ANNIVERSARY ISSUE

COMPUTER LANGUAGE™

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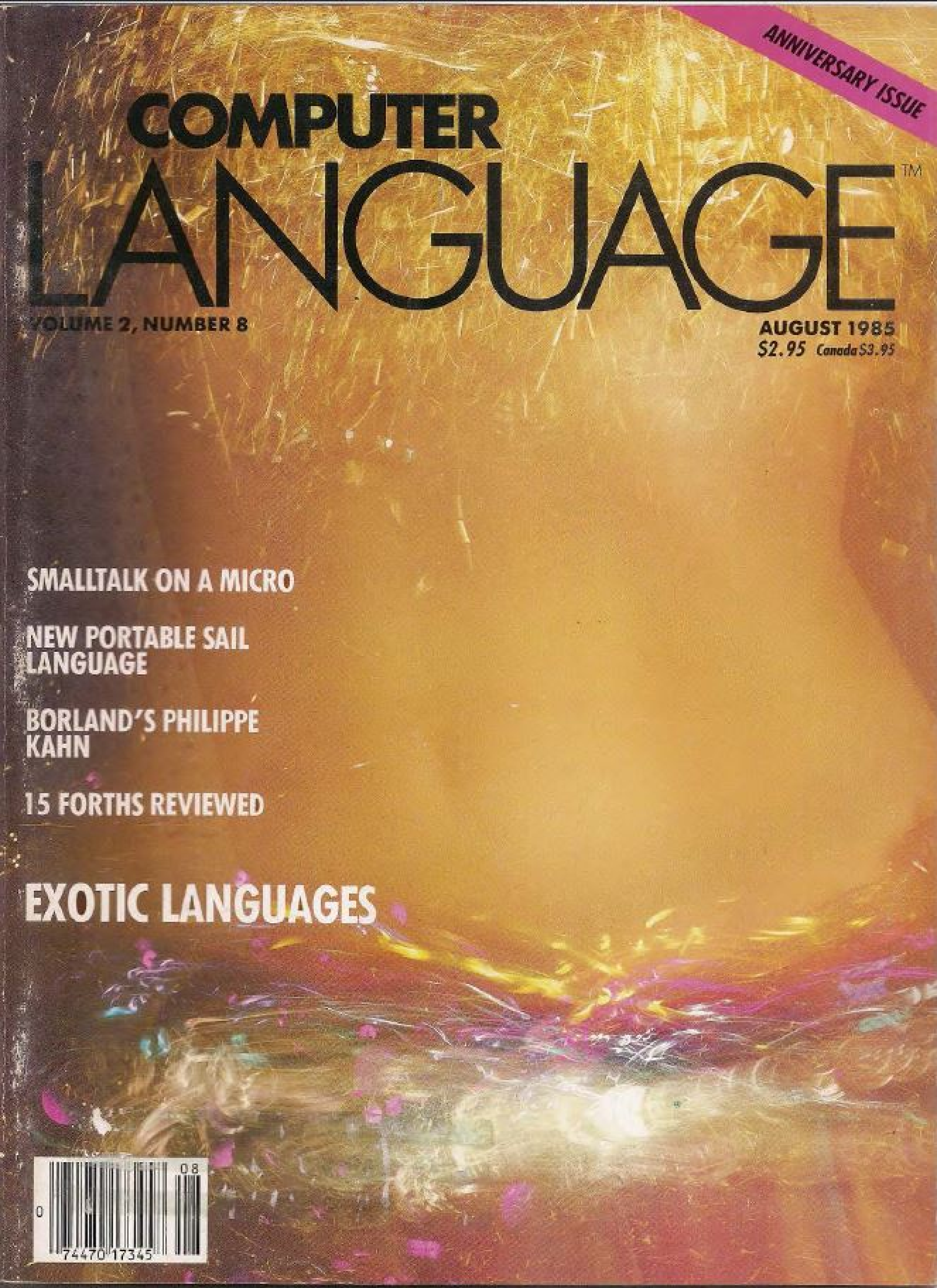

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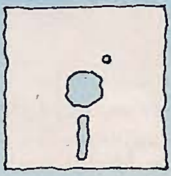

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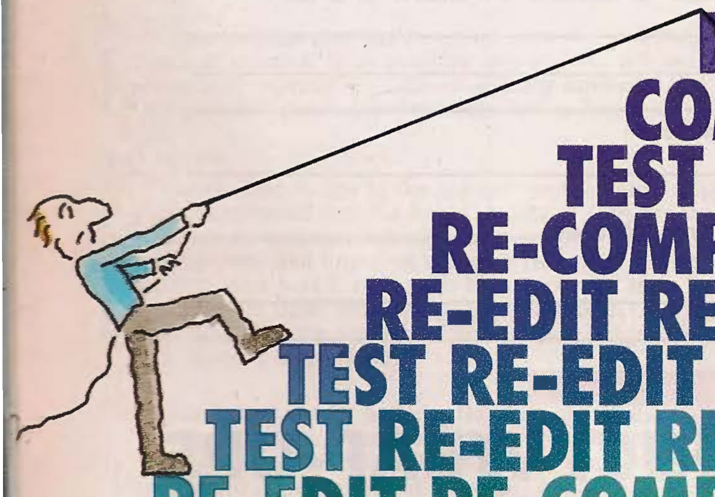

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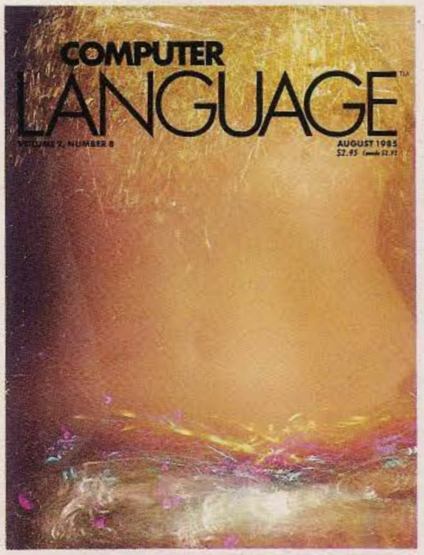

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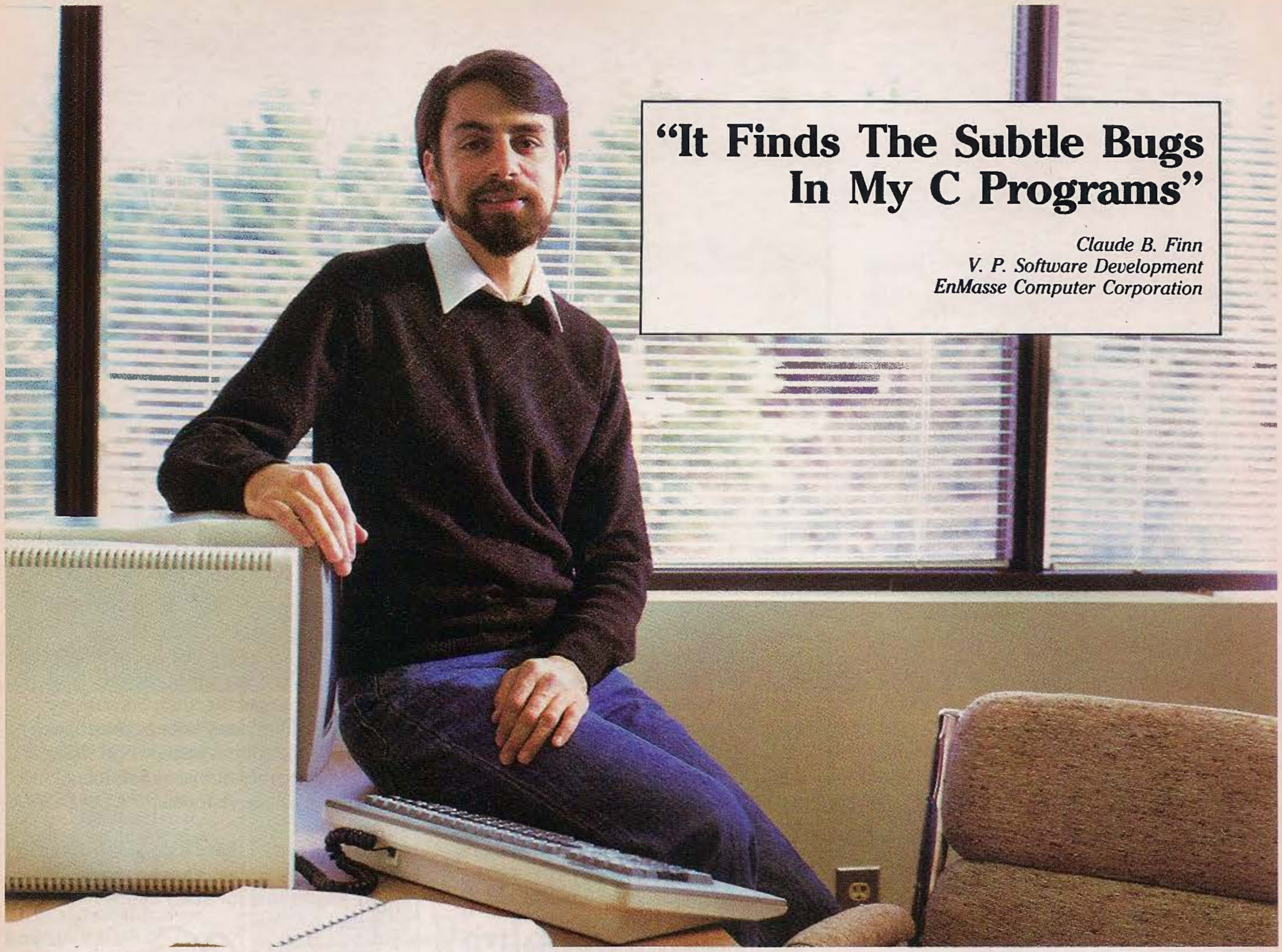

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Editor's Notes

In the days when computers were first being designed, the challenge of programming was almost insurmountable because of one unbelievable truth: programming languages did not yet exist. Then only the computer's native code was available, and using it was a painstakingly detailed process.

But today—like the roots, limbs, and branches of a tree—we not only have languages, but hundreds of languages and variations upon variations of languages. The entire arena of programming languages is a marvelously rich and diverse field.

It is amazing how many of the older, less well-known languages in the world have survived (many without the support of any major computer manufacturer) and how they continue to please groups of people who make exceptionally strong demands on their computing languages. Many of these so-called exotic languages have sprung up between the cracks and have helped us discover the wealth of detail and complexity found in real programming languages.

This month's special issue takes a look at some of the relatively unknown programming languages out there which are used in small academic centers, as in-house systems languages, or as home-grown applications-oriented languages. People who read *COMPUTER LANGUAGE* apparently like to see material on this subject because our Exotic Language of the Month Club department has been our hottest mail generator.

While no anthology could possibly cover all of the existing small languages, *COMPUTER LANGUAGE* will attempt to compile a data base of information on this industry phenomenon. Over time, we plan to compile a comprehensive directory and try to convey historically how each language interrelates.

So if you're aware of a particular language that you think deserves coverage, please speak up!

This issue is also a special occasion for all of us here at *COMPUTER LANGUAGE*—it's our one-year anniversary! Let me extend a heartfelt thanks to all those who have supported us over the past year.

We've been getting the kind of feedback that suggests *COMPUTER LANGUAGE* is maturing more and more as each issue goes by. The issues are becoming easier and easier to put together, because we have attracted many talented free-lance writers who submit manuscripts that reflect the professional and technical tone we originally envisioned for *COMPUTER LANGUAGE*.

We, the staff, have a lot of fun doing what we do, and we look forward to having you around for many anniversaries to come!

Craig LaGrow

Craig LaGrow
Editor

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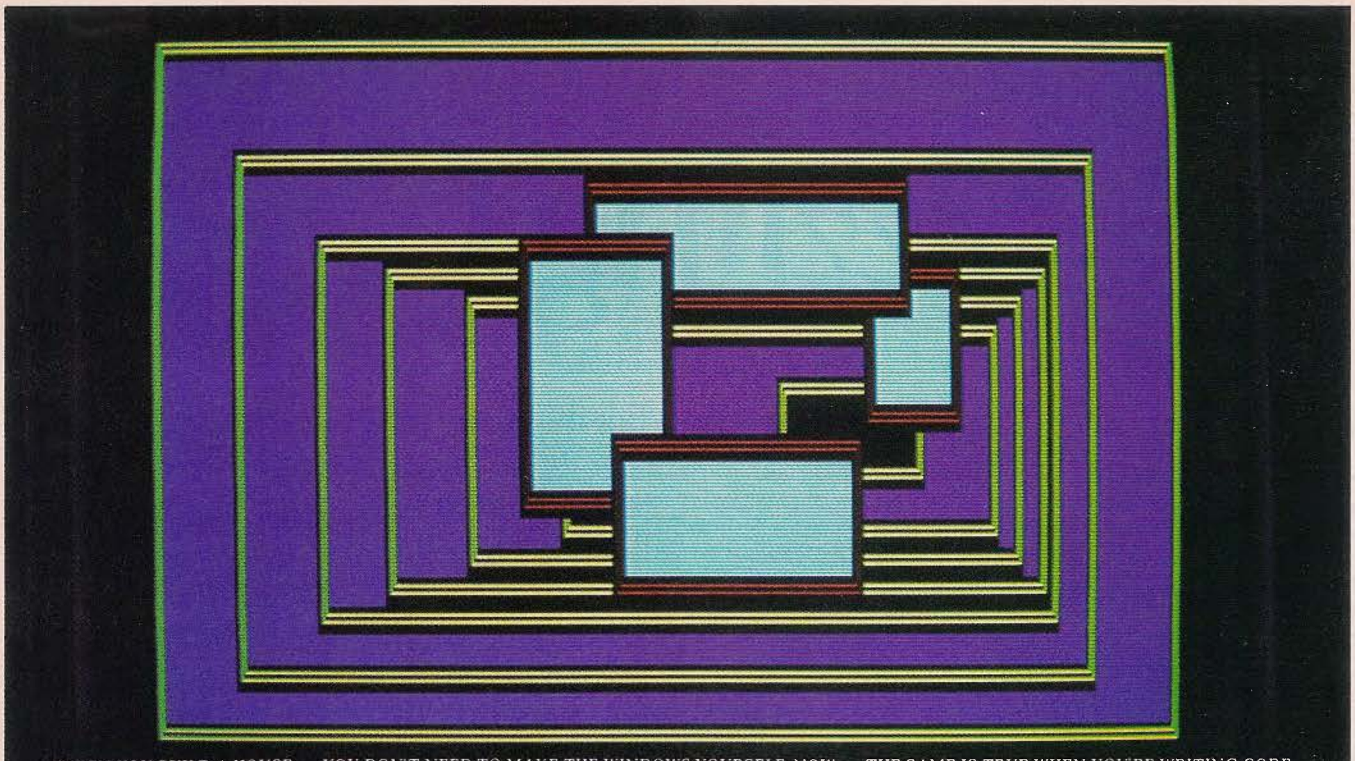
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	Exec Time	Code Size	EXE Size
Microsoft C	:9.39	141	5,914
Lattice C	:12.24	164	20,072

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FEEDBACK

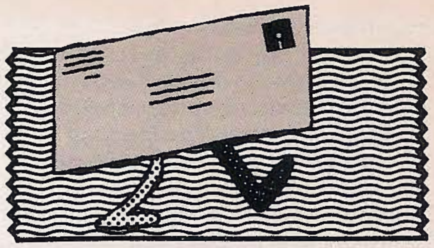
Illustration: Anne Doering

Recursing Forth

Dear Editor:

Jean-Pierre Schachter's article on recursion in Forth (*COMPUTER LANGUAGE*, June 1985, pp. 27-30) was very interesting. Recursion is a useful technique, and as the author states, is easy to do in Forth.

A word of caution, however. Forth has two stacks, the parameter stack (used for calculations and the passing of data) and the return stack. When a Forth verb calls another verb, an address is pushed on the return stack. The maximum size of the return stack is not unlimited, of course, so if a recursive procedure nests sufficiently deeply, the return stack will fill. This error is not detected in most Forth implementations since the speed penalty would be too great. So most Forths will eventually crash if the stack grows too large.

To check to see how many levels your return stack can handle, try the (appropriately named) verb *CRASH* (Listing 1). This verb is an endless recursion with a nest count. It will print 2, 3, 4, . . . until Forth crashes. (It begins with 2 because the *RECURSE* verb is nested once.) The last number it prints is the number of levels that your return stack can handle.

This will only give you a rough idea, of course, since different Forths have different things below the stack. In the standard fig-Forth memory map, the terminal input buffer (TIB) is below the stack. In that case, the return stack might be able to borrow the TIB without crashing.

The | (*BAR*) verb listed by Dr. Schachter works very well but has one potential tial danger (though not a serious one). If it is used only once (or an odd number of times) in a definition, then Forth cannot find the verb you just defined unless you enter *SMUDGE* after the definition is entered. This is because the *;* verb which is used to end a definition reverses the *SMUDGE* that *:* did to hide the verb from *-FIND*.

To avoid the accidental occurrence of this condition, try the variation in Listing 2. I have defined the verbs - | . and | . , which are used in pairs. The | . verb leaves an 8 on the stack to be checked by the | . verb using the verb *?PAIRS*.

This is the standard method of providing compiler security that is used in such verb pairs as *IF . . . THEN, BEGIN . . . UNTIL*, etc., and is a good technique to use when defining immediate verbs that are used in pairs. This method will give an error if the second of the pair is used without the first of the pair, if paired verbs are mixed incorrectly, or if the second verb of a pair is not used before the definition is ended, so quite a bit of checking is done in very little code.

