,down
cpl.w %1en,down
bne.s r1

get_rll_input
move.l (qpl)+,a0/d0 ;parameter location
movea.l a0,a5
move.l d0,d7 ;# of characters
subq %1,d7
beq.s default ;no parameters
move.b (a5)+,d0 ;get first value
subi.b #130,d0 ; and normalize it
lea 1(a5),a5 ;skip space or comma
subq #2,d7 ;2 less characters to read
move.b (a5)+,d1 ;get second value
subi.b #130,d1 ; and normalize it
lea 1(a5),a5 ;skip space or comma
subq #2,d7 ;2 less characters
move.b (a5)+,d2 ;get next value
subi.b #130,d2 ; and normalize
subq #1,d7 ;last character?
beq.s clidone ;branch if no
move.w #10,d3 ;that was 1's digit
andi.w #10f,d2 ;clear rest of bits
mulu.w d3,d2 ;times 10
add.b (a5),d2 ;add 1's digit
subi.b #130,d2 ; and normalize
bra.s clidone

default: ;use default values
move.b #2,d0 ;K1
move.b #1,d1 ;K2
move.b #5,d2 ;C0

clidone:
move.b d0,k1
move.b d1,k2
move.b d2,gg
moveq.b #50,d0
sub.b gg,d0
move.b d0,diff ;10-gg
lea.l bpl,a0

dhwiti:
ulleft ;upper-left; cell 0
movea.l array1,a4
movea.l array2,a5
moveq #0,d0
move.b (a4),d0 ;its value
test len*lenml,leml,1,1en

trow ;cells 1 - (lenqth-2)
movea.l array1,a4
lea 1(a4),a4 ;cell 1
movea.l array2,a5
lea 1(a5),a5
moveq #0,across
move.w #lenm3,across ;number of times
tr1
moveq #0,d0
move.b (a4),d0
test (len*lenml)-1,1,1en
lea 1(a4),a4
dbf across,tr1

uright ;upper-right; cell length-1
movea.l array1,a4
lea lenml(a4),a4
movea.l array2,a5

```

```

lea lenml(a5),a5
moveq #0,d0
move.b (a4),d0
test len*lenml,-1,mlenml,1en

leftside
movea.l array1,a4
lea len(a4),a4
movea.l array2,a5
lea len(a5),a5
moveq #0,down
move.w #lenml,down
lal
moveq #0,d0
move.b (a4),d0
test mlen,leml,1,1en
lea lenml(a4),a4 ;move to
lea lenml(a5),a5 ; rightside
moveq #0,d0
move.b (a4),d0
test mlen,-1,mlenml,1en
lea 1(a4),a4
dbf down,lal

llft ;lower-left
movea.l array1,a4
lea len*lenml(a4),a4
movea.l array2,a5
lea len*lenml(a5),a5
moveq #0,d0
move.b (a4),d0
test mlen,leml,1,1en*lenml

lrow ;bottom row
movea.l array1,a4
lea (len*lenml-1)(a4),a4
movea.l array2,a5
lea (len*lenml-1)(a5),a5
moveq #0,across
move.w #lenm3,across
brow
moveq #0,d0
move.b (a4),d0
test mlen,-1,1en*mlenml
lea 1(a4),a4
dbf across,brow

lright ;lower-right
movea.l array1,a4
lea lenml*lenpl(a4),a4
movea.l array2,a5
lea lenml*lenpl(a5),a5
moveq #0,d0
move.b (a4),d0
test mlen,-1,mlenml,1en*mlenml

center ;center square
movea.l array1,a4
lea lenpl(a4),a4
movea.l array2,a5
lea lenpl(a5),a5
moveq #0,down
moveq #0,across
move.w #lenm3,down
l1
move.w #lenm3,across
c1
moveq #0,d0
move.b (a4),d0
test mlen,-1,1,1en

```

```

lea    1(a4),a4
dbf    across,c1
lea    2(a4),a4
lea    3(a5),a5
dbf    down,l2

switch                                ;for slower computers
move.l array1,a4
move.l array2,a5
move.w #lenn1,down
s1 move.l #len/4-1,across
s2 move.l (a5)+,(a4)+
dbf    across,s2
dbf    down,s1

;
movea.l array1,a4
movea.l array2,a5
movea.l bp1,a1
lea    byte(a1),a1
move.l #lenn1,down
qp5
moveq  #wpl,across    ;length/32-1
qp4
moveq  #51f,d2       ;fill all 32 bits
qp3
move.b (a5)+,sum
; move.b sum,(a4)+
cmpi.b #0,sum
beq.s  qp1
asr.b  #2,sum
addq.b #1,sum
qp1
asr.b  #1,sum        ;1st color bit to x
roxl.l #1,d3        ; and to d3
asr.b  #1,sum        ;2d color bit to x
roxl.l #1,d4        ; and to d4
asr.b  #1,sum        ;3d color bit to x
roxl.l #1,d0        ; and to d0
asr.b  #1,sum        ;4th color bit to x
roxl.l #1,d1        ; and to d1
dbf    d2,qp3        ;do 32 times
move.l d1,$5dc0(a1) ;all 4th color bits
move.l d0,$3e80(a1) ;all 3d color bits
move.l d4,$1f40(a1) ;all 2d color bits
move.l d3,(a1)+     ;all 1st color bits
dbf    across,qp4
lea    byteoff(a1),a1
dbf    down,qp5

loop
btst  #6,$bfe001    ;pressed LMB?
bne  showit        ;branch if not

syslib permit
close_mem:
movea.l array2,a1
move.l #size,d0
syslib freemem
close_out:
movea.l array1,a1
move.l #size,d0
syslib freemem
close_window:
movea.l window,a0
intlbr closewindow
close_screen:
movea.l screen,a0
intlbr closescreen
close_libs:
movea.l gfxbase,a1

```

```

syslib closelibrary
close_int:
movea.l intbase,a1
syslib closelibrary
done:
move.l stack,sp
rta

evenpc

stack    dc.l 0
gfxbase dc.l 0
intbase  dc.l 0
screen   dc.l 0
window   dc.l 0
xp       dc.l 0
yp       dc.l 0
array1   dc.l 0
array2   dc.l 0
bp1      dc.l 0
bp2      dc.l 0
bp3      dc.l 0
bp4      dc.l 0
bp5      dc.l 0
k1       dc.b 0
evenpc
k2       dc.b 0
evenpc
g0       dc.b 0
evenpc
diff     dc.b 0
evenpc

graphics dc.b 'graphics.library',0
evenpc
intuition dc.b 'intuition.library',0
evenpc

;open
dc.w 0,0,320,200,depth
dc.b 0,1
dc.w customscreen
dc.l 0,0,0,0
evenpc
#window
dc.w 0,0,320,200
dc.b 0,1
dc.l mousebuttons
dc.l borderless|activate|rbn
dc.l 0,0
dc.l 0,0
dr.w 0,0,0,0
dc.w customscreen
evenpc
color_table:
dc.w $000,$12f,$24e,$36d
dc.w $48c,$5ab,$6ca,$7e9
dc.w $8e8,$9c7,$aa6,$be5
dc.w $c64,$d43,$e22,$f01
end

```

For any questions or comments regarding this correction or the article, write to
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example.c

```

14 /* Start of Prologue */

/* Preamble Source file written by StateMachine */
/* Copyrighted 1992, by J. T. Stalchen */