A method of recursion was shown in *Forth Dimensions*, vol. 4, no. 2 (published by the Forth Interest Group, P.O. Box 1105, San Carlos, Calif. 94070) that is worth reviewing. The technique was used in a Forth decompiler. *MYSELF* uses the standard fig-Forth verb *LATEST*, which leaves the NFA of the last word in the dictionary and is unaffected by *SMUDGE*. The NFA is then changed to a PFA, then to a CFA, which is compiled. Since the last word in the dictionary is the verb being defined, the verb then calls *itself.*

Recursion as a programming technique can be very useful but do not be led to believe that a recursive routine is always superior to an iterative one. A.K. Dewd-

```
( CRASH - determine size of return stack
 by crashing FORTH )

: MYSELF LATEST PFA CFA , ; IMMEDIATE  ( call myself )

: RECURSE 1+ DUP . MYSELF ;

: CRASH 1 RECURSE ;
```

Listing 1.

```
 ( FIBONACCI using BAR with compiler security )

 : |.  SMUDGE 8 ; IMMEDIATE

 : .|  8 ?PAIRS SMUDGE ; IMMEDIATE

 : ONACCI                                ( n1 --- n2 )
   DUP 1 = IF DROP 0
         ELSE DUP 2 = IF DROP 1
                    ELSE DUP  1 - |. ONACCI .|
                         SWAP 2 - |. ONACCI .| +
                    THEN
         THEN ;

  : FIB ONACCI U. ;                       ( n --- )
```

Listing 2.

ney pointed out in the Computer Recreations column in *Scientific American* several months ago that the Towers of Hanoi problem can be programmed as a recursive algorithm. (The Towers of Hanoi has three pegs. On one of these pegs is *n* disks of graduated sizes, the larger on bottom. The object of the puzzle is to move all of the disks from the original peg to any other, moving one disk at a time, and never placing a larger disk on a smaller one.)

Indeed, it appears at first to be a prime example of a recursion. To move all the disks, all you have to do is move disk *n* (the largest disk). To move disk *n*, all you have to do is move disk *n–1*, etc.

Dewdney points out that an iterative routine is not only easier, it is more efficient. In the routine, the pegs are viewed as being in a triangle. Here's the algorithm:

1. Move the smallest disk clockwise
2. Move any other disk (that is a legal move)
3. Repeat until all of the disks are on another peg.

Forth is a very interesting language that has a lot of power. Serious professionals would be wise to learn more about it.

Bill Hall
Burleson, Texas

Author Jean-Pierre Schachter responds: Bill Hall is quite right about the return stack, and I thoroughly agree that it is a wise precaution to find its limits ahead of time.

As far as the point about odd numbers of BAR *implementations is concerned, I'd first stress that such a case would clearly be one of error—there would be no legitimate use in which the* BAR *would appear in an odd number. Should one wish to build in error checking, Mr. Hall's device seems perfect for the task. However, I should add that the possibility of accidently omitting a* BAR *might recommend simply using* MYSELF *instead of bothering to modify the* BAR *at all.*

Both recursion words work; the fact that the BAR *must be used in two places rather than one might be a reason for preferring* MYSELF. *On the other hand, I'm inclined to prefer the* BAR *for being a conceptually simpler piece of machinery. I do rather like Mr. Hall's error-checking device.*

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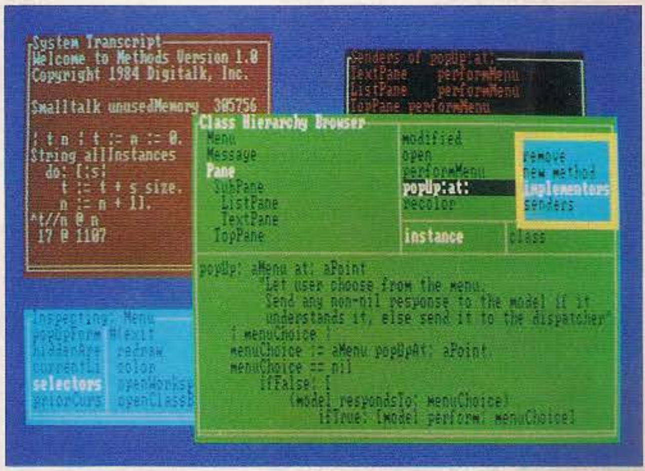

```
System Transcript
Welcome to Methods Version 1.0
Copyright 1984 Digitalk, Inc.

Smalltalk unusedMemory  385756

| t n | t := n := 0.
String allInstances
  do: [:s|
    t := t + s size.
    n := n + 1].
^t//n @ n
 17 @ 1107
```

```
Senders of popUp:at:
TextPane    performMenu
ListPane    performMenu
TopPane performMenu
```

```
Class Hierarchy Browser
Menu
Message
Pane
  SubPane
    ListPane
    TextPane
  TopPane
```

```
popUp: aMenu at: aPoint
        "Let user choose from the menu.
        Send any non-nil response to the model if it
        understands it, else send it to the dispatcher"
    | menuChoice |
    menuChoice := aMenu popUpAt: aPoint.
    menuChoice == nil
        ifFalse: [
            (model respondsTo: menuChoice)
                ifTrue: [model perform: menuChoice]
```

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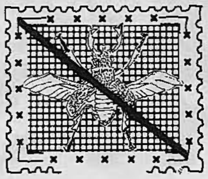


Modem7's evolution

Dear Editor:

I particularly enjoyed Craig LaGrow's "ComputerVisions—On-line with Ward Christensen" (*COMPUTER LANGUAGE*, June 1985, pp. 71-78). It's always nice to read about one's personal heroes. However, I was disappointed to learn that Christensen seems to have no interest in the latest versions of the modem programs originated by himself. That's too bad, because all who use the current versions of Modem7 (now called MDM7), XMODEM, and BYE credit him as the father upon whose work the newer stuff is based.

It's true—Christensen probably would not recognize any of the recent releases of the MDM7 program series as related to his original Modem7. Others, and most particularly Irv Hoff, have added so many features that the software now competes directly with commercial products costing many dollars. The big difference, of course, is that Hoff has picked up the role of torchbearer and kept his MDM7 series in the public domain—100% free (another Christensen tradition). For the price of a phone call, anyone can obtain copies of the MDM740, XMODEM-106, and the BYE-326 libraries from one of the hundreds of RCP/M systems around the world.

Your readers may be interested in knowing that Irv Hoff and systems operator Wayne Masters have assumed clearinghouse responsibilities for the Modem7 descendants. Current releases are available from their POTPOURRI RCP/M in San Jose, Calif., at (408) 378-7474.

Masters reports that later this summer new versions of MDM7 and XMODEM will be released which complement the greater speeds of 1200- and 2400-baud modems. The newest feature will be a 1K block transfer protocol using 16-bit CRC verification, which will enhance data throughput to approximate 95% efficiency. The price will remain the same—free, plus the cost of a phone call!

From this point forward, if not before, I hope we'll all be sure and remember to include their [Hoff and Masters] names when it's time to give credit where it's due. Surely they deserve no less for their yeomanlike labors expended on behalf of the backbone of personal computer modem communications.

Bond Shands
San Francisco, Calif.

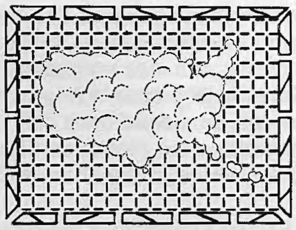
Not-so-simple sort

Dear Editor:

M.B. Clausing pointed out several problems with his simple sort algorithm (*COMPUTER LANGUAGE*, June 1985, p. 9). Unfortunately, the most important flaw was missed: it does not work. It can fail for sets of data with as few as four elements. In particular, it incorrectly sorts each of the following three ordered quadruples (and uncountably more data sets of greater size): (2, 3, 4, 1), (3, 4, 2, 1), and (4, 3, 1, 2).

The algorithm can be fixed in a variety of ways; however, as Clausing stated, "attempts to improve it mutate it into more familiar algorithms."

Daniel L. Stock and
Randall L. Brukardt
Madison, Wis.



COBOL improvements

Dear Editor:

In "Back to the Drawing Board—Electronic soapboxes" (*COMPUTER LANGUAGE*, Dec. 1984, pp. 15-18), Greg Law complains: "COBOL, the only program to require 300 lines of initialization per line of code . . . Talk about hassles." COBOL-85, available already from DEC and some other vendors, contains three enhancements to reduce this problem, specifically:

- A *VALUE* clause can now be written in an entry with a table element; this initializes all elements to some single value, avoiding the need for a long, separate entry.
- The new *INITIALIZE* verb can initialize an item to a default of zeros or spaces, depending on its category, or to some specified value. If a group item is specified, its elementary items are initialized individually, by category. Multi-item operands can also be specified.
- The new *INITIAL* clause of the *PROGRAM-ID* paragraph implicitly reinitializes all data items in a subprogram to their *VALUE*s whenever the subprogram is called.

COBOL-9x, now being put together, contains two further features:

- The *VALUES ARE* clause can now be used in a table entry; its multiple operands initialize individual elements to different values. This eliminates the need to have separate entries for the *OCCURS* clause and the literal, the need to count out inter-element blanks in the literal, and the unreadability that occurs when such a literal wraps around a line. Most usefully, it enables data division initialization of elementary items of different categories that are subsidiary to a group item with an *OCCURS* clause.
- The *INITIALIZE* verb adds the *TO VALUE* phrase, enabling the reinitialization of any data item, even a complicated table, to its initial *VALUE*(s).

These additions will turn COBOL from a chump to a champ at initialization. If any vendors are listening who would like to make COBOL more lovable, I suggest they add the last two items as extensions to their 1985 compilers. (They might charge a bit extra for them, I suppose.)

Roger Knights
Seattle, Wash.

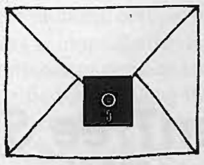
Unsolicited—honest!

Dear Editor:

Gimme a break, willya? Ever since a colleague strolled in to my office with a comparison of 21 C compilers (*COMPUTER LANGUAGE*, Feb. 1985, pp. 73-102), my productivity has plummeted. Stacks of *EDN, Computer Design, EE Times, Digital Design, Electronic Design, MiniMicro Review, Computer World*, etc., are occluding the view of my desk. What right have you folks got to publish a magazine where more than 75% of the material is not only interesting but pertinent to me as a software professional? When am I supposed to find the time to do my work, much less browse through the pulps? And now that I have just received all the back issues, it is apparent to me that the situation will only worsen in the near term!

No periodical I have read (from *CACM* to *Dr. Dobbs*) seems to address the exact niche you are carving, which lo and behold is the niche I must be in. To make matters worse, I have spent more than a month's pay in the last two days buying software and tools I saw advertised in *COMPUTER LANGUAGE*. So I repeat, GIMME A BREAK, WILLYA? If if keeps up, I'll be both broke and buried in old pulps. Thanks for the forum.

Chris Pinkard
Austin, Texas



Illustrations: Anne Doering

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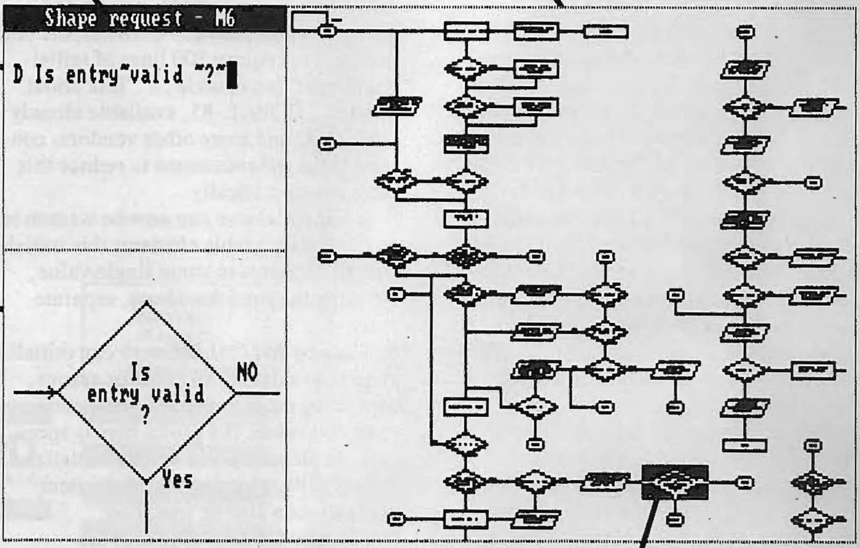

SHAPE CURSOR shows where you are in the chart. Cursor keys move it around; chart window scrolls if you run off the edge of the window.

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CIRCLE 67 ON READER SERVICE CARD

Virtual memory data simulation

By Namir Clement Shammas

Virtual memory is a memory management technique that has been employed since the early days of mainframe computers with 4K to 16K memory. VM allows programs and data to exceed the actual or real hardware addresses. This is possible through the use of mass storage (both floppy disks and hard disks) as an extension of real memory and the efficient swapping of required memory sections.

One may recall the Apple-UCSD operating system implementing a program-swapping technique to enable large UCSD Pascal programs to run on microcomputers. UCSD BASIC implements virtual variables, which allows very large matrices and arrays to be declared as virtual variables and to be used like any other BASIC memory-resident variable. In this system, the BASIC interpreter is solely responsible for swapping data between memory and disk. This month's column will cover the simulation of these variables.

Before we continue, I want to point out that it looks like MS-DOS 4.0 will include virtual memory management. Regarding micros, it appears the subject not only is behind us but also ahead of us. The simulation of virtual data structures uses techniques similar to those in operating systems.

Let's begin with a discussion of the simulation of virtual one-dimensional arrays.

Basically, we assign the array a virtual size that is actually too big to be contained in RAM but can be stored in mass storage devices. Part of the array can be contained in RAM at any time and portions can be swapped systemically between RAM and mass storage as needed. Handling virtual memory requires speed; without it, the application program suffers from intolerable slowness.

Since we are dealing with buffered I/O, we must transfer pages instead of individual data items. This takes care of the inefficiency that comes from handling too little data, but having to work with large pages also causes time loss. Suppose a 20K page is used and we need to update only 5K of modified information to mass storage. We would be wasting time rewriting 15K of unaltered data!

Fortunately, the strategy of divide and conquer comes to the rescue once again. Instead of having only one big page resident in RAM, we employ a number of smaller, equal-sized pages. This enables us to localize any altered elements that need to be swapped with mass storage. In other words, we obtain higher resolution for data I/O. The chosen page size acts as a yardstick in counting and mapping the total number of pages representing the virtual array.

We also need to maintain a small RAM-resident table to indicate the pages that are in RAM. This table can be searched to see if the sought page is already in RAM, thus avoiding a blind and time-consuming recall from mass storage.

Another simple measure we can adopt to decrease the I/O time is assigning each page a Boolean flag or bit, called the dirty bit. When a page is recalled into memory, its dirty bit is set to zero, declaring it clean. As long as data is read only from a page, its dirty bit remains zero. But once data is written to a page, the dirty bit is set to one and declared dirty. When it comes time for a page to be swapped back to the disk to make way for another page, the dirty bit is used to determine whether the page actually needs to be written back. The small overhead of bits saves us from performing unnecessary output to mass storage.

The PPL code in Listing 1 is a function that takes the virtual array index and returns the index of a RAM-resident array. It is important to note that while a large single array is used to store all the RAM pages, we swap page-size bytes of the array at a time. The RAM array does not contain the pages in accordance with their virtual sequence. The map table must be used to determine exactly where a sought element is located. The function *LOC* takes the virtual array index and calculates the index of the virtual page.

Next we search the map table entries to see if the sought page is already in memory. If the search is successful, we assign the entry number value to the sought page number, transforming the virtual page number into a RAM page number. On the other hand, when the search fails we swap a least-desirable RAM page.

The page read is entered into the map table and the entry number is used as the RAM page number. The exact location is obtained as shown by the return statement in *LOC*. The procedure *VM_Assign* relies on the return statement in *LOC*, performs the actual array assignment, and sets the dirty bit to one.

The matrix is another popular data structure used in virtual memory. Since it is a two-dimensional array we can unwrap it into one big array and use the *VM_Assign* approach. A matrix can be transformed into a series of chained rows or columns depending on how convenient it is for the application.

What about when it is more efficient to access the virtual matrix in pages containing submatrices? This resembles the way spreadsheets are viewed on microcomputers: you normally see a portion of the entire table. We will call this the checkerboard method, where the entire matrix is divided into similar and smaller structures.

The virtual matrix is divided into equal-sized pages, each containing the same number of rows and columns. To achieve a perfect fit, the virtual matrix may be slightly larger than our arbitrarily sized matrix. The partitioned matrix yields a matrix of pages. The latter pages are unwrapped into continuous arrays.

We can adopt one of two page-numbering systems. The first, double indexing, specifies each page by a row and column coordinate. The second, single indexing, systemically numbers pages row-wise or column-wise. The page numbers are used as pointers and stored in the map table.

Since it is faster to search for a page using a single numeric comparison, single page indexing is more desirable. But the maximum number of rows or columns must be specified when using this method, allowing the virtual matrix to grow only in one direction. With double indexing, the matrix can grow in either direction.

Listing 2 shows a function that accepts

the row and column indices of a virtual matrix and returns the exact index location of the RAM-resident array containing the submatrix pages. A single page index is calculated and used in the map table search.

The method shown in Listing 2 is similar to virtual one-dimensional arrays. In this method we first attempt to locate the sought page in memory. If this fails, we select a page to swap and then bring in the sought page. With the sought page known, we close in on the RAM array index by calculating the row and column index of the submatrix. The *return* statement shows the expression used to map our submatrices into a large one-dimensional array index.

Let's now focus our attention on the page replacement algorithms. In Listing 1 and Listing 2 we use a *Selected_Page()* function that returns the page number of the best page to replace. This plays an important role in the speed of the simulated virtual system.

In considering the various algorithms to use, I am assuming that we are integrating the concept of the dirty bit to cover some potential deficiencies. The algorithms to be considered follow.

Random page replacement (RPR). This method uses a very low overhead in selecting the page to be randomly replaced. Thus, all RAM-resident pages have an equal probability of being replaced. But this method doesn't really pay off in the long run because the savings in calculation time is offset by the inefficient and time-consuming data I/O.

First in-first out (FIFO). When getting ready to swap, this algorithm looks at page precedence and selects the page that has been in memory the longest. We use a stack to keep track of precedence. When the sought page is already in memory we manipulate the stack to reposition the page number at the top of the stack. Otherwise we roll the stack so that the oldest element ends up on top, ready to be replaced by the incoming page number.

Optimal replacement. Theoretically, this method is the best. It is based on knowing in advance the pattern of recalling pages. Using this information, we replace the RAM page that won't be used for the longest time. Easier said than done! While this method is difficult to implement, other methods try to approach this same concept.

Least-recently-used (LRU) page replacement. This method tries to approximate the optimal replacement method by attempting to predict the near future based on the recent past. Thus we replace pages that have not been used for the longest period of time. While this method seems to present a very good solution, special attention must be paid to how it is implemented.

There are two forms of implementation. The first alternative is to time-stamp page number entries in the map table as they are used. To select the page to be replaced, we search through the map table for the oldest entry or the entry with least time. If the sought page is already in RAM, we restamp it to update its chronological usage. This method requires that the *Table_Type* record include a time field. The second alternative is to put the recalled page numbers in a stack, which gives an indication of how recently a page was read.

Least-frequently-used (LFU) page replacement. This method is similar to LRU page replacement, but instead of time-stamping page entries, a frequency counter field is employed. As RAM resident pages are referenced their counters are incremented. Pages are replaced by searching the map table for the page with the lowest frequency of use. But this can have an adverse effect on new pages with low usage frequency. They may be replaced only to be read within two page recalls. Only sequentially referenced pages will manage to build a good frequency count fast enough.

Modified, least-frequently-used (MLFU) page replacement. This method is a modification of LRU and LFU page replacement. By employing a time-stamp, it overcomes the tendency of LFU to cause recently read pages to be replaced more likely than other pages. This gives the candidate-for-replacement-page a second chance to remain in RAM because it was recently read and may come into use in the near future.

Listing 3 shows the PPL code for the MLFU method implemented by a version of the *Selected_Page* function. Note the use of two consecutive loops. The search for least recently used pages is carried out in the first loop. The second loop searches for a candidate replacement page according to frequency of usage and residence time in memory. It is important to note that the *Critical_Time* identifier must be systematically updated in other program segments to maintain meaningful results.

Assigned static or dynamic page priority (ASDPP). In some cases, certain data subsets of an array or matrix are more frequently used than others. The user can assign priorities to the virtual pages. These priorities can be page/priority lookup tables or functions that return the priority value if its values are assigned over ranges of indices. The first option is faster but is memory-consuming, while the second is slower but is memory-conserving.

Static priorities are assigned at the beginning of the program and remain fixed. Dynamic priorities are altered during program execution, reflecting the fact that different data areas have become "hot spots." To replace a RAM page, we search the map table and locate the RAM page with the least priority.

Not-used-recently (NUR) page replacement. This algorithm is based on the concept that a page not recently used is not likely to be used in the near future. This involves a small overhead of two Boolean flags or bits. The first is the reference bit used to signal whether a RAM page was referenced at least once after it was brought from mass storage. The second bit is the dirty bit.

The selection is simple and consists of three steps. First, search the map table for an unreferenced page. If this is not successful, search the table for an unmodified page. If this fails, select the preassigned default page. I should point out that the dirty bit should be set by modified versions of the procedures *VM_Assign* and *VM_MAT_Assign.*

Implementing virtual memory is a double-edged sword. A bad choice of algorithms can make the system run very slowly. Allowing the program to run unattended overnight relieves the pressure of pushing the speed to the limit. It does not matter if the program ends execution at 3 a.m. or 5 a.m., there is no one at the office anyway! To gain speed on microcomputers, one can use virtual memory with a RAM electronic disk. This method is useful when the language interpreter/compiler does not allow the use of the entire memory.

Next month I will discuss high-resolution graphics and the mathematics behind two- and three-dimensional shapes and figures. I will also talk about mapping real-world coordinates to hardware screen coordinates, including windows and logarithmic scales. The algorithms for plotting three-dimensional surfaces with hidden areas also will be discussed. ■

```
PPL routines to recall and store elements of a one-dimensional
virtual array

-- Constants are:

-- Table_Size            Maximum number of pages in RAM.
-- Page_Size             Number of array elements in a page.
-- Array_base_Address    Lower array limit in a page.
-- VM_base_address       Starting VM address

-- External identifiers are:

-- Table_Type = RECORD RAM_Page, Dirty_bit : integer; END
-- Table : ARRAY[1..Table_Size] of Table_Type
-- SOUGHT_PAGE : integer
-- RAM_Data : ARRAY[1..PageSize] of Any type

-- File VM_File is assumed already opened

FUNCTION LOC(VM_Index : integer) return integer

BEGIN
    SOUGHT_PAGE = VM_Index div Page_Size
    -- Loop to search for page among RAM resident pages.
    INITIALIZE: Found = FALSE
    LOOP <Table_Lookup>
    BEGIN For i = 1 TO Table_Size
        IF SOUGHT_PAGE = Table[i].RAM_Page
        THEN Found = True
             EXIT <Table_Lookup>
        END IF
    END LOOP <Table_Lookup>
    TERMINATE: None

    IF NOT Found
    THEN
        Page_Swapped = Selected_Page() -- Function to select RAM resident
                                          Page for swapping
        IF Table[Page_Swapped].Dirty_bit THEN SAVE(Page_Swapped) END IF
        LOAD(SOUGHT_PAGE,Page_Swapped)
        Table[Page_Swapped].RAM_Page = SOUGHT_PAGE
        Table[Page_Swapped].Dirty_bit = 0
        SOUGHT_PAGE = Page_Swapped
    ELSE
        Page_Swapped = Selected_Page() -- Dummy call used to update
                                       -- page replacement history
        SOUGHT_PAGE = i
    END IF
    return (SOUGHT_PAGE * Page_Size + VM_Index mod Page_Size
             + Array_base_address)

END LOC
```

Listing 1. *(Continued on following page)*

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CIRCLE 1 ON READER SERVICE CARD

```
PROCEDURE VM_Assign(VM_Index : integer; X : Your_data)

BEGIN
    RAM_Data[LOC(VM_Index)] = X
    Table[SOUGHT_PAGE].Dirty_bit = 1
END VM_Assign


PROCEDURE SAVE(Page_Number : integer)

BEGIN
 INITIALIZE: m = Page_Number - 1) * Page_Size + Array_base_address
             p = (Table[Page_Number].RAM_Page - 1) * PageSize +
                 VM_base_address
     LOOP
     BEGIN  For n = 1 to Page_Size
          WRITE VM_File, (p + n),RAM_Data[m + n]
     END LOOP
END SAVE
PROCEDURE LOAD(VM_Page, RAM_Page_Num : integer)

BEGIN
 INITIALIZE: m = RAM_Page_Num - 1) * Page_Size + Array_base_address
             p = (VM_Page - 1) * PageSize  + VM_base_address
     LOOP
     BEGIN  For n = 1 to Page_Size
          READ VM_File, (p + n),RAM_Data[m + n]
     END LOOP
END SAVE
```

Listing 1. *(Continued from preceding page)*

```
PPL routines to recall and store elements of a two-dimensional
virtual array, using the checkerboard method

-- Constants are:

-- Table_Size : Maximum number of pages in RAM.
-- Page_Col_Size  : Number of columns in a page.
-- Page_Row_Size  : Number of rows in a page
-- ROWS : Number of rows

-- External identifiers are:

-- Table_Type = RECORD RAM_Page, Dirty_bit : integer; END
-- Table : ARRAY[1..Table_Size] of Table_Type
-- SOUGHT_PAGE : integer
```

Listing 2. *(Continued on a following page)*

```
-- RAM_Data :
    ARRAY[1..(Table_Size * Page_Col_Size * Page_Row_Size)] of Any type

-- Procedures SAVE and LOAD are similar to those in listing (1),
the difference being is that they incorporate wrapping and
unwrapping arrays to matrices and vice versa, respectively.


FUNCTION MATLOC(VM_Row_Index, VM_Col_Index : integer) return integer

BEGIN
    SOUGHT_PAGE_Row = VM_Row_Index div Page_Row_Size + 1
    SOUGHT_PAGE_Col = VM_Col_Index div Page_Col_Size + 1
    SOUGHT_PAGE = SOUGHT_PAGE_Row  + (SOUGHT_PAGE_Col - 1) * ROWS
    -- Loop to search for page among RAM resident pages.
    INITIALIZE: Found = FALSE
    LOOP <Table_Lookup>
    BEGIN For i = 1 TO Table_Size
        IF SOUGHT_PAGE_Row = Table[i].RAM_Page
        THEN Found = True
             EXIT <Table_Lookup>
        END IF
    END LOOP <Table_Lookup>
    TERMINATE: None

    IF NOT Found
    THEN
        Page_Swapped = Selected_Page() -- Function to select RAM resident
                                          Page for swapping
        IF Table[Page_Swapped].Dirty_bit THEN SAVE_MAT(Page_Swapped) END IF
        LOAD_MAT(SOUGHT_PAGE,Page_Swapped)
        Table[Page_Swapped].RAM_Page = SOUGHT_PAGE
        Table[Page_Swapped].Dirty_bit = 0
        SOUGHT_PAGE = Page_Swapped
    ELSE
        Page_Swapped = Selected_Page() -- Dummy call used to update
                                       -- page replacement history
        SOUGHT_PAGE = i


    END IF
    Page_Row = VM_Row_Index mod Page_Row_Size + 1
    Page_Col = VM_Col_Index mod Page_Row_Size + 1
    Mat_Size = Page_Row_Size * Page_Col_Size
    return {(SOUGHT_PAGE - 1) * Mat_Size + (Page_Col - 1) * Page_Row_Size
             + Page_Row}

END MATLOC


PROCEDURE VM_MAT_Assign(VM_Index : integer; X : Your_data)

BEGIN
    RAM_Data[LOC(VM_Row_Index,VM_Col_Index)] = X
    Table[SOUGHT_PAGE].Dirty_bit = 1
END VM_MAT_Assign
```

Listing 2. *(Continued from a preceding page)*

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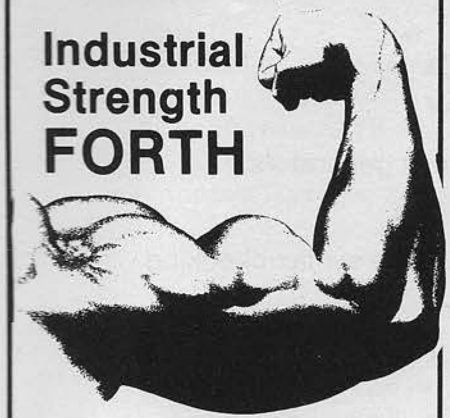

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CIRCLE 79 ON READER SERVICE CARD

```
PPL code for modified, least-frequently-used (MLFU) page
replacement function


FUNCTION Selected_Page() return integer

-- Critical_Time is set as a criterion for giving recently read
pages a second chance for staying.  It must be systematically
updated by other program segments.

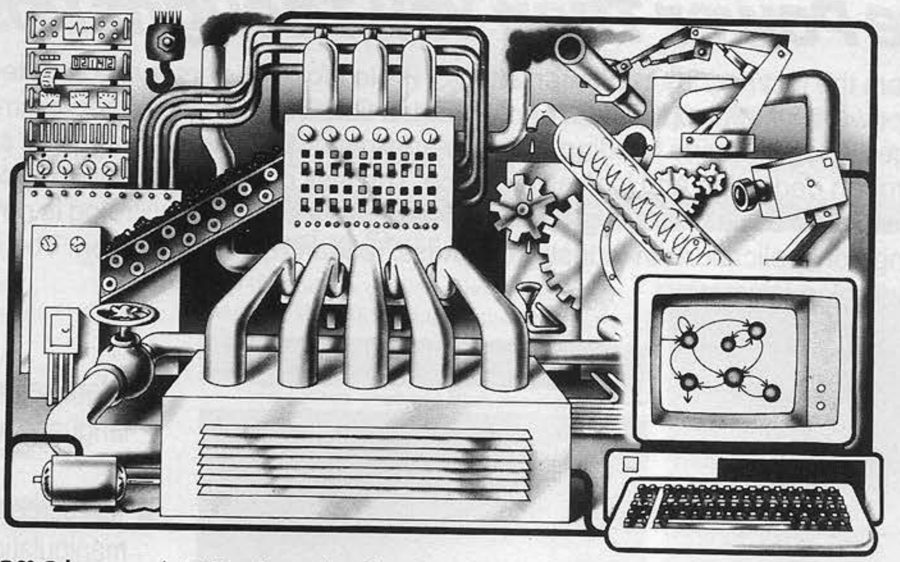
-- The modified Table_Type is
-- Table_Type = RECORD RAM_Page, Dirty_bit, Frequency : integer;
                       Time : Time_Units END

BEGIN
    IF Found
    THEN   -- when sought page is RAM-resident
        Table[i].Frequency += 1
        return ()
    ELSE
        INITIALIZE: Pick = 1
        LOOP <Start_Up>
        BEGIN For j = 1 to Table_Size
            IF Critical_Time > Table[j].Time
            THEN Least_Frequent = Table[j].Frequency
                 Pick = j
                 EXIT <Start_Up>
            END IF
        END LOOP <Start_Up>
        TERMINATE: None

        INITIALIZE: Least_Frequent = Table[Pick].Frequency
                    Pointer = Pick; j = Pick + 1
        LOOP <Search>
        BEGIN IF j > Table_Size THEN EXIT <Search> END IF
            IF Least_Frequent > Table[j].Frequency AND
               Critical_Time > Table[j].Time
            THEN Least_Frequent = Table[j].Frequency
                 Pointer = j
            ELSE j += 1
            END IF
        END LOOP <Search>
        -- Prepare frequency count for new page
        TERMINATE: Table[Pointer].Frequency = 1
        return( Pointer )
    END IF
END Selected_Page
```

Listing 3.

Csharp Realtime Toolkit



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CIRCLE 59 ON READER SERVICE CARD

Philippe Kahn: The man behind the Borland myth

By Regina Starr Ridley

[I] met a goddess, disk in hand,
There in Scotts Valley—home of Borland.

She sang to me with perfect pitch,
Of code that runs without a glitch.

Turbo Pascal; SideKick too,
And SuperKey, the one that's new.

Where Dionysian madness reigned,
Among those usually left-brained.

At what I heard my wonder grew,
For ancient Bacchus lives anew—

Reborn in this Age of Information,
As head of a Software Corporation.

—"Bacchus and The Myth of Borland"[1]

Philippe Kahn, founder and president of Borland International, can't find a bottle opener for the two bottles of Calistoga mineral water.

He improvises. He uses the doorjamb and flips the caps off. Mineral water sprays the air as if from a geyser, splattering his face, Hawaiian shirt, and tan corduroys. He continues talking without wiping his face, oblivious. He's not a man who worries about such things as appearances.

Kahn seems like a man who's living his dream. His two-year-old, privately owned company is bringing in an average of $2 million dollars a month with monthly sales of 60,000 units, which Kahn compares with Lotus Development Corp's 45,000 units.

In 1½ years, Borland has sold 400,000 copies of Turbo Pascal, a widely acclaimed piece of software originally priced at a revolutionary $49.95 (Turbo Pascal 3.0, released in March 1985, costs $69.95). Borland's second big product, the desktop organizer SideKick, has had sales of 300,000 units since June 1984. SuperKey, a data encryption and macro processor program, was released in April, and Borland says 15,000 orders were received in the first three weeks.

PC Week listed Turbo Pascal among the top 10 products of 1984, and *Infoworld* named SideKick product of the year in 1985. Borland was named company of the year in 1984 by *PC Magazine.*

Thirty-three-year-old Philippe Kahn holds the spotlight for this success. The media seems suddenly to have caught on to a hot personality. *The Wall Street Journal* covered Kahn in a front page story on June 6, playing up his maverick nature and flamboyant lifestyle under the headline, "L'Enfant Terrible is also L'Enfant Riche." Two days later—perhaps a typical day, perhaps not—Kahn participated in a morning radio talk show, at noon began a 2½-hour interview with *TIME* magazine on U.S. entrepreneurs, and immediately followed with the *COMPUTER LANGUAGE* interview.

"We'd like to get Philippe on the cover of *TIME* magazine," Borland's corporate communications director confides. Some might see an ego problem here, but that's an oversimplification. More accurately: Philippe Kahn is a very intelligent man who recognizes his abilities and has formed a company in his image. But there's more to the man than that.

"You have to be careful of appearances, you know," Kahn says. "People and things are never as good as they appear to be. Sure, the company is super successful. I can be considered maybe even the most successful guy of the year, whatever, so what? There's more to it, there's more to someone than that."