/
.....
** STATE: Example <input_file>
**
** WARNING: Since all scanners generated by FLEX used re-
**          directed input,
**          This Example program can only be run from the
**          CLI properly!
**          (unless you want to type the input_file by
**          hand)
**
** See the Makefile for info on how to turn Example.fsm into
**          Example.
**
** See the Article for the syntax that Flex expects to
**          see in the
**          input file.
.....;

#include <stdio.h>
#include <string.h>
#include <exec/types.h>
#include <intuition/intuitionbase.h>

void Ignore();
void RptErr();
void ShowMsg();
void DrawFunc();
void MoveFunc();
void OpenGraph();
void ChgColor();
void Cleanup();

/* Bottom of Prologue */

*)

SCANNER yylex;
MACHINE main;
RETURNS 0;
TYPE int;

TRANSITIONS

) /* Start of Transition table */

#DivPile      #Whitespace      #Semicolon
#Lines
#Lines      #Move_          #Draw_
#Color
#Number      #Comma          #EndLines;

>Begin< Done,Cleanup, Begin,Ignore, Begin,Ignore,
Begin,OpenGraph,
Begin,OpenGraph, DefMove,Ignore, DefDraw,Ignore,
DefColor,Ignore,
Error,RptErr, Begin,Ignore, Begin,Ignore;
>DefColor< Error,RptErr, DefColor,Ignore,

Begin,ChgColor, Error,RptErr,
Error,RptErr, Error,RptErr, Error,RptErr,
Error,RptErr,
DefColor,ShowMsg,DefColor,Ignore,
DefColor,Ignore;
>DefMove< Error,RptErr, DefMove,Ignore, Begin,MoveFunc,
Error,RptErr,
Error,RptErr, Error,RptErr, Error,RptErr,
Error,RptErr,
DefMove,ShowMsg, DefMove,Ignore, Begin,Ignore;
>DefDraw< Error,RptErr, DefDraw,Ignore, Begin,DrawFunc,
Error,RptErr,
Error,RptErr, Error,RptErr, Error,RptErr,
Error,RptErr,
DefDraw,ShowMsg, DefDraw,Ignore, Begin,Ignore;
>Error< Done,Cleanup, #Begin,Ignore, #Begin,Ignore,
Begin,OpenGraph,
Begin,OpenGraph, DefMove,Ignore, DefDraw,Ignore,
DefColor,Ignore,
Error,RptErr, Begin,Ignore, Begin,Ignore;
>Done< Done,Cleanup, Done,Cleanup, Done,Cleanup,
Error,RptErr,
Error,RptErr, Error,RptErr, Error,RptErr,
Error,RptErr,
Done,Cleanup, Done,Cleanup, Done,Cleanup;

});

18 /* Start of Code Section: */

extern char *idstr;

int linecount = 0;

void Ignore()
{
    if (idstr[0] == '\n')
        linecount++;
    return;
}

void RptErr()
{
    fprintf(stderr, "ERROR in input stream!\n");
    fprintf(stderr, "Found on line %d\n", linecount);
    fflush(stderr);
}

struct NewScreen ns = {
    0, 0, 640, 200, 4, 0xFF, 0xFF, MIPSET, CUSTOMSCREEN,
    NULL, (UBYTE *) "StateMachine Example", NULL, NULL
};

struct NewWindow nw = {
    0, 0, 640, 200, 0xFF, 0xFF, CLOSERWINDOW,
    WINDOWCLOSE | ACTIVATE | SMART_REFRESH,
    NULL, NULL, (UBYTE *) "StateMachine Example",
    NULL, NULL, 20, 20, 640, 200, CUSTOMSCREEN
};

extern struct IntuitionBase *IntuitionBase;
struct GfxBase *GfxBase = NULL;

struct Window *example_window = NULL;
struct Screen *example_screen = NULL;

void OpenGraph()
{
    if (strcmp(idstr, "LINES") == 0)
    {
        ns.ViewModes = 0;
        ns.Depth = 3;
    }
}

```

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```

ns.Width = 320;
ns.Height = 300;
nw.Width = 320; /* Make window larger also! */
nw.Height = 200;
nw.MaxWidth = 320;
nw.MaxHeight = 200;
}

if (!IntuitionBase = (struct IntuitionBase *)
    OpenLibrary( "intuition.library", 0L
)) == NULL)
    return;
if ((GfxBase = (struct GfxBase *)
    OpenLibrary( "graphics.library", 0L )) ==
NULL)
{
    CloseLibrary( IntuitionBase );
    return;
}
if ((example_screen = (struct Screen *) OpenScreen( &ns
)) == NULL)
{
    CloseLibrary( GfxBase );
    CloseLibrary( IntuitionBase );
    return;
}
nw.Screen = example_screen;
if ((example_window = (struct Window *) OpenWindow( &nw
)) == NULL)
{
    CloseScreen( example_screen );
    CloseLibrary( GfxBase );
    CloseLibrary( IntuitionBase );
    return;
}
return;

int  nums[5] = { -1, -1, -1, -1, 0 };

void ShowNums()
{
    extern int atoi( char * );

    int index = 0;

    while (nums[index] == 0)
        index++;
    nums[index] = atoi( idata );
    return;
}

void DrawFunc()
{
    if (example_window != NULL)
        Draw( example_window->Port, nums[0], nums[1] );
    nums[0] = nums[1] + -1;
    return;
}

void MoveFunc()
{
    if (example_window != NULL)
        Move( example_window->Port, nums[0], nums[1] );
    nums[0] = nums[1] + -1;
    return;
}

void ChgColor()
{
    extern struct ViewPort *ViewPortAddress( struct Window *
);

    if (example_window != NULL)
    {
        SetRGB4( ViewPortAddress( example_window ), nums[0],
nums[1],

```

```

        nums[2], nums[3] );
        SetAPen( example_window->Port, nums[0] );
    }
    nums[0] = nums[1] = nums[2] = nums[3] = -1;
    return;
}

#ifdef TRUE
#define TRUE 1
#define FALSE 0
#endif

void Cleanup()
{
    int          Checking = TRUE;
    ULONG        class = 0;
    struct IntuiMessage *message = NULL;
    char         nil[256], *title = nil[0];

    if (example_window == NULL)
        goto SkipLoop;
    strcpy( title, nw.Title );
    strcat( title, " Click on close window gadget to EXIT!" );
    SetWindowTitles( example_window, title, NULL );

    while (Checking == TRUE)
    {
        if ((message = (struct IntuiMessage *)
            GetMsg( example_window->UserPort )) ==
NULL)
        {
            (void) Wait( IL == example_window->UserPort-
Msg_SigBit );
            continue;
        }
        class = message->Class;
        (void) ReplyMsg( message );
        switch( class )
        {
            case CLOSINGWINDOW:
                Checking = FALSE;
                break;
            default:
                break;
        }
    }

SkipLoop:
    if (example_window != NULL)    CloseWindow(
example_window );
    if (example_screen != NULL)    CloseScreen(
example_screen );
    if (GfxBase != NULL)          CloseLibrary( GfxBase );
    if (IntuitionBase != NULL)    CloseLibrary(
IntuitionBase );
    return;
}

/* End of Code Section! */

```



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Need an Extra Joystick Port?

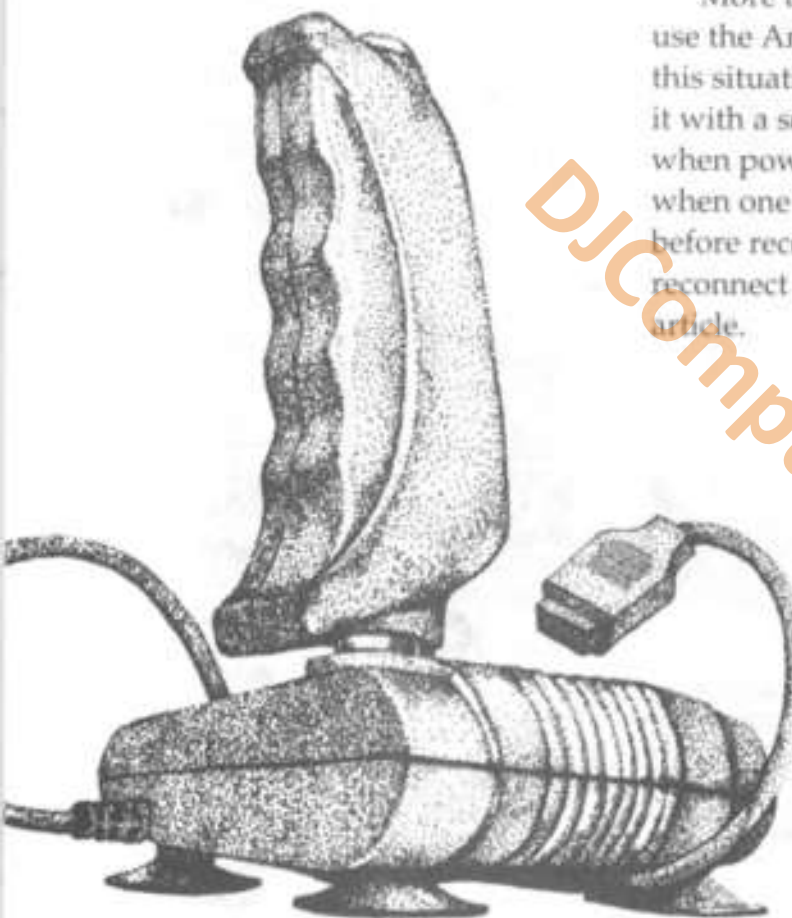
More than anything else, my two young children like to use the Amiga to wage competition against each other. For this situation, they must disconnect the mouse and replace it with a second joystick, not a recommended operation when power is on. Near disaster struck, almost inevitably, when one of my children forgot to switch the computer off before reconnecting the mouse. If you have this disconnect-reconnect problem, you may be interested in the following article.

There are only two ports on your Amiga, one for the mouse and the other for a joystick. But sometimes you may want to play a game against another human, not only against the computer. To switch devices safely, you must switch the Amiga off or you may have the problem I had. I had to replace a microfuse which protects the mouse port on my Amiga 2000. This is not an easy job because the fuse is soldered to the motherboard. One must open the case, remove the motherboard, and resolder a new microfuse.

To protect my computer, I considered buying a switch costing around \$40, but I enjoy small electronic projects, so I decided to design my own with two extra gadgets that the other switches don't have.

My switch is different from the commercial ones I have seen. Mine has no button for choosing between the mouse and the second joystick. When you want to use the second joystick, you just push the fire button on it; when you want the mouse back, you simply push the left button on it. The switching is done by the electronics inside the box without mechanical parts.

Another difference with my switch: it has a rapid-fire function for the first joystick, the one you use when playing single. So with my switch, I have two functions combined in the same box for less than the price of a store-bought.



Any electronic project or project which may or may not require modification of your Amiga should only be attempted by experienced persons. AC's TECH is not responsible for any damage to your Amiga or any other equipment that may occur as a result of this project.

Build One!

by Jaques Halleé

The parts I used are easy to find at any electronic components supply. And if you follow the instructions, you will be able to build yours during the next weekend.

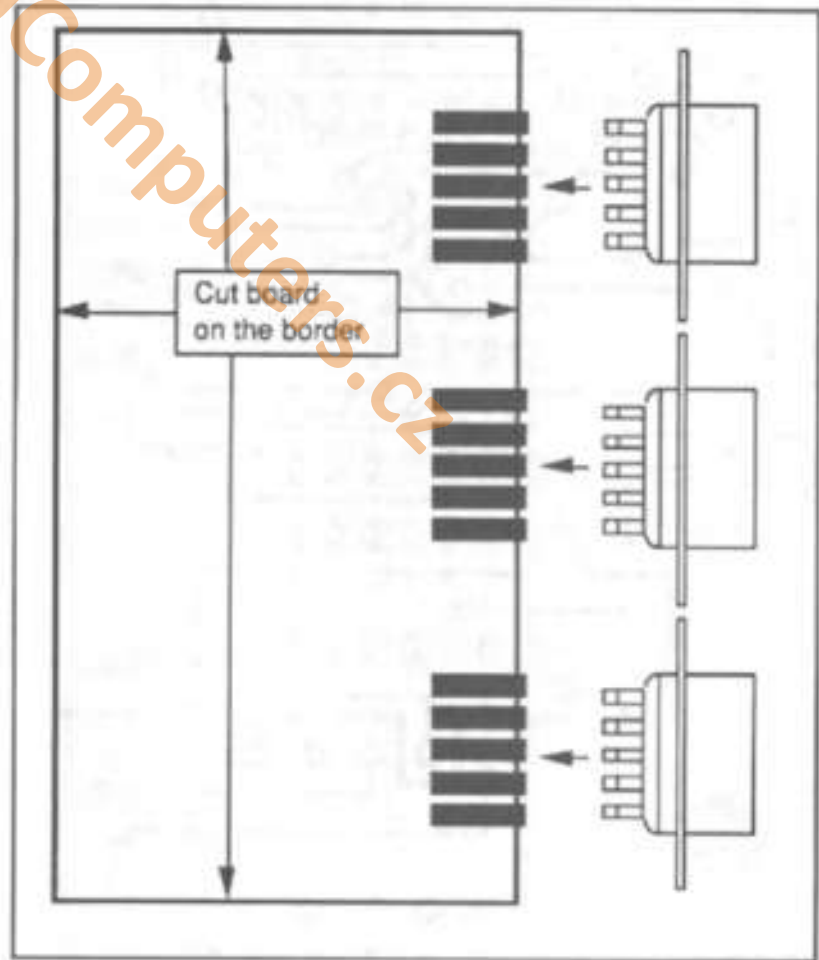
How It Works

Please refer to the schematic in Figure 1 for the description of the parts and their functions. There are two sections in the unit: the first section is the switch itself and the second section is the rapid-fire function.