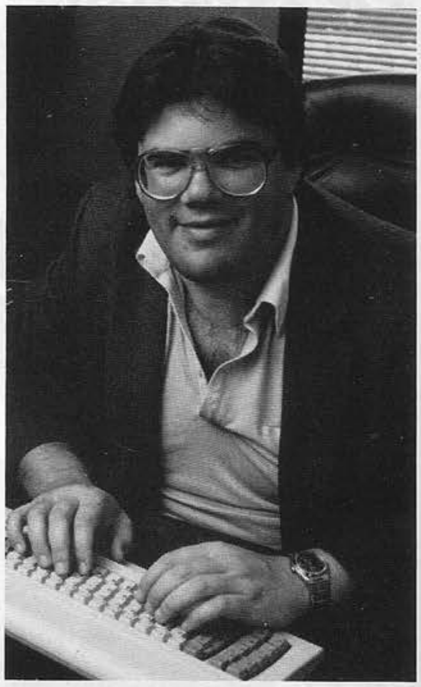
Now Zeus, as you know, is fond of risk;
Of earthly maidens who boot the disk.

For if she smiles, Zeus can't refuse her,
And thus he consorted with the End-user.

Semele her name, the Market Place;
A princess full of riches and grace.

There in her womb grew the seed of Zeus,
Philippe, Bacchus, Ease of Use.

Kahn's university years were spent in France, where he was born, and Switzerland. He made money on the side playing his saxophone in French jazz clubs. His academic interest focused on theoretical mathematics and number theory, and he received an Agrégation de Mathématique, equivalent to a Ph.D. in mathematics, certified by the French Academy of Science. He taught university-level math in Nice and Grenoble, France.



"Computers were just a way for us to do applied mathematics and solve problems," says Kahn. "I was more interested in proving theorems and in the beauty of absolute pure mathematics done with just the mind and no machine."

"In the States computers at that time already had kind of an aura—there was another dimension than the pure scientific dimension, kind of like the dimension a rock group has to a high school class.

"The aura around the Apple is much more than just business and computers. It's something else. There is something a little mystical. But the mystique [in Europe] at that time didn't exist. The

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    until Organized;
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```

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CIRCLE 56 ON READER SERVICE CARD

punch cards . . . there wasn't much mystique there. For me, the mystique of manipulating ideas was far more attractive than the mystique of the punch card reader."

Kahn studied mathematics in Zurich, Switzerland, for a time. He happened to wind up in a class taught by Niklaus Wirth, champion of structured programming and author of Pascal and Modula. "At that time there was no such thing as a computer class, you had to learn a language," says Kahn. "As far as I can remember, there was a choice between PL/I and Pascal. When I went into the PL/I class there were 200 people. In the Pascal class there were five people, because no one knew anything about Pascal." Wirth was the professor, and Pascal was the first language Kahn learned.

What changed Kahn's mind about computers was his encounter with the video terminal and keyboard in the early 1970s. His first computer was the Apple II. "I discovered with my Apple II the mystique of Silicon Valley," says Kahn. "I thought the center of gravity of the high-tech world was Silicon Valley. It was an opinion, I'm not sure it was a fact. And it was a dream, you know, everyone has a dream."

In 1983, the Borland myth begins. Kahn founded Borland International that May, with a total of $20,000 in family investments. The first office was over an auto repair shop. Kahn chose the name Borland because it sounded very American to him—it was inspired by astronaut Frank Borman's name. Kahn didn't want to draw any attention to his immigrant status as an illegal alien (he now has a green card).

Turbo Pascal, Borland's first product, was released in November 1983. Its actual origins are shrouded in some mystery. Kahn says he and two friends—whose names he cannot (or will not) reveal—wrote it in Europe. They were making a living writing application code in Pascal for CP/M-80 machines.

But when the IBM PC arrived on the scene, "we found ourselves with the worst compilers for Pascal that have ever been written," Kahn says. "We really had a problem. We needed a Pascal compiler that behaved the way we wanted it to behave. First, we wanted it to be fast. Then we wanted it to be small. And we wanted it to generate good code. There came Turbo Pascal."

Then Bacchus, (Philippe) remembered and cried,
At how his Mother in sorrow had died.

How expensive programs dragged her away,
Making her suffer; making her pay.

"The User must have a product that's great!"
He shouted, descending to Pluto's Gate.

"Faster Compilers with vigor and speed,
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Borland's philosophy of selling low-priced software is Philippe Kahn's philosophy. "Everyone was saying 'you should try to sell it [Turbo Pascal] for $400, $500.' One day I said 'hey, we're going to sell it for $49.95 plus $5 shipping and handling,' because I had bought a mail-order book at a B. Dalton's store, and the book said if you want to generate an impulse buy, the product has to be less than $50.

"That's how the whole concept came. And then the concept was such a success that it became a philosophy. When we saw the enthusiasm it generated, we said well, maybe we've got something here, something that everyone's been waiting for—super-quality software at rock-bottom prices."

Some other software publishers have been following Borland's lead in low software prices, notably Adam Osborne's Paperback Software. "I like Adam," says Kahn. "I hope that he will be successful because it will shut the mouths of all the people who have been putting him down for a long time."

"Regarding his company, I'm glad to see that people are following our lead in terms of pricing. Unfortunately, I'd hope that people would follow our lead in terms of quality, too."

Osborne's company markets software it purchases from a pool of software developers, who are then paid royalties. "I don't know how viable it is to do what he does and not develop your own software," says Kahn. "At our prices, you can't offer large royalties to people."

Non-copy protection is another one of Philippe Kahn's beliefs that became a Borland philosophy. Borland's policy of non-copy protection is held without regard to how it affects the company's sales.

"It is a philosophy," says Kahn. "I do not use copy-protected software. Why should I impose copy protection on my customers who are ready to spend money on a piece of software? Why should I tell them to do something I wouldn't do?"

"The problem with copy protection the way it is right now is that it's basically a tax on honesty. It's like saying, 'You're buying this thing and paying me money, but I don't trust you. You're thieves, so I'm copy protected.'

"I think it's a major problem to treat people that way. I think in any business relationship, if there's not at any point some sort of trust in the relationship, then I'm not interested. I'd rather go into the mountains and pick strawberries."

"For all mankind can be glad and hack
If we bring the excitement of programming back.

So let the taste of my programs flow;
Let ecstasy in their phosphor glow."

[redacted] "The core of our corporate strategy is that we are a language company and that we know that languages are here for the long run. We aim to be the language company of the latter part of the eighties," proclaims Kahn.

Borland's choice of language products to develop over the next year or so ("I don't want to talk about time frames anymore" growls Kahn, "you know how software is—you start developing and then you pray") is Modula-2, C, BASIC, and then Ada.

"We chose Modula because I like Modula," says Kahn. He does not see a Borland Modula as a competitor to Turbo Pascal. "I believe that Pascal will probably remain the primary teaching language, as well as gradually supplant BASIC for reasonably small programs. I believe Modula-2 will be for people who want to go for bigger projects and have use for multitasking applications, because it does support quite nicely interprocess communications and things like that."

"It's like a toolbox, you know. If you start trying to use a saw as a hammer or a hammer as a saw you're in trouble. Why would people who want to make small projects, like printing a mailing list, use Modula-2 and have to hassle with some of the inconveniences of Modula-2 because it's a 'better' language?

"I don't think Modula-2 is a better language than Pascal, especially since Pascal has been extended. Now, if you're talking Modula-2 against standard Pascal, then O.K., sure. But a language like Turbo Pascal—probably the de facto standard Pascal—has a lot of the things that Modula-2 has in it, all the low-level stuff.

"Modula-2 will probably be bought by people who need the functionality of Modula-2," he says. "We know that Modula-2 will be far less successful than Turbo Pascal. We know it will be somewhat successful, but there is no way we can sell the same amount of Modula-2s and Pascals."

Borland's Modula-2 for CP/M-80 is currently in beta test. The PC-DOS version is in alpha test. The CP/M-80 Modula is further ahead because "one guy got excited about doing it for CP/M and was faster than the other guys," says Kahn.

"It's a good compiler. It generates code that is two or three times faster than Turbo Pascal. It's the best CP/M-80 compiler.

"I think we're the only company developing new products for CP/M, and that's got to excite the whole CP/M community. We are a company that doesn't do things just because there's a market out there—and I think that's one of the keys to our success. We do things because we think they're going to be useful tools. If they're tools for us, they'll probably be tools for a lot of people, and then there'll be a market. That's how Turbo happened, that's how SideKick happened, that's how SuperKey happened, and that's how the CP/M version of Modula-2 happened.

"I'm sure we'll make money on the CP/M version of Modula-2. It's exciting for people to know there's a company that still cares about CP/M-80. And sure, we care because there are some guys who use CP/M-80; therefore we do products for it."

Kahn chose BASIC to be one of Borland's next compiler products even though he doesn't like BASIC. "The only thing I really needed was a BASIC compiler that could generate executable files out of a Microsoft 3.0 interpreter program," says Kahn. "And I thought that's what people needed. A machine that would allow you to run all those programs you find in the magazines or in the public domain. And eventually everyone will buy one even if they don't use BASIC, because everyone has a few BASIC programs that do something on their machine, whether it's a game or something like that."

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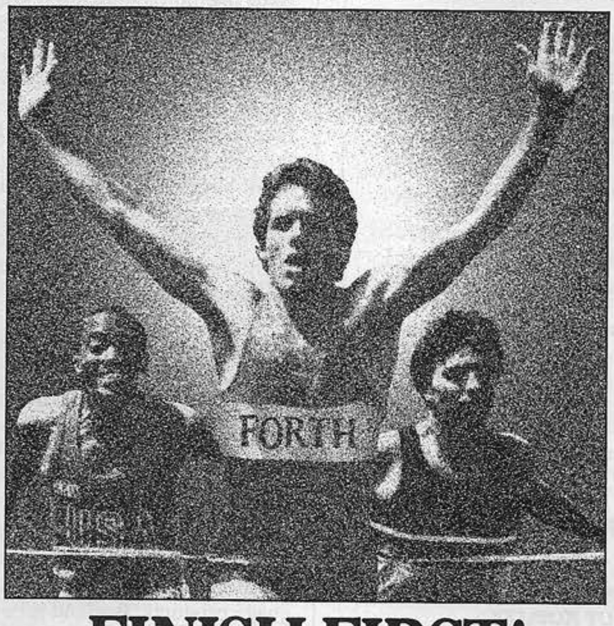

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In the past Kahn has been quite vocal about his distain for C. He's only mellowed a bit, but C is high up on the Borland product list.

"If people want a C compiler, we'll give them a C compiler. We're a language company, and we have the technology to produce very good compilers. Producing a C compiler is essentially writing a slightly different parser than Modula-2's, because the functionality of C is very close to that of Modula-2."

Kahn says he uses C for certain things, such as drivers. He's working on a Sun terminal and uses C on it because he doesn't think its Pascal compiler is very good.

"But I personally don't like to take C and write a program," says Kahn. "I like to take Pascal and Modula-2 and fiddle around, write little games, have fun on a plane with my DG while people are watching 'Karate Kid' or something. Write a little Space Invaders game, something useful, or something funny."

"Do you know what C is? There are two types of languages. C is a write-only language. Pascal is a read and write language. Take two 1,000-line programs. One in Pascal, one in C. You didn't write them, someone gave them to you. You know both languages well. With the Pascal program, after 10 minutes maximum you'll know what it does. With the C program, you could spend two weeks figuring out what it does. It's a write-only language.

"I think the dazzling penetration of C among a certain fringe of programmers is due to the craze over UNIX. Everybody said 'UNIX is going to be successful, therefore C is the language.' Well, everybody knows by now that UNIX won't be successful, and therefore C probably will be an interesting language in certain areas, but won't be 'the' language."

After Modula-2, BASIC, and C language products, Borland is considering coming out with an Ada compiler. Kahn plans to implement a reasonable subset of Ada for people who want a fast, efficient development system. "The goal here is that if people develop software with our compiler, then once they finish, when it works, then they can compile it on a validated Ada compiler. And then they have a really easy way to work," says Kahn.

Kahn has no plans for COBOL, Forth, or AI language products. "We do what we like to do, and I never really liked COBOL. Unless someone comes on with the company who just loves COBOL, wants to do a Turbo COBOL or something, I just won't get involved with it."

"Forth is a religion, and we've kind of decided right now not to participate in religion, one side or the other.

"I think AI is a big bunch of baloney. What they call AI is simply manipulating more data in less time. AI is not much more than glorified Animal programs.

"AI languages are interesting. LISP is an interesting language. PROLOG is probably even a more interesting language. A language like Smalltalk is cute. I like it, I think it's nice."

Kahn sees Borland as a fun place to work. And judging from the parties, it is. The story of the Borland toga party at the 1985 West Coast Computer Faire in San Francisco, Calif., received a great deal of press coverage. About 600 Borland employees and guests—most wearing grape leaves in their hair—participated in an unparalleled spectacle of a party.

Philippe—Bacchus—wore a toga and played his sax. A troupe of San Franciscan clowns, called I Fratelli Bologna, led high-tech versions of Olympic games, such as throwing the diskette. Other entertainment included a stunning male trapeze artist and a rock band. Meanwhile, party-goers feasted on an outrageous buffet— which included a whole roasted lamb and pig—and enjoyed the flowing spirits. Borland's cost: $45,000.

Kahn says Borland employees have fun at work too. "If you're a software developer at Borland you're proud of what you're doing because we don't have 'junk products.' There's no product we're ashamed of. And that's important. That's a craftsman's pride."

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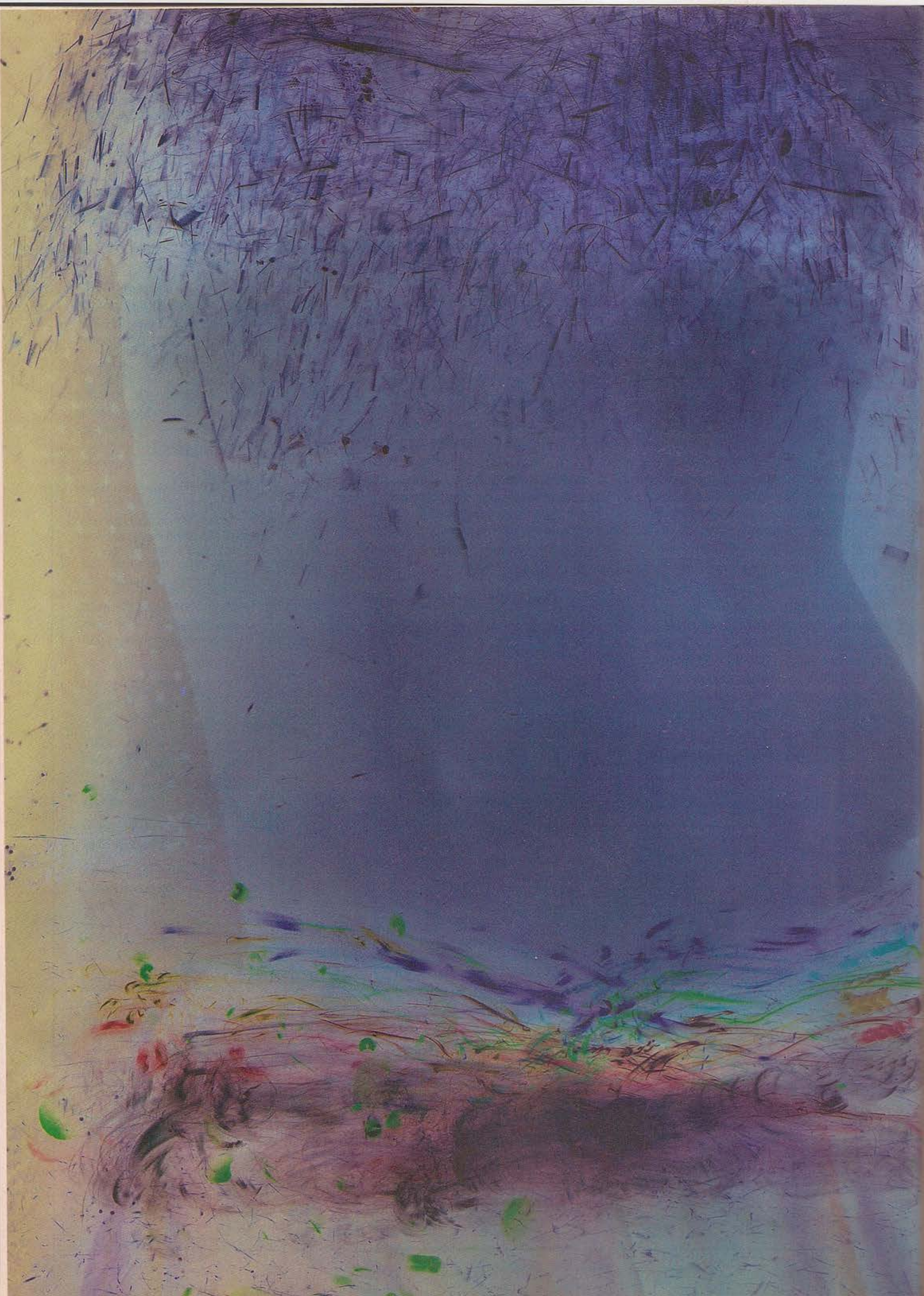


Smalltalk Comes to the Micro

By Darryl Rubin

Ten years before Apple's Macintosh opened its first window, researchers at Xerox Corp. were using personal computers that sported a what-you-see-is-what-you-get, point-and-click user interface with bit-mapped graphics, overlappiing windows, and pop-up menus.