The first section can be divided in three blocks. The first block is represented by U3, the selector. The selector is equivalent to four switches. One side of the switch is connected to the mouse and the other side is connected to joystick 2. The output is connected to the Amiga port #1, normally the mouse port. The selector is activated by the second block which is represented by U2, the latch. The latch itself is activated by the left mouse button or the fire button of the joystick. The latch acts as a memory; as long as you don't touch the fire button of the joystick, the output of the latch remains low and the selector outputs the movement of the mouse. If you touch the fire button on the joystick, the output of the latch flips to a high level and the selector outputs the movement of the joystick. The third block of this section consists of one gate U4 to combine (logic OR)

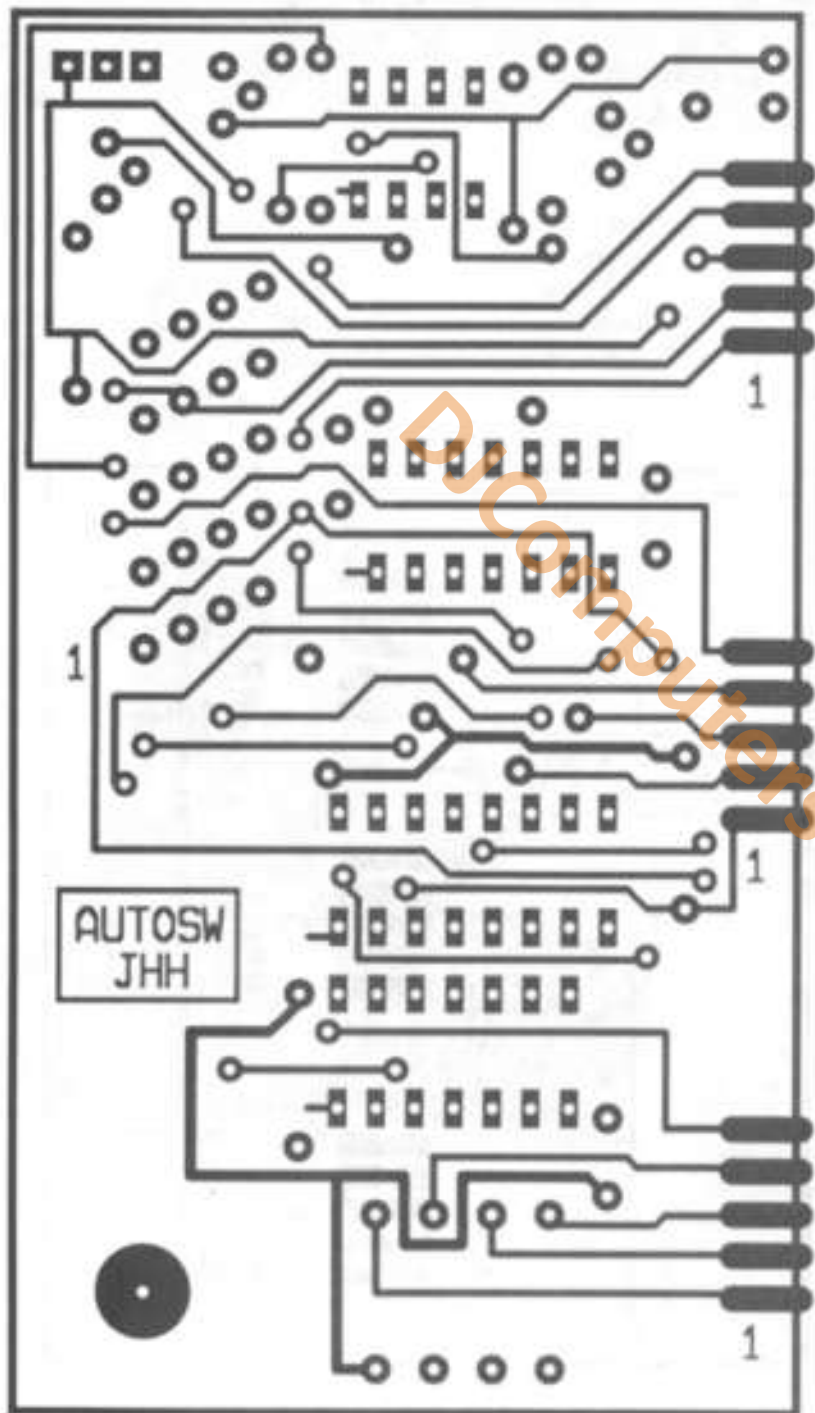
the action of the left mouse button and the fire button of the joystick.

The second section of the unit is the rapid-fire function for joystick 1. The heart of this part is the timer U1. It is an oscillator producing a train of pulses as long



Right: Figure 5. Not to scale.

Figure 5



as fire is pressed. You can adjust the pulse rate, or frequency, by turning POT1. One pulse is equivalent to one hit on the fire button. The transistor Q1 senses the fire button and starts the oscillator if held down. Transistor Q2 takes the output of the oscillator and feeds it to the input of the Amiga pin. Switch SW1 is there to select the normal function of the fire button or the rapid-fire mode.

First, Buy All the Components.

For a complete list of parts, see the Parts Table. The three ICs (U2,U3,U4) are "HCTLS" and could be replaced by "HC" family instead of "HCTLS" but not by regular "LS" or "S" family because of their power consumption.

I chose a tantalum capacitor type for C2 because of the small size; you may choose any type of capacitor with the same value, but be careful of the size. All the components are standard parts and you should not have any difficulties finding them. When they are available at a Radio Shack, I give the catalogue number because these stores are well known. If you shop carefully, the parts should not cost more than \$20 plus the cost of the PCB.

Also, if you are not interested in the rapid-fire function, omit the parts referring to this section. The switch should work on any Amiga including the new A4000. I have already tested it on A500, A1000, A2000 and A3000.

Then Install the Parts

First, identify which side is the components side, the side where you insert the parts, and which one is the solder side. Refer to Figure 2 for the components side (top) and Figure 3 for solder side (bottom). It is very important that you insert the parts on the good side (top).

For those of you who are making the PCB, there are some points to consider. *Figures 2 and 3 are double size*

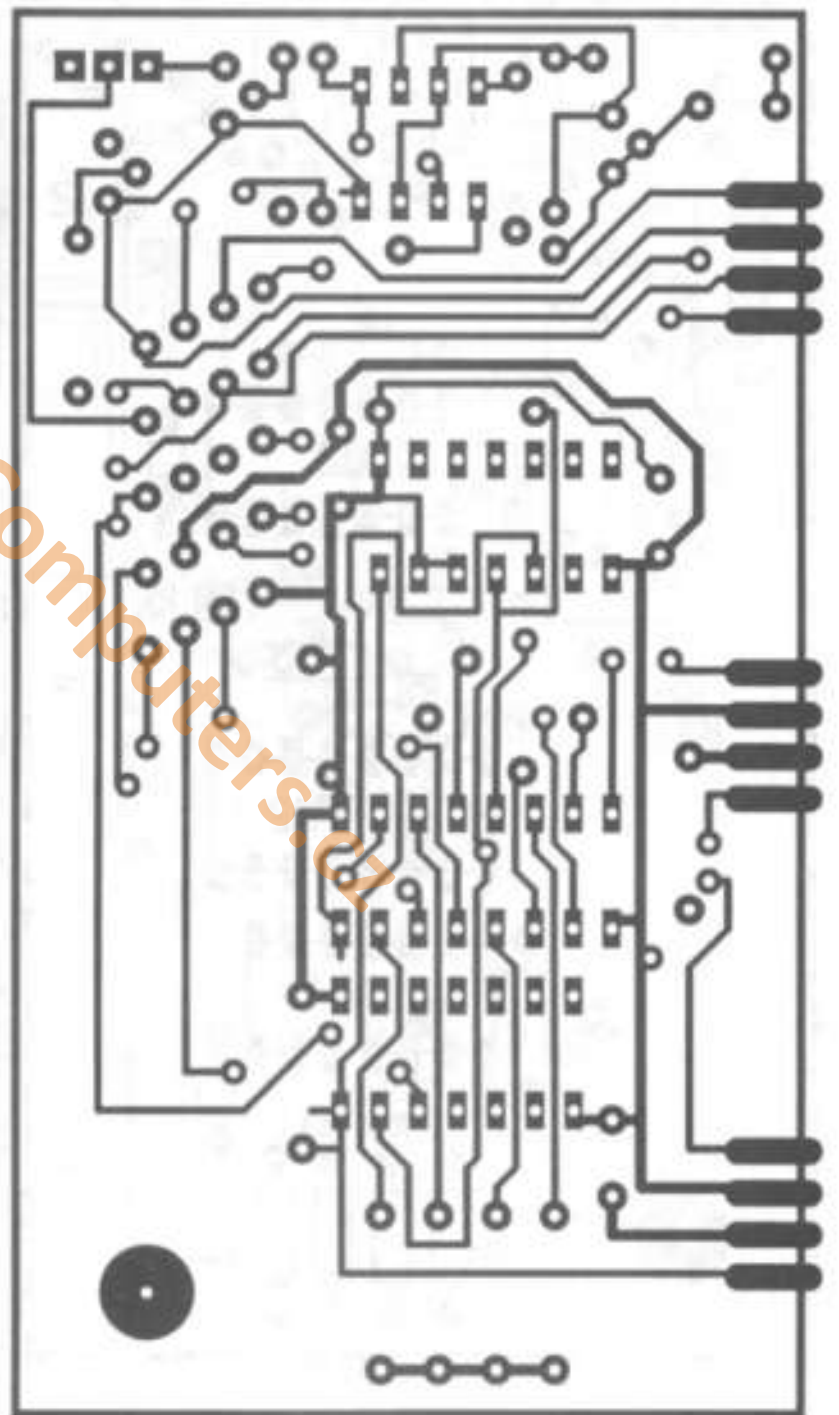
Left: Figure 2. Image is 2x actual size. If you use this figure as a template, remember to reduce it by 50%!

(2X). Make a negative of these two figures and reduce to half size. Then align the two negatives carefully with the letter on top; you should see "JHH." When your PCB is done you have to cut it on the border (cut off the border) as shown in Figure 5. The last thing to do before soldering parts is to drill the holes at the right size. If you drill all the holes at 0.028 inch, you should be able to insert all the parts.

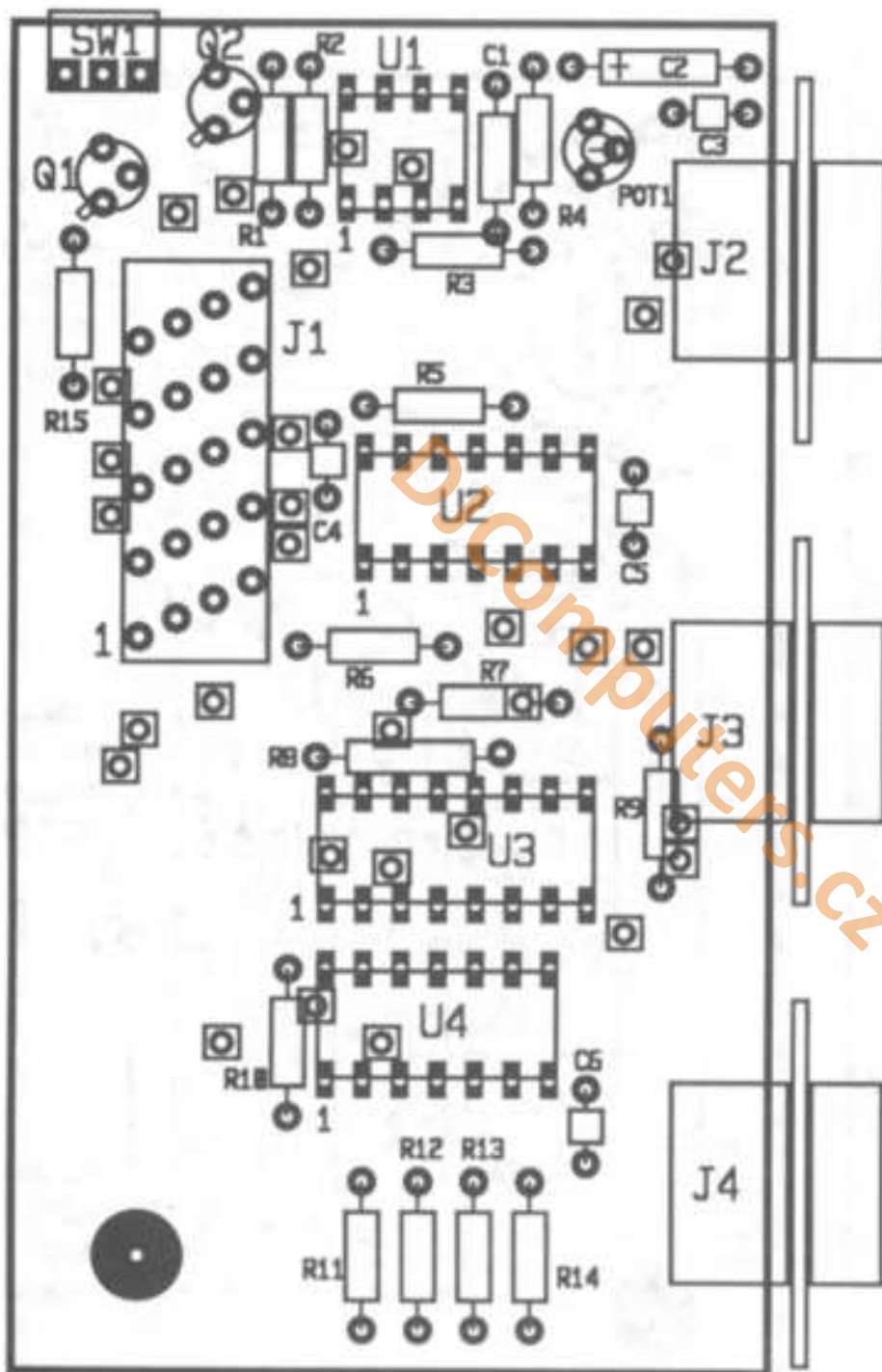
Now you have your PCB ready. The first step before installing the components is to solder the feed-thru. I call a feed-thru a piece of wire soldered on both sides to make a connection from one side of the PCB to the other; refer to Figure 6. There are 30 feed-thrus to make before installing components. The feed-thrus are easy to locate: the pad for a feed-thru is smaller than the others. Refer to Figure 4 for the component locations you can see feed-thrus with a square over the pad. Before soldering your first feed-thru, install the PCB on two spacers at both ends. The thickness of the spacers can be about 1/8 inch.

The easiest way of soldering a feed-thru is to take a piece of solid wire, #22. Then you skin two or three inches off it and you insert it into a hole, solder it on one side, cut it, and do the same with all the feed-thrus for that side. After, you flip the board over and solder all the feed-thru on the other side. To assure a good solder, you must put the iron tip on one side of the wire and the solder on the opposite side. When you see the solder melting all around the pad, you remove the iron quickly to prevent overheating. Make sure that you cut the wire as close as possible to the PCB; refer to Figure 6.