These minicomputer-sized "PCs" were called Altos, and they were programmed in a language called Smalltalk.

Smalltalk pioneered many of today's most important software concepts, including object-oriented programming, message passing semantics, and modeless design. The most recent version of the system, Smalltalk-80, was also an unprecedentedly accessible one; it was written almost entirely in itself and provided multiwindowed "browsers" through which you could inspect or extend the system. And extending the system was easy, because by its very design principles, the Smalltalk-80 system encouraged exploratory programming and a toolkit approach to software design and reuse.

Not long ago, if you wanted to explore a Smalltalk-80 system you had to work at Xerox—no commercial implementations existed. But that situation is changing, and at least one product is now available for personal computers: Methods, from Digitalk Inc. Methods implements a large subset of the Smalltalk-80 system as described in *Smalltalk-80: The Language and its Implementation,* by Adele Goldberg and David Robson (Addison Wesley, 1983).

In this article we'll explore the Smalltalk-80 language and learn how to write Smalltalk-80 programs. As programming examples, we'll present some surprisingly short routines that implement UNIX-style filters and even an interactive spelling checker. We'll also highlight the differences between "pure" Smalltalk-80 and the Methods implementation of it.

For a quick intro to Smalltalk-80 syntax, check out the window labeled Language Comparison in Figure 1. This and the other figures and listings we'll present were all developed on an IBM PC/AT running Methods. If you have your own copy of the program, fire it up and come explore!

Object lesson

A Smalltalk-80 system is made of objects that send messages to each other. Objects include everything from numbers and characters to arrays, sets, files, windows, code blocks, and text editors. Each distinct kind of object is called a class. An object that belongs to a particular class is called an instance of that class. Some examples of objects and their classes are:

29	Integer
$A	Character (A)
'ABC'	String
#Smalltalk	Symbol (unique string)
#(1 2 3)	Array (of integers)
#(1 $A 'BC')	Array (of various)
[x := 1 + 2]	Block of code

More complex objects are the text editor labeled *Workspace* in Figure 1 and the *Class Hierarchy Browser* in Figure 2. Of course, you can add your own classes of objects to a Smalltalk-80 system. To write a Star Trek game, for example, you might first create a *Starship* class, then create an instance of that class called *Enterprise*.

All computations in Smalltalk-80 are performed by objects. Indeed, objects are like little computers: each stores some data plus the procedures that operate on that data. To access or manipulate the data stored in an object, you send it a message detailing your request. In response, the object executes the internal program selected by your message and returns the result (another object, naturally).

An object's stored data, called its instance variables, serves to describe the current value or state of the object. For example, *Integer* objects have a single instance variable that specifies the numeric value of the integer. *Starship* objects would probably be more complex, having instance variables for the *Starship*'s current speed, heading, fuel, and damage level.

An object's internal programs, called its methods, serve to implement the behavior or functionality of the object. The code for these methods is contained in the class definition for the object. For example, objects of class *Integer* have methods for performing arithmetic, numerical comparison, and type conversion, among others. *Starship* objects might have methods for changing speed, turning, raising shields, refueling, and so on.

If you think Smalltalk-80's encapsulation of data and procedures inside

objects smacks of Ada's packages or Modula's modules, you're right. It's also what makes all three languages so modular and extensible, because it prevents software components from depending on each others' internal representations or implementations. Smalltalk-80 smacks of Ada in another interesting way, thanks to its message passing semantics, as we'll see later.

The message is the medium

All computation in Smalltalk-80 occurs as a result of sending messages to objects. For example, the expression *2 + 3* causes the message " + " (called the message selector) to be sent to the object *2* (the message receiver), with the object *3* as a message parameter. The object *2* responds to the " + " message as you would expect: by adding its own value to that of the parameter and returning the result, *5*, as another object.

The *Workspace* window in Figure 1 shows several kinds of message expressions and the results they return. The Smalltalk-80 system is unlike others in the flexibility it gives you for entering and evaluating expressions. You can type expressions anywhere in almost any window on the screen, scrolling the window contents in any direction if you need to.

To evaluate the expression, you highlight it with the cursor and pick the command *Show It* from a pop-up menu. Just like that, the answer prints out adjacent to the highlighted expression. (Or, if the expression has an error, an error message is inserted into the expression adjacent to the error.)

Smalltalk-80 syntax and sample expressions

Language Comparison

```
PASCAL                      SMALLTALK-80

x : = 2 * (y + z);          x : = 2 * (y + z).
a[i] : = a[j];              a at: i put: (a at: j).
x : = max (y,100);          x : = y max: 100.

s : = 'string';             s : = 'string'.
l : = length(s);            l : = s size .
t : = concat(s,s);          t : = s , s.
u : = copy(t,1,l);          u : = t copyFrom: 1 to: l.

new (aSet);                 aSet : = Set new.
aSet : = aSet + [2];        aSet add: 2.

if [n] in aSet              (aSet includes: n)
   then n : = log(n)           ifTrue:  [n : = n log]
   else n : = abs(n);          ifFalse: [n : = n abs].

for i : = 1 to 10           1 to: 10 do:
   do a[i] : = 0;              [:i | a at: i put: 0].

while not(eof(f))           [f atEnd] whileFalse:
   do read(f,ch);              [ch : = f next].
```

Workspace

```
EXPRESSION                        RESULT

-2 * -3 abs                       -6
('ab' , 'de') size                4
$* isLetter                       false
'abc' asUpperCase                 'ABC'
'abc' at: 2                       $b
#(1 2 $a 'b') at: 4               'b'

"Assume an empty set Myset"
Myset add: 1                      1
Myset add: $a                     $a
Myset includes: 2                 false
Myset                             Set($a 1)

"Assume an empty dictionary D"
D at: 'yes' put: 'si'             'si'
D at: 'yes'                       'si'
D keyAtValue: 'si'                'yes'
D includes: 'si'                  true
D includes: 'yes'                 false
D includesKey: 'yes'              true
D at: 8 put: 10                   10
```

Figure 1.

There are three kinds of messages: unary, binary, and keyword. A unary message consists of a message name with no arguments, as in:

```
'ABCD' size    4
```

Here, the unary message *size* is sent to a string object, which responds by returning the string's length. The *size* message is quite a common one in Smalltalk-80; almost every kind of object implements its. Array objects, for example, respond to *size* with the number of cells they have.

Binary messages take a single argument and are written in infix notation, as follows:

```
2 + 3            5
'ab' > 'cde'     false
'ab'~= 'cde'     true
```

Keyword messages take one or more arguments and use message selectors that have trailing colons. An example of a one-argument keyword message is *2 max: 3*, which returns the object *3*. Here is a two-argument message:

```
Prompter prompt: 'Suspect word'
     default: 'hee*'
```

This message sends the selector *prompt:default:* to the object *Prompter*, with the two strings as arguments. The result is the pop-up prompter shown in Figure 2. You build messages with three or more arguments in a similar manner.

Smalltalk-80 lets you build arbitrarily complex message expressions from simpler ones. The language has few precedence rules. Terms of equal precedence are evaluated left to right, with parenthesized expressions being evaluated first. Unary messages are sent first, binary messages next, and keyword messages last. So the expression:

```
anArray at: aSymbol hash
     put: aSymbol size + 1 * 2
```

is evaluated as if it had been written:

```
anArray at: (aSymbol hash)
    put: (((aSymbol size) + 1 ) * 2)
```

Here's an example that shows when parentheses are a must:

```
aSet add: (anArray at: 1)
```

Had this expression been written without parentheses, the invalid message selector *add:at:* would have been sent to the object *aSet* with *anArray* and *1* as arguments, hardly what we intended!

If you need to send several messages to the same object, you can cascade them with semicolons, like this:

```
Enterprise turn: 90;
    ahead: 5; shieldsUp
```

You can also assign the results of an expression to a named variable, as in *aDict := Dictionary new* (here, as in Methods, we use the symbol ":=" rather than Smalltalk-80's left arrow). This creates a new dictionary and assigns it to the symbol *aDict*, which will now serve as a name for that object in any expression. So now you can write:

```
aDict at: 'yes' put: 'si'   "Store"
aDict at: 'yes'             "Look up"
```

Perhaps you noticed that dictionaries and arrays use the same messages, or protocol, for storing (*at:put:*) and retrieving (*at:*) elements. Indeed, objects have a great deal of commonality in the messages they implement. This provides a consistent and type-independent way to deal with many kinds of objects, be they numbers, strings, arrays, sets, or display windows. Type independence is further promoted by the fact that Smalltalk-80 implements dynamic binding, meaning that a message specifies the name rather than address of the desired operation.

These characteristics make it possible to write general-purpose routines akin to Ada's generic procedures. Suppose you write a Bubble Sort method, using the message "<" for comparisons. Then your method will be able to sort any kind of object that implements "<", including numbers, strings, and dates. Write a LIFO stacking method, and this one routine will be able to stack numbers, arrays, sets, windows, even starships!

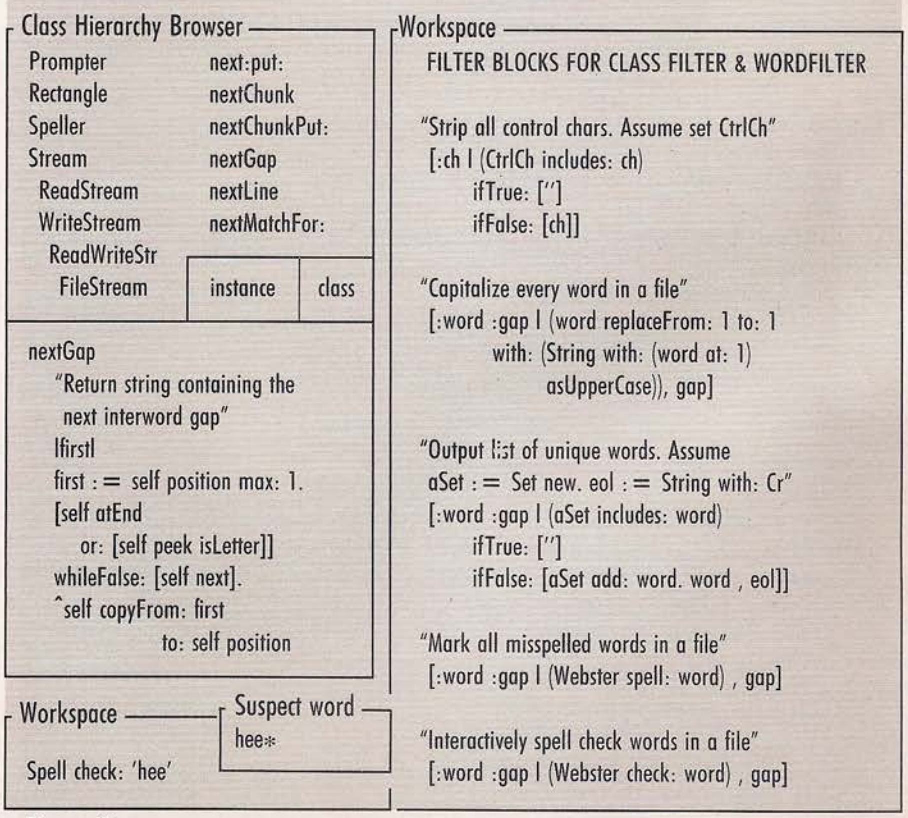
Class act

A Smalltalk-80 system consists of many kinds, or classes, of objects, each of which performs different functions. *Integers, Strings, Sets,* and *Dictionaries* are some of the standard classes. All objects of the same class have the same structure: the same instance variables, message protocol, and methods. For example, all *Integer* objects have an instance variable for the integer's value, and all respond to messages for performing arithmetic and type conversion.

Smalltalk-80's class structure is hierarchical, consisting of a root class, called *Object*, and many subclasses. Class *Object* provides the common protocol for all objects, including standard messages for testing an object's class (*isKindOf: aClass*), copying the object (*copy*), or printing it out symbolically (*printOn: aStream*). Each subclass adds to this its own messages and methods for implementing the subclass-specific functionality.

The most significant feature of Smalltalk-80's class system is that each class inherits the entire functionality of all

nextGap, sample Filter blocks, and a Spell window



```
Class Hierarchy Browser
Prompter          next:put:
Rectangle         nextChunk
Speller           nextChunkPut:
Stream            nextGap
 ReadStream       nextLine
 WriteStream      nextMatchFor:
  ReadWriteStr
   FileStream     instance | class

nextGap
  "Return string containing the
   next interword gap"
  |first|
  first := self position max: 1.
  [self atEnd
     or: [self peek isLetter]]
  whileFalse: [self next].
  ^self copyFrom: first
            to: self position
```

```
Workspace
Spell check: 'hee'
```

```
Suspect word
hee*
```

```
Workspace
 FILTER BLOCKS FOR CLASS FILTER & WORDFILTER

 "Strip all control chars. Assume set CtrlCh"
  [:ch | (CtrlCh includes: ch)
       ifTrue: ['']
       ifFalse: [ch]]

 "Capitalize every word in a file"
  [:word :gap | (word replaceFrom: 1 to: 1
          with: (String with: (word at: 1)
                asUpperCase)), gap]

 "Output list of unique words. Assume
  aSet := Set new. eol := String with: Cr"
  [:word :gap | (aSet includes: word)
       ifTrue: ['']
       ifFalse: [aSet add: word. word , eol]]

 "Mark all misspelled words in a file"
  [:word :gap | (Webster spell: word) , gap]

 "Interactively spell check words in a file"
  [:word :gap | (Webster check: word) , gap]
```

Figure 2.

its superclasses, straight up to class *Object*. This means you can add new classes to the system simply by changing or extending an existing class to create a subclass of it. You never need reinvent an existing piece of functionality. You are also free to modify existing classes, because Smalltalk-80 is written almost entirely in itself.

Like everything else in a Smalltalk-80 system, adding or modifying classes is done through windows. The *Class Hierarchy Browser* in Figure 2 shows one such window for doing this. Clockwise from the top left corner, this window shows a class pane, message pane, and method pane. To modify an existing class, all you do is select a class name from the class pane, then select one of the class's messages from the message pane, and finally edit the method that appears in the method pane.

You can also add methods or classes by selecting those respective functions from pop-up menus associated with browser windows. Figure 2 shows an example of my having done exactly that: the *nextGap* method is one that I added to class *Stream*. It complements the standard *nextWord* method and is useful in writing UNIX-like filters that process streams a word at a time, as we'll see.

When you add a class to the system, you must specify several things:

- The names of the new class and its parent class.
- The names of the instance variables for the new class. Each object of the class will get a private copy of these variables.
- The names of the class variables for the new class. The class variables are shared by all objects of the class.
- The message selectors for the new class.
- The methods for each defined message selector.

Once you've entered this information, Smalltalk-80 compiles it into the system image, and it's ready for use. Listing 1 shows a class that I added to my copy of Methods. The class, called *Filter*, implements a UNIX-like filter capability. Here's a simple example of using a filter to convert a file to uppercase:

```
(Filter using:
     [:ch | ch asUpperCase])
fromFile: 'in.txt'
toFile:     'out.txt'
```

This expression first creates a new *Filter* object by sending the block of code *[:ch | ch asUpperCase]* to the *Filter* class (we'll describe blocks in the next section). The *Filter* class stores that block as an instance variable of the newly created filter object. The new filter is next sent the *fromFile:toFile:* message, which specifies input and output file names for the filter to use. The result is to read the input file a character at a time, sending each character to the stored block and writing the block's resulting value to the output file.

Sometimes it's useful to process a file a word rather than character at a time. For this purpose I created a subclass of *Filter* called *WordFilter.* The definition of *WordFilter* (Listing 2) consists of but a single method that implements the message *from:to*. This message overrides a mes-

```
Filter class definition and methods

Object subclass: #Filter
  instanceVariableNames:
    'filterBlock '        "Code that does the filtering"
  classVariableNames: ''  "None"
  poolDictionaries: ''    "None"

Filter class methods

using: aFilterBlock

  "Create a new filter using the specified block."
   ^self new using: aFilterBlock

Filter methods

from: inStream to: outStream

  "Filter from input to output stream, returning output
   stream."
   inStream do: [:item |   "Do for each item in inStream"
     ((item := filterBlock value: item) isKindOf: String)
       ifTrue:  [outStream nextPutAll: item]
       ifFalse: [outStream nextPut: item]].
  ^outStream.

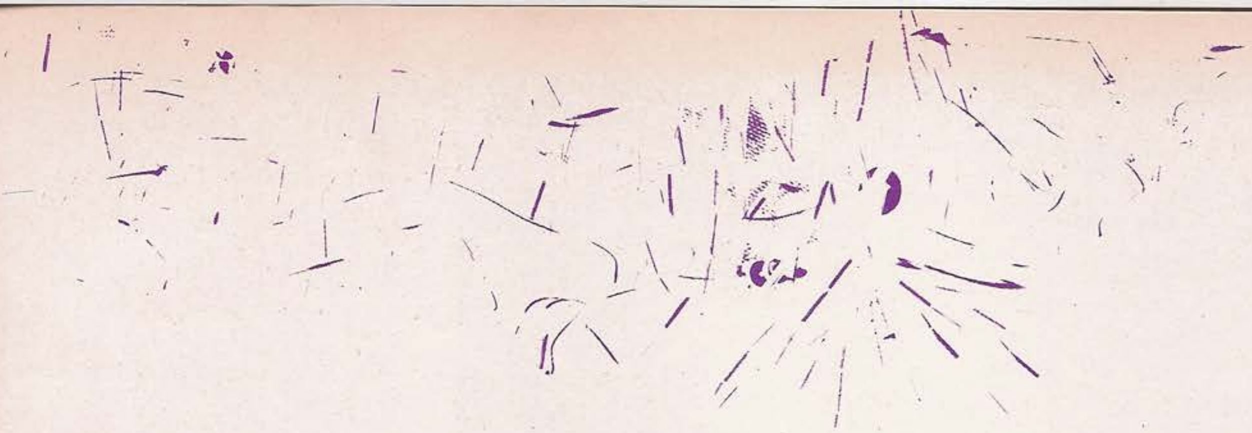
fromFile: inFile toFile: outFile

  "Filter from the specified input file and append to the
   output file. Return the output file name."
  ^(self        "Invoke self with files opened as streams"
     from: (Disk file: inFile)
     to:   (Disk file: outFile) setToEnd)
    close file name.

using: aFilterBlock

  "Make the specified block be this object's filter block."
   filterBlock := aFilterBlock
```

Listing 1.



sage of the same name defined in class *Filter*. The difference is that *WordFilter* reads its input stream a whole word at a time and sends two arguments to the stored filter block: the input word and the interword gap (white space) that follows the word in the input stream. To accomplish this, notice how *WordFilter* uses the *nextGap* method (Figure 2) that I added to class *Stream.* Here's how to convert a file to upper case using a word filter:

```
(WordFilter using:
    [:word :gap |
      word asUpperCase , gap])
fromFile:  'in.txt'
toFile:    'out.txt'
```

WordFilter demonstrates the true power of Smalltalk-80's class inheritance mechanism because *WordFilter* inherits and uses all of *Filter*'s messages and methods except *from:to:*, which it overrides. For example, when you evaluate the preceding expression, Smalltalk-80 searches the *WordFilter* class definition for the *using:* message. *WordFilter* doesn't implement this message, so Smalltalk-80 searches upward through the class hierarchy for the first class that does implement the message, which happens to be *Filter*. *Filter*'s method for *using:* is therefore executed. Ditto for all the other messages that *WordFilter* doesn't itself implement.