When you have built all the feed-thrus, you are ready to install the rest of the components. The following list shows the order that I recommend for



Right: Figure 3. Image is 2x actual size. If you use this figure as a template, remember to reduce it by 50%!



soldering the components:

- 1- sockets
- 2- resistors
- 3- capacitors
- 4- transistors
- 5- potentiometer
- 6- DB-9 male
- 7- wires and switch SW1
- 8- transition connector and the flat cable

Sockets

When you install the sockets, you must take care of the direction. Refer to Figure 4 for the good socket direction. All sockets have a way to identify pin 1; find it and install the socket with pin 1 facing the transition connector J1, as shown on Figure 4. If you want your socket to remain in place while soldering, just bend one pin at each corner after insertion into the PCB, then solder sockets on the bottom side only. Don't insert the ICs into the sockets right now.

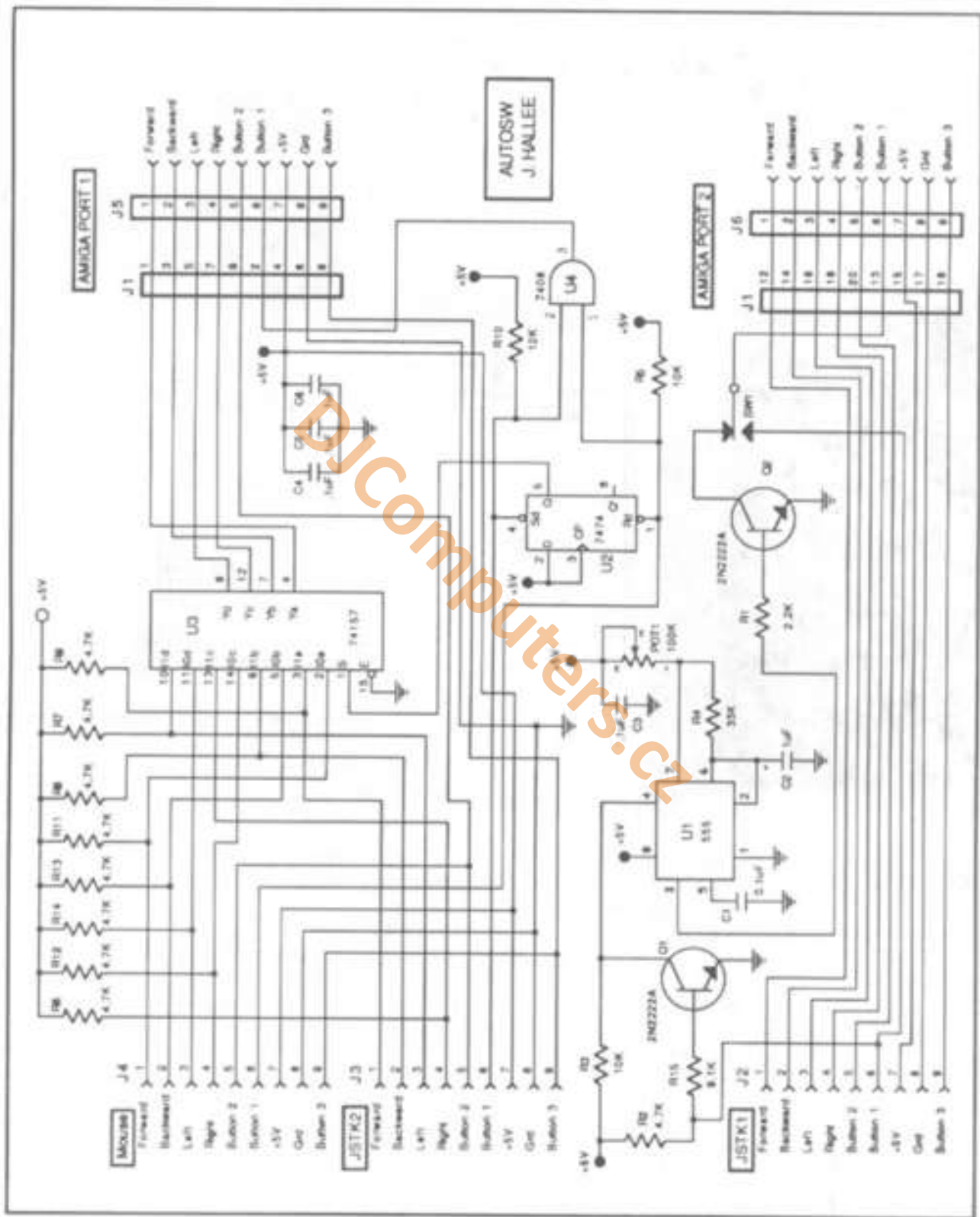
Resistors

Check the color of the resistors before installing them on the PCB. The way you read the value of a resistor is simple: there are four color bands on the resistor. One band should be gold (5% tolerance), turn the resistor to put the gold band on the right side. Refer to the parts list for the color corresponding to each value. For all the resistors, you must solder them on both sides of the PCB, because some connections are also made on top.

Capacitors

Except for C2, there is no preferred way for mounting the

Left: Figure 4. Image is 2x actual size. If you use this figure as a template, remember to reduce it by 50%!
Right: Figure 1. This schematic is not to scale.



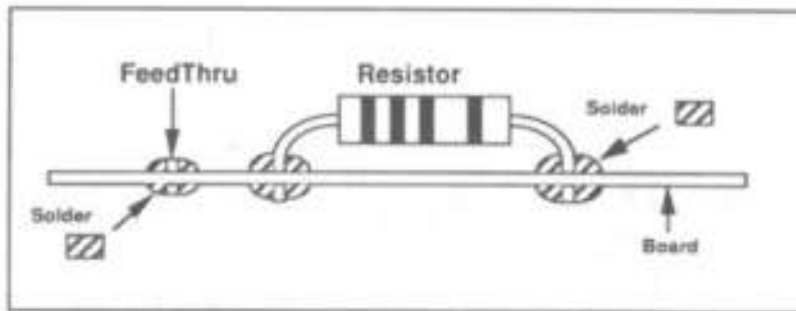


Figure 6

Figures 6 & 7

An extra
joystick port
can reduce
wear and
tear on your
existing ports.

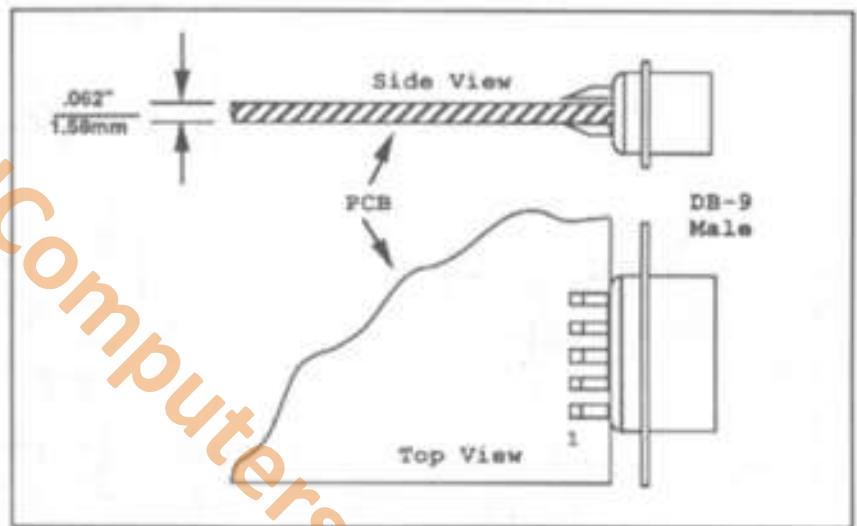


Figure 7

capacitors. C2 should have a "+" sign to identify the polarity. Make sure that you install it with the sign in the good direction. As for the resistors, you must solder the capacitors on both sides of the PCB.

Transistors

There are two types of transistor you can buy. The first type has a metal case and it is round with a little tab to identify the emitter. Make sure that the tab is on the good direction as shown in Figure 4. The other type has a plastic case and there is a flat on it. When you look at the transistor with the pins down and the flat in front, you should read the pins from left to right. The emitter is left, base is center and collector is right. Make sure that the emitter is on the tab side in Figure 4. For the plastic transistor, you will have to bend the center pin to insert it into the PCB. For both types of transistors, leave at least 3/8-inch between the transistor and the PCB. You

must solder them on both sides of the PCB to ensure the connection with the top conductors.

Potentiometer

If you use the potentiometer from Radio Shack, you will have to bend the pins before inserting it into the PCB. Use a pair of long-nose pliers to bend the pins. Identify the center pin; it should go into the center hole. You can also use another type of potentiometer and drill it hole in the box so you will be able to adjust the frequency externally without opening the box. For this, you will have to solder three wires from the PCB pads (SW1) to the potentiometer pins on the box. Remember, the center wire (slider) must be soldered to the center pad on the PCB.

DB-9 male

You have to slide the PCB between the two rows of

Figures 8 & 9.

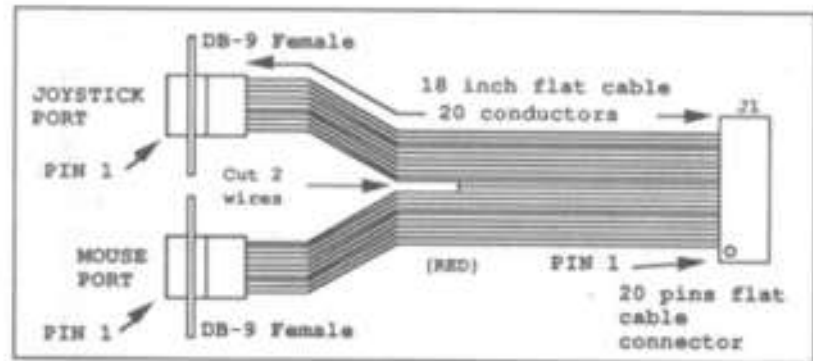


Figure 8

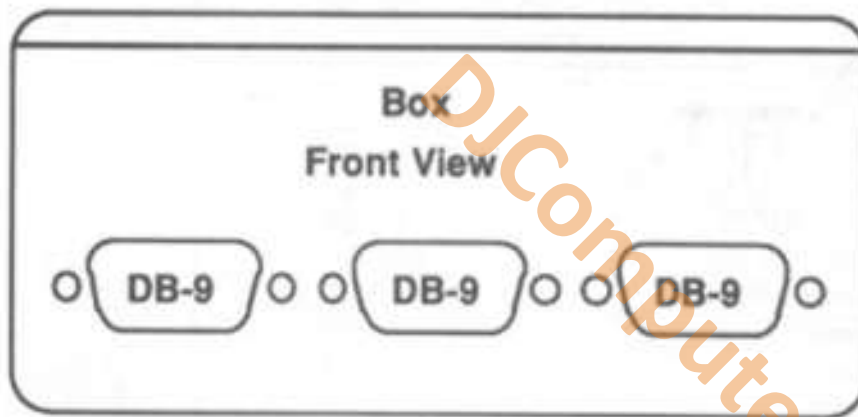


Figure 9

Commercial switches of this type run \$40 or more.

pins of the connector. The top row has five pins. The bottom row has only four pins, and there is only one way to install it. Refer to Figure 7 for the installation of these connectors. Install the three connectors before soldering. The alignment of these connectors is critical; center the pins on the pads of the PCB. They should be pressed completely against the PCB. A little trick after you have inserted the connectors is to put the PCB vertically on a table using the connectors as a support. It is much easier this way to align the connectors. The space between the three connectors should be the same. When you are sure the connectors are correctly seated, then solder them to the finger pads.

Switch SW1

Cut three #22 wires six inches long and then solder them on the PCB pads marked "SW1." Don't use solid wire; it is too easy to break when you bend it several

times. Then solder the other end of the wires on the switch. Make sure the center wire is soldered on the center pin of the switch. Make sure that you solder them on both sides of the PCB

Transition Connector J1

For the transition connector you have two parts, one with the pins and the other is the cover (J1). Solder the pins part on the bottom side of the PCB only. Then install one end of the 20 conductors flat cable between the two parts of the connector. The red wire must be on the right side as shown in Figure 8. Use a small vise to crimp the flat cable into the connector. Be careful with the alignment of the flat cable and the connector.

Then at the other end of the flat cable, install the two DB-9 female connectors. Next, remove an eight-inch section of the two center wires. There should remain nine conductors on each side of the flat cable.

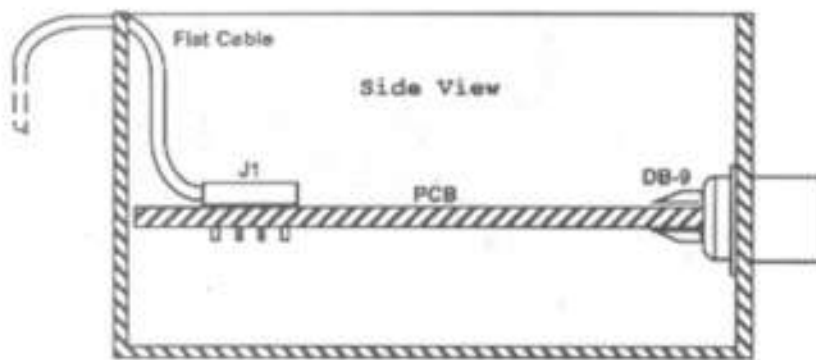


Figure 10

Left: Figures 10 & 11.
Opposite: Table of Parts.

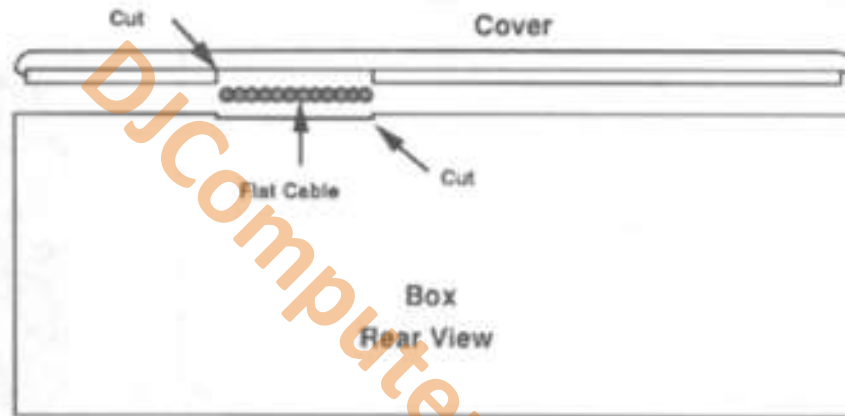


Figure 11

Crimp the two connectors DB-9 on each part of the flat cable. Take care with pin 1 of the connector; it should match with the red wire for one side. Then the other connector should go with the pin 1 on the center of the flat cable; refer to Figure 8. Now you are ready to test the unit.