You can do quite a lot with *Filter*s and *WordFilter*s. The *Workspace* window in Figure 2 presents some blocks that you can plug into the previous filter expressions to perform various operations. The brevity of the code to do such jobs could make even a UNIX wizard envious!

Method actor

Methods are what perform all the actions in a Smalltalk-80 system. In fact, almost all the Smalltalk-80 system code is implemented as methods and any software you add to the system will be in the form of methods, too.

Analogous to function calls in other languages, methods can take zero or more arguments and always return a value. They can also declare local variables that are created anew each time the method executes.

You can add methods to any class in the system—none are sacred. Simply display the desired class in a browser and pick *Add method* from a pop-up menu. This puts you into the browser's method pane where you use Smalltalk-80's excellent text editing functions to enter the method. The *nextGap* method in Figure 2 is a perfect example. It shows that a method consists of four things:

- The message pattern for the method. This is the name of the message, if unary (for example, *nextGap*), or the name of each keyword and its argument (for example, *fromFile: aFile toFile: aFile*).
- An optional declaration of temporary variables (for example, | *first* |, | *x y* |).
- A sequence of one or more expressions to be executed, with each expression delimited by a period.
- An optional return expression prefaced by an up arrow (^) that specifies the object to be returned as the value of the method. If omitted, the object executing the method (*self*) is returned.

The *nextGap* method also illustrates another important Smalltalk-80 programming concept: the importance of *self*. *Self* is a pseudovariable that lets an object send messages to itself, as when one of its methods needs to call another. In Figure 2, *nextGap* uses *self* to call two of the other methods defined in class *Stream*: *position* and *copyFrom:to:*. The more you get into Smalltalk-80, the more you'll notice objects talking to themselves!

To really get into methods, you need to understand Smalltalk-80's control structures. Like everything else, these are implemented as messages sent to objects. A simple example is the repeat loop:

```
10 timesRepeat: [Enterprise fire]
```

Integer objects respond to the *timesRepeat:* message by evaluating the bracketed expression a number of times equal to their value. Another pair of messages they respond to are *to:do:* and *to:by:do:*, which implement what you Pascal programmers would call a *For* loop (Figure 1 has an example).

```
WordFilter class definition and methods

Filter subclass: #WordFilter
  instanceVariableNames: ''   "inherited from Filter"
  classVariableNames: ''
  poolDictionaries: ''

WordFilter class methods

  "Inherited from Filter"


WordFilter methods

from: inStream to: outStream

  "Filter words from input to output stream, returning
   output stream."
   [inStream atEnd] whileFalse:
     [outStream nextPutAll:
        (filterBlock value: inStream nextWord
                     value: inStream nextGap)].
  ^outStream.
```

Listing 2.

```
Speller Class Definition and Methods

Object subclass: #Speller
  instanceVariableNames:
    'wordList correctList ' "Valid word list and autocorrect list"
  classVariableNames:
    'Marker'                "Char for marking misspelled words"
  poolDictionaries: ''

Speller class methods

words: wordFile corrections: correctFile

  "Create a new speller object, reading the word list
   from wordFile and correction list from correctFile.
   Also initialize the character that misspelled words
   are marked with."
   Marker := $*.
   ^self new initialize
      words: wordFile;
      corrections: correctFile


Speller methods

addCorrections: inStream

  "Add correction word-pairs from the input stream to
   the correction list.  Each word pair is on its own line.
   A line with only one word specifies a word to be deleted
   rather than replaced."
   |entry word|
   [inStream atEnd]
     whileFalse:  [entry := ReadStream on: inStream nextLine.
                   word := entry nextWord.
                   entry nextGap.
                   entry atEnd
                     ifTrue:  [self correct: word with: '']
                     ifFalse: [self correct: word
                                   with: entry nextWord]]

addWord: aWord

  "Add a word to the word list."
   aWord notNil
     ifTrue: [wordList add: aWord trimBlanks asUpperCase]

addWords: inStream

  "Add words in the input stream to the word list"
  [inStream atEnd]
    whileFalse: [self addWord: inStream nextWord].
  self addWord: ''

check: aWord
```

Listing 3. *(Continued on following page)*

Strange as it may seem, the bracketed expressions used in control structures are actually objects—objects of class *Block*. Whereas Smalltalk-80 responds to unbracketed expressions by evaluating them, it responds to bracketed ones by instantiating them as block objects.

Blocks serve as containers for message expressions that are not to be executed until a later time. When the time is right, sending the block the message *value* causes its contents to be evaluated and a result returned. For example, in the previous expression, the integer 10 sends the argument block the message *value* 10 times. You can also pass arguments to blocks by using the messages *value:*, *value:value:*, etc., as in:

```
[:str | str size] value: 'myString'.
avg := [:n1 :n2 | (n1 + n2) / 2].
avg value: 2 value: 4
```

Blocks give great power to Smalltalk-80 because they allow methods to pass code as arguments to other methods or even to synthesize code on the fly. This makes Smalltalk-80 suitable for AI programming.

Although not exactly an example of AI, Listing 3 does present a surprisingly small yet functional spelling checker, complete with pop-up prompters and an automatic misspelling correction feature! The comments in the first five methods give you the details. Here's how you would create a *Speller*, with the dictionary and correction list loaded from disk:

```
Webster := Speller
    words: 'words.lst'
    corrections: 'corrs.lst'.
```

To spell check a single word, you could now evaluate the expression *Webster check: 'hee'*. The result is the prompter shown in Figure 2. If you'd like to spell check an entire file, look just to the right of the prompter. What you see is the filter block you'd pass to *WordFilter* in a *using:* message (see last section). Yes, *Speller*s are actually designed to be used with *WordFilter*s; because of this, they inherit all the generality (and code!) that filters have to offer.

The Smalltalk of Digitalk

Digitalk's version of Smalltalk-80 may surprise you. It does what many, including myself, weren't sure was possible. Here is a personal computer implementation of not just the Smalltalk-80 language, but also much of the Smalltalk-80 system—pop-up windows, browsers, and all. Here is an implementation that is faithful to the spirit of a system implemented in its own language, with all the source code accessible to every end user (almost 200K worth). Here is an implementation whose performance is adequate for serious use.

Of course, personal computers are not (yet) Xerox Altos, so Methods does betray some disappointing, though reasonable compromises. There are no bit-mapped graphics or mouse support, two of Smalltalk-80's hallmarks. Instead, you get character mapped equivalents to Smalltalk-80's *Bitblt, Point,* and *Rectangle* classes, but with color thrown in (something the Alto didn't have). As for the mouse, Digitalk's way of using the numeric keypad makes for a serviceable alternative, but still . . .

You'll also find that Methods' classes and message protocols are not always identical to Smalltalk-80's. *Views* are called *Panes*, *Controllers* are called *Dispatchers*, the file system is different (thank goodness—it uses standard DOS files and directories). You get walkbacks, but no debugger. And no multitasking.

I spent a long time looking for other differences and discovered something else. You can spend months browsing the Methods source code and still discover a useful new method at every turn, or think of one you'd like to add, and can, on the spot.

Methods, like a Smalltalk-80 system should be, is yours to explore, to mold, and to master. ■

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Darryl Rubin is section manager for network products at ROLM Corp.

```
   "Spell check a word and if misspelled, prompt the
    user with the marked word.  The user may hit CR
    to output the marked word, erase the mark to accept
    the word as is, or edit the word to correct it.  If
    the user accepts or edits the word, the wordList and
    correctList are updated accordingly."
    |word|
    word := self spell: aWord.
    (self isMarked: word)
    ifTrue: [word := Prompter prompt: 'Suspect word'
                              default: word.
             (self isMarked: word)
             ifFalse: [self addWord: word.
                       word ~= aWord
                       ifTrue: [self correct: aWord
                                         with: word]]].
   ^word

correct: badWord with: goodWord

  "Add a word pair to the correction list."
   ((badWord notNil) and: [goodWord notNil])
     ifTrue: [correctList at:  badWord trimBlanks asUpperCase
                         put: goodWord trimBlanks asUpperCase]

corrections: correctFile

  "Add correction pairs from the specified file to the
   correction list."
   self addCorrections: (Disk file: correctFile)

initialize

  "Create word list and correction list objects for speller"
   wordList := Set new.
   correctList := Dictionary new.

isMarked: aWord

  "Return true if aWord has been marked by the spell method"
   ^(aWord size > 0) and: [(aWord at: aWord size) = Marker]

matchCase: aWord using: modelWord

  "Make aWord conform to the case/capitalization of
   the model word."
   |word|
   (modelWord at: modelWord size) isUpperCase
     ifTrue: [^aWord asUpperCase].
   word := aWord asLowerCase.
   (modelWord at: 1) isUpperCase
     ifTrue:  [word at: 1 put: (word at: 1) asUpperCase].
   ^word

spell: aWord

  "Spell check a word: replace it if it has an entry
   in correctList, otherwise mark it if not in WordList.
   If the word is being replaced, make the case of the
   replacement word correspond to that of the input word."
   ^self
     matchCase:
       (correctList at: aWord trimBlanks asUpperCase
          ifAbsent:
            [(wordList includes: aWord trimBlanks asUpperCase)
               ifTrue:  [^aWord]
               ifFalse: [^aWord , (String with: Marker)]])
     using: aWord

words: wordFile

  "Add words from the specified file to the word list."
   self addWords: (Disk file: wordFile)
```

Listing 3. *(Continued from preceding page)*

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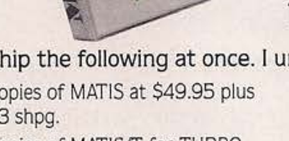

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BLISS Lures System Programmers

By Bruce Leverett

BLISS is a language designed for system programmers. This term is used loosely to denote two groups of people: those who write operating systems and those who read operating system programmer's manuals. BLISS is one of several languages developed between 1965 and 1975 for these people. It can be compared with C, a much better known language used by roughly the same kind of programmers.

BLISS originally was designed at Carnegie-Mellon University,[1] Pittsburgh, Pa., and has since been adopted by DEC for internal use.[2] At the time BLISS was designed, it was felt that system programmers had to be lured away from using assembly language by means of high-level languages with equal capabilities. Thus, BLISS offers much of the hands-on feel of assembly language programming with minimal built-in run-time support, while retaining the syntax of ALGOL-like languages. In addition, all BLISS compilers have been sophisticated optimizing compilers.

To the casual glance, a BLISS program looks much like an ALGOL-68, C, or Pascal program. Each of these languages has its own favorite punctuation and keywords, but the experienced programmer soon learns to discount the surface differences. Why, then, do we call BLISS exotic? It is not the syntax that is unusual but the semantics. BLISS brings along its own philosophy of system programming. One can learn a great deal about system programming just by studying this language. It is also instructive to compare BLISS with other languages or to compare the Carnegie-Mellon version with the subsequent DEC version. In this article I will describe a few of the highlights of the BLISS language design.

Distinguishing features

In BLISS, the name of a variable always refers to the address of the variable, never to its value. To get its value, you must use an operator, the dot (.). Since the main purpose of a variable is to hold a value, BLISS programs have a lot of dots. Here are some typical assignments in more conventional languages and their BLISS equivalents:

Pascal	C	BLISS
A := B	A = B	A = .B
A := B + C	A = B + C	A = .B + .C

The assignment $A = B$ copies the address of B, not its value, into A. The equivalent assignment in the C language would be *A = &B.*

Why this departure from convention? The principal reason is to allow programmers to manipulate addresses easily and comfortably. In particular, the structure definition facility described later on could hardly be conceived of in a language with the usual semantics. Many languages don't allow a programmer to get at the addresses of variables at all. Those that allow the programmer to access these addresses have elaborate rules for specifying when the name of a variable denotes its *lvalue* (or address) or its *rvalue* (or value). In the wild free-for-all of pointers, integers, records, etc., involved in a complicated data structure access, elaborate rule systems can be useless or worse. But I am getting ahead of myself.

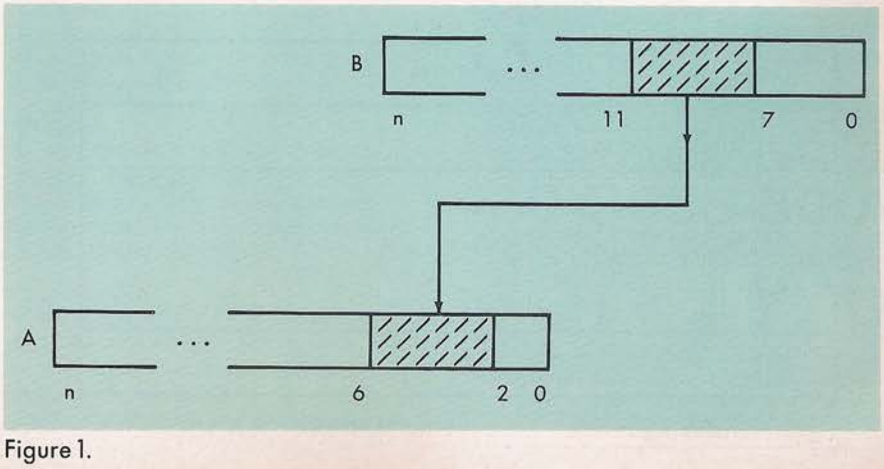
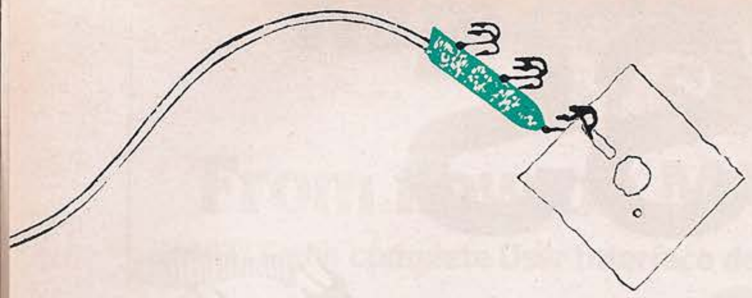


Figure 1.



Any contiguous subfield of bits in a word can act as an address. In other words, it can be assigned to or fetched from. For instance, the assignment:

```
A <2, 4> = .B <7, 4>
```

copies the value of a group of 4 bits within B into another group of 4 bits in A (Figure 1).

The exact rule is this: $<m, n>$ is a group of n bits starting at bit m; bits are numbered from 0 up, with bit 0 being the least significant. For instance, on a DEC VAX-11, A <0,8> denotes the byte at address A. Many computers do not provide good hardware support for this kind of addressing. For instance, on the DEC PDP-11, the previously listed assignment would require quite a lot of shifting and masking, perhaps making copies of A or B. The choice of the "best" code sequence, from the point of view of a compiler, is not an easy one, depending as it does on which byte boundary each field is close to and whether or not the variables are in registers.

To the assembly language programmer, then, this feature is a significant abstraction. It allows him or her to play freely with the positions of fields within words without losing sleep over tricky modifications to long code sequences.

When system programmers write manuals and other documentation for each other, they often use diagrams like the one in Figure 2. This is a diagram of the layout of information in a block of 32-bit words. Each box represents a field; in this case, the *parms* field is an array. It may be that the size of this array is stored in the *size* field, so the program cannot access the *mung* field without first looking up that size. To add a further complication, it may be that some additional fields exist in a separate block pointed to by the field *gorp*, a kind of layout that is common when blocks share data with each other.

The possibilities available to the programmer who designs such a layout are limitless. In many languages, type definition facilities allow the programmer to specify some kinds of layouts using records or arrays, but a finicky programmer inevitably will be disappointed by his or her inability to get just the layout he or she has in mind. In BLISS, the programmer specifies an arbitrary algorithm that, given a base value (usually but not necessarily an address) and a field name, array index, or sequence of names and indexes, computes the address of the field to be accessed. This address can, of course, be a bit-field address, as described earlier.

Space does not permit me to show the syntax of these structure definitions, but suffice it to say that they are similar in appearance to subroutine definitions. Accesses to structures, no matter how bizarre the structure access algorithm, have a rather conventional appearance. For instance, supposing that F is the address of a block with the layout in Figure 2, the following accesses to the block might take place:

```
F [foo] = 3;
F [parms, .i] = .AnotherArray [.i];
X = .F [mung];
```

The hidden computations behind these statements can be rather startling, for example, when looking up the *size* field to look up the *mung* field in the last statement. However, this example was chosen only to illustrate the generality of the structure definition feature. The programmer who does not use this generality does not pay for it; there are no hidden computations for conventional records, and for conventional arrays, the only hidden computation is scaling to access full-word elements on computers that are byte-addressed. System programmers can talk to their compiler just as freely and expressively as they talk to each other, without losing sleep over how it will understand or misunderstand their intentions.

I have described the three features of BLISS that distinguish it, in a truly instructive and useful way, from other languages used for system programming. The language has other unusual features, but as they are much less important, I will list them briefly.

- BLISS is an expression language with no distinction between expressions and statements; a statement is nothing more than an expression whose value is not used. The value computed by a block is defined as the value of the last of its statements (or, properly speaking, the last of its expressions). This is a minor convenience in that the programmer can freely add extra statements to the computation of any expression.
- BLISS does not have a *goto* construct. It has some constructs for exiting from loops and other types of expressions. Despite all the breath that has been wasted over this issue, programmers do not find this feature of BLISS to be very important in their lives, either for good or for ill.
- BLISS has powerful features for defining preloaded data. In the original Carnegie-Mellon BLISS, this was done with a general macro facility. DEC BLISS has more advanced features that allow the programmer to use the same structure accesses to define data that he or she would use if initializing it at run time.
- BLISS is typeless. No type checking is done at compile time. At the time BLISS

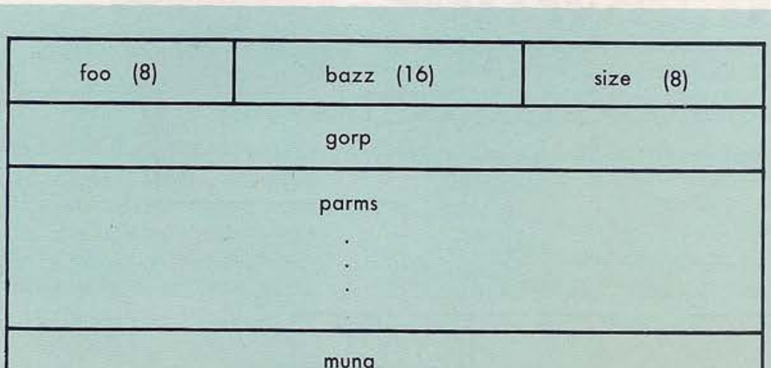


Figure 2.

was designed, it was thought that in system programs, which were notorious for manipulating bit fields within pointers, having wild kinds of variant records, and other practices, type checking might be more of a nuisance than a help. Hindsight suggests that some kind of type checking would have been useful. BLISS programmers constantly make errors that cause integers to be used as pointers and vice versa, especially when they forget to use dots. They generally agree that compiler checking for this kind of error would be worthwhile.

BLISS, past and present

The original published description of BLISS is from 1971.[1] A compiler for BLISS for the PDP-10 was in use at least from 1970 at Carnegie-Mellon. A cross compiler running on the DEC PDP-10 and producing code for the DEC PDP-11 became available around 1972. This compiler was used heavily at Carnegie-Mellon and some other sites and is still in use today. After several years of positive experience with both compilers, DEC revised and expanded the language and implemented compilers for the new language for the PDP-10, PDP-11, and VAX-11, an effort that began in 1975 and was more or less complete in 1978. Many large systems have been written in BLISS, notably the Hydra multiprocessor operating system,[3] the Scribe document formatter,[4] and the BLISS compilers themselves.[5]

The designers of BLISS thought that for a high-level language to catch on among system programmers, it would have to provide many of the features that system programmers claimed to depend on in assembly language coding: close control over the type of code generated, especially the layout of storage; generation of optimal or near-optimal code; and access to all the unusual features of the underlying instruction set.

In retrospect, it seems that system programmers are not so finicky after all. The widespread use of C, a language that is much more conventional than BLISS and is not supported by optimizing compilers, is an object lesson. Though C is a reasonably well-designed language, programmers choose it not for its design but for what it provides access to (UNIX on various computers). Unique languages such as SNOBOL and LISP are attractive for their own sake. More commonplace languages, such as those that are ALGOL-like, are attractive mainly for their availability. In this respect, code optimization is as much a hindrance as a help. No native BLISS compiler for the DEC PDP-11 was ever developed because the design of the original BLISS compiler for the PDP-11, a cross compiler that ran on the PDP-10, was too large for porting to a 16-bit minicomputer.

In spite of these reservations, I can wholeheartedly recommend the design of BLISS. I have used BLISS and other languages for many years and most recently have helped construct an automated translation system to convert programs from BLISS to C. There is simply no language other than BLISS in which system programming is so natural and the compiler provides the programmer with so much useful abstraction while so cleanly staying out of the way. To the programmer who is dissatisfied with the design of the language or languages he or she uses from day to day, I say: study the design of BLISS if you want to know how it should have been done. ■

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Bruce Leverett has a Ph.D. in computer science from Carnegie-Mellon Univ., Pittsburgh, Pa. As a student, he was one of the implementers of BLISS-11. He is currently involved in research and development for Unilogic Ltd. and Lexene Corp.

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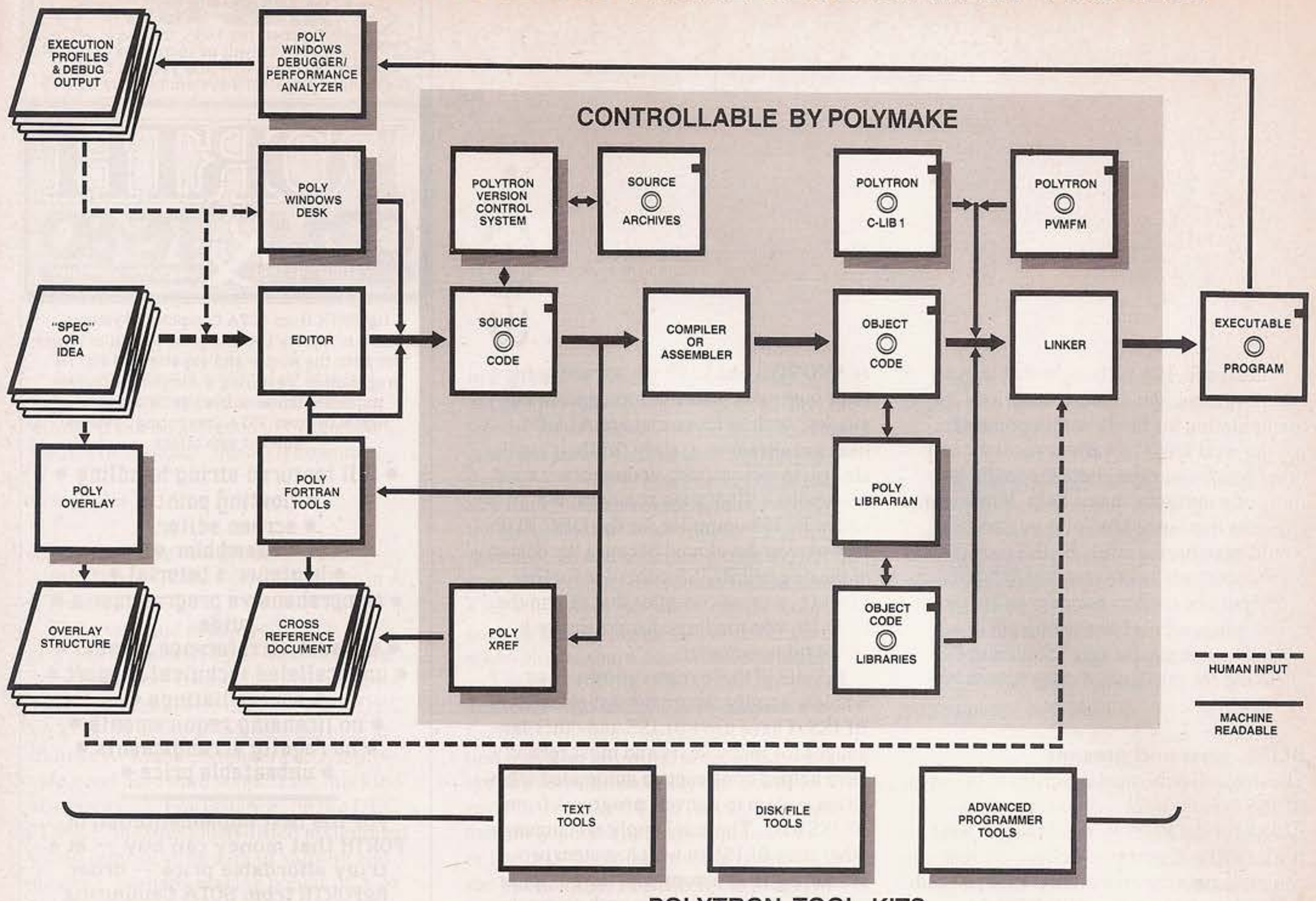

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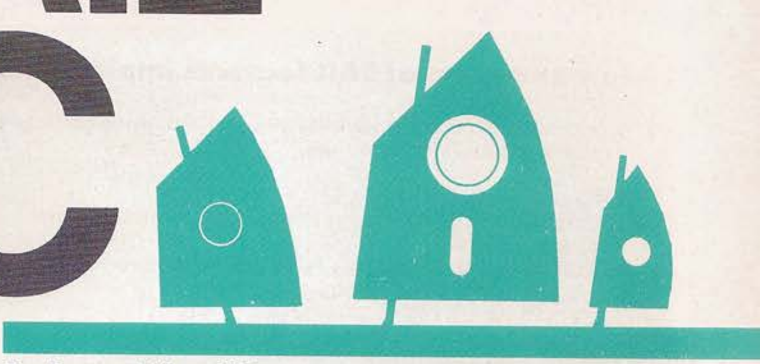
PSAIL: SAIL to C



By Peter F. Lemkin

Wouldn't it be nice to be able to use dynamic text strings in a Pascal-like environment as we currently are able to do in BASIC? Well, it appears we can— plus more.

The SAIL language has had dynamic strings for years. The original SAIL compiler, developed between 1969 and 1976 at the Stanford University Artificial Intelligence Laboratory, Stanford, Calif., runs only on DEC-10 and DEC-20 computers. Unfortunately, most of SAIL was written in 36-bit dependent assembly language and is thus nonportable.

A portable version of SAIL, called PSAIL, is being constructed to run in most medium size C environments. This article will present PSAIL in the context of the original SAIL language.

What is SAIL? It is a robust ALGOL-dialect programming language with many useful extensions.[1,2,3] Because of its expressivity, SAIL lends itself to writing large, complex application and system programs. Its robust approach to type coercion makes it closer to a D.W.I.M (Do What I Mean) algorithmic language than other popular; block structured, strong type-checking languages such as Pascal, Modula-2 or Ada. On the other hand, C—which has looser type checking—does not have enough type coercion capability, especially in forcing arguments to the types expected in procedure calls. Without a lintlike syntax checker, writing large modular programs can be difficult.

Although not an ideal D.W.I.M. language by any means, SAIL comes closer to this approach than the other common block-structured languages mentioned. Of course, the price of more type coercion is that you can hang yourself more often.[4] Our experience, however, is that you learn to live with occasional pitfalls and take advantage of D.W.I.M. most of the time for greater overall productivity. Repeatedly SAIL has been selected in the National Institute of Health DECsystem-10 community as the implementation language of choice for large, complex systems.

Language overview

SAIL can be easily partitioned into several independent language subsets. This reduces what a new user has to learn to start programming quickly. These include: dynamic strings, dynamic arrays, dynamic records, macro expansion, conditional compilation, code inserted from other files, separate compilation of modules, bit manipulation, *if* and *case* statements and expressions, flexible I/O, powerful string scanning and conversion functions, LEAP (an associative data structure facility which includes dynamic data entities called items, datums, sets, lists, associations as well as associative search constructs—more on this later),[1,2,3] processes, contexts, interrupts, in-line assembly language, etc.

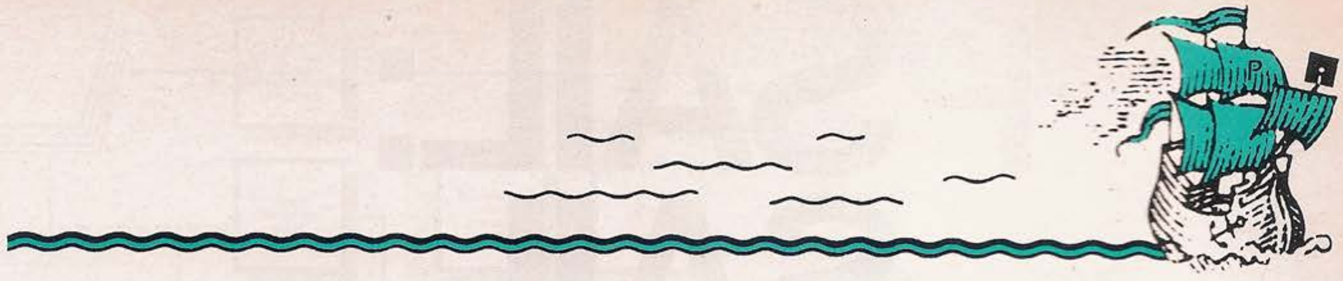
Note that complete exclusion of some of these sublanguages or features is easily achieved in actual programming practice. The most often used remainder is the core subset of SAIL, which captures its paradigm. This is relatively small—on the order of Pascal. For example, the PSAIL source code itself, written in SAIL, uses no records, LEAP, embedded assembly language, interrupts, processes, or context language constructs.

Table 1 illustrates some of the language elements with examples of SAIL fragments. Obviously, a much longer list would be required to illustrate the full language described in the *SAIL* reference manual.[1] In the examples, keywords appear in uppercase and user-defined symbols in lowercase. However, SAIL does not make alphabetic case distinctions as C does.

The PSAIL compiler project began as a result of the announced demise of the 36-bit/word DEC-10 and the increasing popularity of small UNIX systems. I had written a large data analysis system in SAIL called GELLAB,[5,6] which involved image processing and data base analysis for two-dimensional electrophoretic gels. To export this system, as well as other SAIL programs, the SAIL source code needed to be translated to some other language.

PSAIL was derived from an early program called SAITOC, written to translate GELLAB to C. Later, the goal of PSAIL was changed from that of a translator performing a partial translation to a full compiler capable of:

■ Handling any SAIL program and flagging illegal SAIL syntax, unimplemented SAIL language elements, and C portability problems



A few examples of SAIL features implemented in PSAIL

1. Dynamic strings, string concatenation, substrings, string garbage collection, and some explicit string conversion functions.

```
STRING s, s1, s2;  INTEGER i, j, k;
s1 := "Adam";  s2 := "Eve";
s  := s1 & s2;
i  := LOP(s); COMMENT extract 1st char of s, shorten s;
s1 := s & s1[i for 10] & " AND " & s2[k for j];
r  := CVD("3."&"14159"); s := CVS(j+2**k);
s  := "The value of k is " & CVS(k) & " decimal and" &
   CVOS(k) & " octal";
```

2. Extensive macro facility including conditional compilation.

```
DEFINE # = "COMMENT ";  COMMENT # is short for COMMENT;
DEFINE dbug(x) = "PRINT(""""x="""",x,CRLF)";
IFC (tops10=10 AND nFiles<15)
      THENC ... ELSEC ... ENDC
```

3. Dynamic n-dimensional arrays with ragged (i.e. > 0 or < 0 bounds).

```
REAL ARRAY abc[-10:10], xyz[p:q];
STRING ARRAY  xyzzy[500:1000,-7:25,-10:-5];
```

4. Optional dynamic array bounds checking which may be toggled on/off.

```
SAFE REAL ARRAY x[1:10]
NOW!UNSAFE x; ...  # No bounds checking on 'x';
NOW!SAFE x; ...    # Resume bounds checking on 'x';
```

5. Nestable variable declarations inside of LABELED blocks. Note redefinition of x and y and that QUOTED block labels must match.

```
BOOLEAN z;
DO BEGIN "block one"
   INTEGER x, y;
      BEGIN "block two"
      REAL x, y;
       ... Compute z ...
      END "block two";
   END "block one"
UNTIL z;
```

6. Type coercions automatically generated where they are least likely to cause trouble. (Some Pascal supporters might disagree with this!)

```
STRING s;  INTEGER i;
i := s;           s := i + "A";
IF s = "Q" THEN ...
```

7. Separate compilation with INTERNAL/EXTERNAL storage modifiers and REQUIRED source code file modules with optional VERSION checking.

Table 1. *(Continued on following page)*

■ Compiling itself so that PSAIL would be portable and programs could continue to be developed in a SAIL environment
■ Running on a wide variety of systems.