Before connecting the unit to your Amiga, inspect the PCB and your solder joints carefully. If you have a magnifying glass, use it to check if you forgot a solder spot, or if you have shorts between two pads or two traces. This operation is very important and could prevent damage to your computer. The time you spend on inspection could save you lots of trouble and time debugging your unit. If you have done a good job soldering the parts, the unit should work right away. The most common problem is a forgotten solder joint on the top side of the board.

After the inspection, you are ready to connect it to your computer without the chips in the sockets. Be sure

your computer is *off*. Remove the mouse and the joystick if you have one already connected. Then connect the unit to your computer; the connector with the red wire should go to the mouse port. Turn your computer on and with a multimeter check if you have +5 volts on each socket according to the schematic. If you have all the sockets with the +5V and your computer still boots, then an important part is done. Otherwise, turn your computer off immediately and double-check your PCB, especially the trace with the +5V on it.

With your computer still off, install all the chips in their appropriate sockets and connect the mouse to the unit in the left connector; refer to Figure 13. You can also connect your joysticks to the other connectors. Turn your computer on again. Your pointer should move with the mouse as before.

If the mouse is OK, then you can first test-fire the button of the joystick, which is connected in the center connector. This action should freeze the mouse. Now

Parts list for AUTOSW

Qty	Reference	Description
1	U3	74HCTLS157
1	U2	74HCTLS74
1	U4	74HCTLS08
1	U1	555 Timer
2	Q1,Q2	Transistor 2N2222A
3	J2,J3,J4	DB-9 Male, RS #276-1427
2	J5,J6	DB-9 Female flat cable
1	J1	20 pins flat cable transition connector (see note below)
1	POT1	Micro-potentiometer 100 Kohms, RS #271-284
1	SW1	Switch SPDT RS #275-662
1	R2	4.7 Kohms 1/4W 5% (yellow, purple, red, gold)
4	R6-R9	4.7 Kohms 1/4W 5% (yellow, purple, red, gold)
4	R11-R14	4.7 Kohms 1/4W 5% (yellow, purple, red, gold)
2	R3,R5	10 Kohms 1/4W 5% (brown, black, orange, gold)
1	R10	12 Kohms 1/4W 5% (brown, red, orange, gold)
1	R4	33 Kohms 1/4W 5% (orange, orange, orange, gold)
1	R1	2.2 Kohms 1/4W 5% (red, red, red, gold)
1	R15	9.1 Kohms 1/4W 5% (white, brown, red, gold)
1	C2	1.0 uF Tantalum
1	C1	0.1 uF Mylar
4	C3-C6	0.1 uF Decoupling capacitor
2		sockets 14 pins
1		socket 16 pins
1		socket 8 pins
1		small plastic box, RS #270-222
1		18 inches flat cable 20 wires

NOTE: For J1, you can buy it from the next three companies or an equivalent.

- Robinson Nugent #IDT-C20-1-T
- Ansley #609-2003
- 3M #3422-0000T

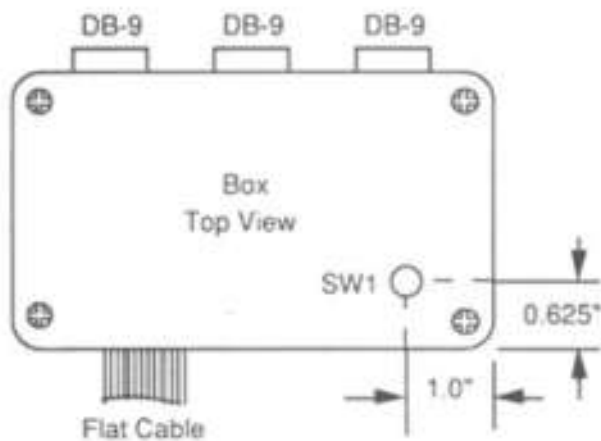


Figure 12

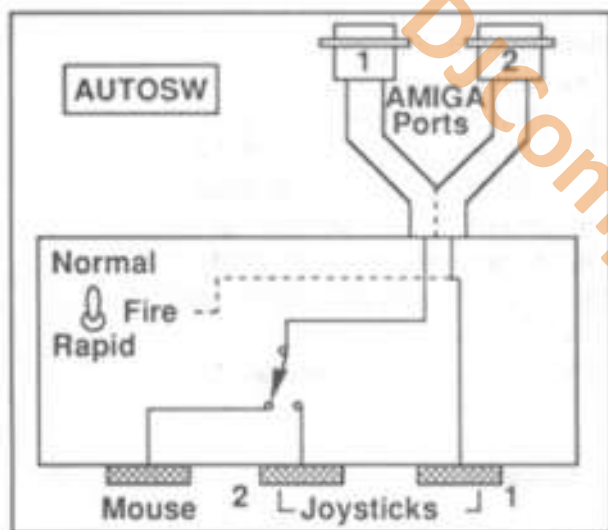


Figure 13

press on the left mouse button and your mouse should work again.

It is now time to check the two joysticks. Boot your computer with a game using two joysticks. Press the fire button on the central joystick and try to move your object in each direction with one joystick; then try the second joystick.

The last thing you have to check is the rapid-fire function of the joystick on the right connector. Boot a game with shooting action like *SideWinder*. Adjust the potentiometer in the center position with a small screwdriver and then press the fire button and hold it. The rapid-fire function should be active; if this is not the case, change the state of switch "SW1" and try again.

When you have found which position is rapid and which is normal mode, adjust the potentiometer for speed you prefer.

If everything works OK the first time, that means you have done a good job. Then turn your computer off. Disconnect the unit, the mouse, and the joysticks. Now you are ready to put it in a box.

Put the Unit in a Box

The box I used is the Radio Shack #270-222 plastic box. You can use anything you like, but the rest of this section concerns this type of box. I designed the PCB to fit tightly in the box, there is not much lost space. I always like to keep things as small as possible.

The first thing to do on the box is to remove the slides inside the box on one side. You will drill the holes for the DB-9 into this side. I used a small cutter to remove these slides. Then you can finish the job with a piece of sand paper.

Next cut the three holes for the DB-9 male connectors. The easiest way is to draw the pattern for these connectors on a piece of thick paper. Put the PCB with the connectors face down on the paper. While holding the board with one hand, trace a line around each connector with a pencil. Then cut the inside part with a sharp knife. With this template, it will be easier to mark the holes on your box. The three holes must be centered on the box; check Figure 9 for more details. After you have cut three holes for DB-9 connectors, insert the three connectors externally into the box; with this way, you will be able to mark the six small holes for the screws on DB-9. Then you can install the board inside the box.

If you put six screws to hold the DB-9, it will be enough to hold the PCB inside the box. The next thing to do is to cut the edge of the box and the cover for the flat cable; refer to Figure 10 and 11.

The next operation is to drill a hole for switch SW1 inside the cover. Refer to Figure 12 for marking this hole. The size of the hole depends on the size of the switch you chose. If you have the one specified in the parts list, the hole will be 1/4 inch. After you have drilled the hole, install the switch according to Figure 13. You can take a reduced photocopy of Figure 13 and glue it to the cover.

I hope you and your computer will feel better when young kids want to play a game. If you have any questions or comments, please write.



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 c/o AC's TECH
 P.O. Box 2140
 Fall River, MA 02722

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