At the NIH, we have had FORTRAN, ALGOL-60, and SAIL available. Over the past decade, a large body of SAIL code (greater than 200,000 lines) was written for some very large systems (GELLAB, about 70K lines, MLAB,[7] over 25K lines, and MATEXT,[8] over 35K lines). Other SAIL programs include BRIGHT, PUB, and the original TEX. Like C, SAIL supports modularity but with most of the type-checking capability of Pascal and similar languages. SAIL has often been used to build quickly large, reliable systems.

Studies have shown that the majority of algorithmic code, especially code involving numerical routines[9] and salvaging user libraries, could benefit from a high-level language translation rather than rewriting the code from scratch in a target language. It is then possible to translate verbatim much of the existing SAIL code to C using PSAIL in those cases where 36-bit dependencies are not a problem.

Using a high-level language translator preprocessor with a target system compiler causes some additional overhead. The arguments made for the FORTRAN preprocessor RATFOR (added portability, added language functionality, and user productivity) also hold for PSAIL since a SAIL environment is superior to C for program development.

By modularizing large SAIL programs into small files that are separately compiled, the additional translation cycle time should not be excessive. W. Teitelman[10] suggests that short compilation times are conducive to rapid interactive development. PSAIL should be fast enough to minimize this time. It will continue to improve as processor speeds and memory size increase.

Selecting C

To achieve portability over a wide variety of target computer systems, a portable target language is required. By writing a machine-independent, run-time library in the same target language, using machine-conditional, high-level language code where required, the feasibility of portability is greatly enhanced.

Assembly language was ruled out because it is not portable. It was decided to use a high-level language as the target language; thus the compiler is more a translator or transliterator between high-level languages than a conventional compiler which generates assembly language or machine code.

A number of popular languages, including C, Pascal, Ada, Modula-2, and MESA, were evaluated for their ability to express high- and low-level structures available in SAIL. A. Feuer and N.G. Gehani[11] give a valuable comparison of Ada, C, and Pascal, exposing their strengths and weaknesses. A further constraint we imposed was that the language should be commonly available and consistently implemented. C was selected as coming closest to meeting most of these goals.

Others have also selected C as a target language for translators. Recently there have been a number of high-level language translators including: S-TRAN for BASIC-to-C, a Pascal-to-C by J. Peterson, and FORTRIX for FORTRAN-to-C. Another advantage of a C high-level language translator is that the target code is just C code. Generated code can be used with the PSAIL run-time library or merged with other C programs, which are becoming increasing available.

PSAIL is based on the published language standards for SAIL[1] and for C.[12] Brian Kernighan and Dennis Ritchie's *The C Programming Language* is developing into the ANSI X3J11 standard.[13] There are several advantages in trying to stay within the existing language standards. Both have been well documented by these existing reference manuals.

Adhering to the standards helps ensure portability of much existing SAIL code and target C code. However, a price for standardization is not being able to polish some of the rough edges of SAIL with more modern language forms. A PSAIL language extension facility lets us optionally do this to some degree, giving us the best of both worlds.

Sublanguages

In general, adding additional language facilities missing from Pascal and C to an abstract, block-structured language increases the complexity of the language. It is generally understood that one price of

```
INTERNAL INTEGER p, d, q;     # in defining module;
EXTERNAL INTEGER p, d, q;     # in other modules;
EXTERNAL STRING PROCEDURE match(REFERENCE STRING s);
REQUIRE "boobah.sai" SOURCE!FILE;
REQUIRE "48.55" VERSION;

8. Records, checked record classes and record garbage collection.

RECORD!CLASS spot  (REAL angle, rad;
                    INTEGER area, xMom, yMom;
                    RECORD!POINTER (spot) next;
                   );
RECORD!POINTER (spot) rp1;
spot:xMom[rp1] := spot:rad[rp1]*COS(spot:angle[rp1]);

9. More natural Boolean relations as well as assignment embeddings.

STRING s; INTEGER ch;
s := "This string has 28 characters.";
WHILE s NEQ NULL DO
   If ("0" LEQ (ch:=LOP(s)) LEQ "9") OR
      (ch= ".") DO OUTSTR(ch);
   IF "Z" LEQ ch LEQ "A" THEN ch := ch-"A"+"a";

10. String scanning facility comparable to C's scanf() and scans().

11. Arrays which are dynamically defined and active in local blocks.

For i:= 1 STEP 10 UNTIL 101 DO
   BEGIN "Perform dynamic array allocation"
   REAL ARRAY vectorA[0:i], matrixB[0:2*i,0:i];
      . . . process the arrays . . .
   END "Perform dynamic array allocation";

12. Additional control statements: NEXT<label>, DONE<label>,
    CONTINUE<label> where <label> is optional.

DO BEGIN "outer loop of nonsense code"
    INTEGER x; REAL y, z;
    FOR x := 0 STEP 1 UNTIL 511 DO
       BEGIN "Loop x"
       FOR y := 25 STEP -(x+0.141) WHILE (x Leq 3001) DO
          BEGIN "Loop y"
          IF (z:=x+y)=123 THEN CONTINUE "Loop x";
          IF (z:=x-y)=1234 THEN DONE "Loop x";
          IF (z:=z+y)=321 THEN NEXT
                            ELSE NEXT "Loop x";
          END "Loop y";
       END "Loop x";
    END "outer loop of nonsense code"
UNTIL z<3.14;
```

Table 1. *(Continued from prreceding page)* increasing the power of a language by extending its vocabulary and semantics is to increase the complexity perceived by the listener or writer in understanding and using the language. Computing history has shown that many programmers avoid the excessive complexity and size of languages such as PL/I and ALGOL-68. Even new languages such as Ada and MESA suffer from similar problems.

In addition, complex programming language solutions are more difficult to construct and port to other systems. I would suggest that it is this cost of portability that is partly responsible for the demise of these large languages' popularity.

So what can we do to get expressive power in a language at minimum cost? I suggest breaking the language into natural sublanguages so that programmers can use as much of the language as they want (or need)—and require the compiler enforce these language partitions.

We are experimenting in PSAIL with the hypothesis that a reduction in apparent language size is achieved by partitioning a large language into smaller disjoint sublanguages enforced by the compiler and held together by other connecting sublanguages. This should be reflected in reducing apparent complexity as observed by the user and would seem especially useful if some exotic aspects of the language are only needed in one or two modules.

Programmers normally think about their programming environment in terms of a language subset. A compiler should be able to enforce this thinking by having the programmer declare sublanguages either to exist or other sublanguages to be excluded. PSAIL currently contains the following four sublanguages and can handle more defined by the user:

- L0 = ALGOL-60 subset, strings, macros, etc.
- L1 = LEAP associative structure language
- L2 = Processes events and interrupts
- L3 = PSAIL extensions
- L4 = User definable

. . .

As a consequence of language partitioning:

- Less experienced users can work with a reduced language, which is easier to learn.
- Sophisticated users can expand the language to take advantage of advanced features.
- The PSAIL L3 extensions can be added. These currently include: generic procedures, array slices, the C ++, —, <opr> = operators, and embedded C code.
- Programmers may supply their own dynamic extensions to PSAIL (through *PSAIL!FORGET* and *PSAIL!DEFINE* compiler directives to modify the compiler by adding new keywords using existing parser capability as well as associating new run-time procedures). These extensions can become available to other users by specifying the new language definition in a REQUIRE file module. Some possible extensions might be to implement a concurrent LISP or add relational data base language extensions.

Portability

By assuming a consistent standard C environment such as ANSI X3J11, another hurdle to portability is overcome as target language code generators are easier to write. By divorcing the code generated by PSAIL from the much more machine- and operating system-dependent run-time library, we greatly facilitate the ease of porting SAIL source code between systems. The PSAIL run-time library consists of a number of *#include* type .h header files for C code files <sairun.c>, <pmath.c>, <gcrun.c>, <leaprun.c> and <procesrun.c>.

A potential disadvantage of this approach is that some run times could call <stdio>—effectively doing double interpretation. To avoid this, PSAIL run-time packages do their own file buffering and string handling rather than calling <stdio.c> repeatedly where major bottlenecks would appear.

These run-time libraries are also written in the same portable dialect of C that PSAIL generates. They use conditional C code, which is machine dependent only when required to handle machine-specific problems, whereas PSAIL generated code is completely machine independent. This method has been used for years in writing portable C code for different UNIX environments. One needs to compile the PSAIL run-time library only once after adjusting the <config.h> file to the specific system being ported.

PSAIL abstracts some of the code generation to a higher level than basic C code. For instance, whether the target system has a 32- or 16-bit integer is not important since PSAIL emits all integers as type *INTEGER*. This in turn will be defined differently in the only machine-specific file <config.h> for the two classes of machines, for example:

```
typedef int INTEGER; /* for 32-bit
                        word int */
```

or:

```
typedef long INTEGER; /* for 16-bit
                         word int */
```

Strings are another instance of this abstraction. PSAIL uses the C string pointer strategy to facilitate use of PSAIL strings with other C packages. The *STRING* declaration uses the C *typedef* of:

```
typedef char *STRING;
```

Using a compacting string garbage collector, PSAIL keeps track of all active string pointers using a run-time string pointer stack. Garbage collection is performed when the string allocator run-time *salloc()* runs out of space. For example, *salloc()* is called from the concatenation run-time procedure *catlist()* when it needs space the size of the strings to be concatenated. Strings may be as large as the memory available from the system. Another very useful SAIL feature is dynamically allocated arrays, which may have nonzero or negative lower bounds (sometimes called ragged arrays) and optional bounds checking.

The SAIL subset used in PSAIL was derived using several constraints. By restricting the language of PSAIL to a useful subset of full SAIL constrained by several factors, the resulting PSAIL language is a relatively robust portable language. These constraints include:

■ A few subsets of the full SAIL specification are omitted at this time from PSAIL as few SAIL users in our programming community use them—for example, contexts. Although LEAP is translated, run-time code will not be written for L1 (or L2) in the first release of PSAIL. The open library scheme permits PSAIL users to redefine or write these initially missing run times in C.

■ Features that are difficult to map to C or expensive to implement in terms of run-time efficiency are not currently implemented—for example, contexts. Similarly, PSAIL does not currently support nested procedures or global *GOTO*s, although code with warnings is produced.

■ Features that take advantage of the DECsystem-10 specific instruction set but are not efficiently simulated on different architectures (for example, variable byte size operators for 36-bit words) are not currently implemented.

■ There are also subtle data structure difference issues. In all of these cases, warning errors or comments are issued for the programmer. PSAIL's "warning" and "trash graphics" comments are used to catch these types of problems. For example, as the DECsystem-10 has a 36-bit word size, 36-bit arithmetic operations are also checked and when found, reported using "trash graphics."

PSAIL, a language translator as well as compiler, uses the philosophy of optional embedded C-style warning messages to warn about possibly illegal constructs. A summary appears at the end of compilation. Warnings are given both for SAIL source code syntax errors and target C code that would be nonportable due to limitations of C or in computation (for example, 36-bit operations). Programmers should use these warnings to edit their SAIL source code and try again. These forms include:

■ "Trash graphics" are used to warn of possible problems. There is a continuum of warning levels to let you pick the message level you are comfortable to work with (Figure 1).

■ Embedded warning C-style comments of the form:

```
/*WARNING*/ = check manually for
             possible semantic or
             syntax problem
/*UNDF*/ = Undefined symbol
/*N.P.*/ = Nonportable
/*N.I.*/ = Not implemented
/*LEAP*/ = LEAP sublanguage syntax
```

■ Fatal SAIL syntax error messages that indicate what is wrong with the code, suggest what should be fixed (if it can figure it out), and point to the actual illegal SAIL source code.

■ C portability tests are built into PSAIL. For example, you can optionally test for identifier name uniqueness to *n* characters. The proposed ANSI X3J11 standard has six-character external symbols, but other systems may have different lengths.

Although both SAIL and C are block-structured languages, simple one-to-one translation from SAIL to C is not always possible. For example, the following SAIL and C fragments are similar but not a simple 1:1 mapping:

```
SAIL: For i:=(a+b) Step -c Until d Do
    <SAIL statement>;
C: for (i=(a+b); i>=d; i-=c) <C
    statement>;
```

Therefore we perform simple translation where possible and elsewhere do recursive descent parsing and generate the nonlinear mappings where required. In some cases, where it is impractical to generate in-line C code, run-time procedure calls are generated instead.

By abstracting the target language, more attention can be paid to local optimization, taking advantage of the consistency of the target language and of C's power as a high-level assembler language. For example, the SAIL fragments:

```
INTEGER ARRAY a[1:10,1:20,1:30];
INTEGER b;
STRING s1;

a[i,j,k] := a[i,j,k] + b;
(s1[k For 1] = "Q")
```

are optimized to:

```
(a) a[i][j][k] += b;
     /* No dynamic arrays, C-style */
(b) *aAry(&a,i,j,k,3) += b;
     /* Dynamic arrays, no bounds
        check */
(c) *aChk(&a,i,j,k,3) += b;
     /* Dynamic arrays, bounds check*/
(d) (*(s1+k-1) == 'Q')
```

rather than the unoptimized C code, which includes redundant calculations and higher overhead with a run-time call:

```
/**************************/
/*<5>    /\        /\     */
/*         /------\       */
/*       --|      |--     */
/*      |  | o  o |  |    */
/*        -\------/-      */
/*       |    \/    |     */
/*       +          +     */
/* BEWARE!                */
/**************************/

/* WARNING! SHIFT OF > 31-BITS IS NOT PORTABLE */
or
/* WARNING! LOGICAL OPERATION > 31-BITS IS NOT PORTABLE */
```

Figure 1.

Current status of SAIL features implemented in PSAIL

SAIL language feature	Implemented?
'DEFINE' macros	Yes, with arrays and recursion
Conditional macro expressions	Yes, = = > #if or eval in PSAIL
FORC, WHILEC, etc.	Not yet, extended SAIL macro facility
REQUIRE file statements	Yes, map = = > #include, run-time pkgs
ALGOL-60-like declarations	Yes
Declaration type checking	Yes
Automatic type coercion	Yes
Nested procedure declarations	Yes, but may be nonportable
Nested variable declarations	Yes
Dynamic arrays	Yes, arymk(), aryfree(), aChk()
Positive ragged arrays	Yes, both C and dynamic arrays
Negative ragged arrays	Yes, currently only for dynamic arrays
Safe array bounds checking	Yes, C arrays, aAdr() for dynamic
ALGOL-60-like control statements	Yes
String concatenation	Yes, a&b&c = = > catlist(a,b,c,0)
String operators	Yes, LOP, sub-strings, EQU(), etc.
Infix to prefix operators	Yes, MAX, MIN, ABS, etc.
PRINT and OUTSTR	Yes, map = = > pprintf(. . .) in <sairun.c>
TOPS10 I/O run time	Yes, most are handled in <sairun.c>.
TOPS20/TENEX I/O run time	Only those which are TOPS10 compatible
In-line assembly code	Yes, mapped to #asm/#endasm
RECORDS	Yes, mapped to struct's, no ralloc() yet
LEAP sublanguage	Most, maps through to <leaprun.c>
PROCESSES, EVENTS, INTERRUPTS	Most, maps through to <procesrun.c>
DEC-10 byte pointers in SAIL	Yes, Map = = > procedure calls, /*N.P.*/
CONTEXTS AI sublanguage	Not yet
<sairun.c>	Yes, written—not debugged
<gcrun.c>	Yes, written—not debugged
<pmath.c>	Yes, written—not debugged
<leaprun.c>	Not yet, not written, calls generated
<procesrun.c>	Not yet, not written, calls generated
STRING garbage collection	Yes, <gcrun.c> written—not debugged
RECORD garbage collection	Not yet, rec_gc() will mimic str_gc()
Procedure profiling	Yes, different from SAIL—not debugged
BAIL dynamic debugger	Not yet (maybe never . . .)
36-bit dependent code	Forget it! Recode your program!!!

Table 2.

```
(a) a[i][j][k] = a[i][j][k] + b;
(b) *aAdr(&a,i,j,k,3) =
      *aAdr(&a,i,j,k,3) + b;
(c) *aAdr(&a,i,j,k,3) =
      *aAdr(&a,i,j,k,3) + b;
(d) (*subsr(s1,k,1) = = 'Q')
```

The generation of these different array access forms *(a)-(c)* is controlled by *COMPILER!SWITCHES /CHECK* or / */NOCHECK, SAFE, NOW!SAFE, NOW!UNSAFE* compiler directives.

Status of PSAIL implementation

Because PSAIL can handle most of SAIL and has an extensive error and warning facility, the compiler is relatively large—certainly more than 64K bytes. No attempt is being made to try and squeeze it into today's toy computers since real machines with lots of memory and large disks are becoming increasingly available (at toy machine prices).

The first machine selected for export will be DEC's microVAX, then 68000-, 32016-, or 80286-class machines. Any reasonably sized machine with a decent C compiler is a likely candidate for porting PSAIL. It may also be possible to fit an optimized PSAIL into the limited memory 8088-class machines.

A SAIL code validation test suite and large number of actual working source code programs were and are being used as a compiler construction and debugging tool. These programs represent radically different styles and requirements in areas of numerical analysis, string processing, and data base analysis. Working program sources are extremely useful for finding subtle compiler bugs because, as has often been stated, no compiler is completely bug-free.

Table 2 lists the features currently implemented. It is the author's intention to place PSAIL in the public domain when it is released and to make it available on various bulletin boards and to user groups. (Watch for a *COMPUTER LANGUAGE* Users Group and Bulletin Board Service announcement of PSAIL's availability.) For those interested in working with this emerging, portable SAIL environment, it should be available later this year.

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Peter Lemkin is a computer scientist at the National Cancer Institute of the National Institutes of Health in Bethesda, Md. He applies image processing and data base techniques to biomedical problems.

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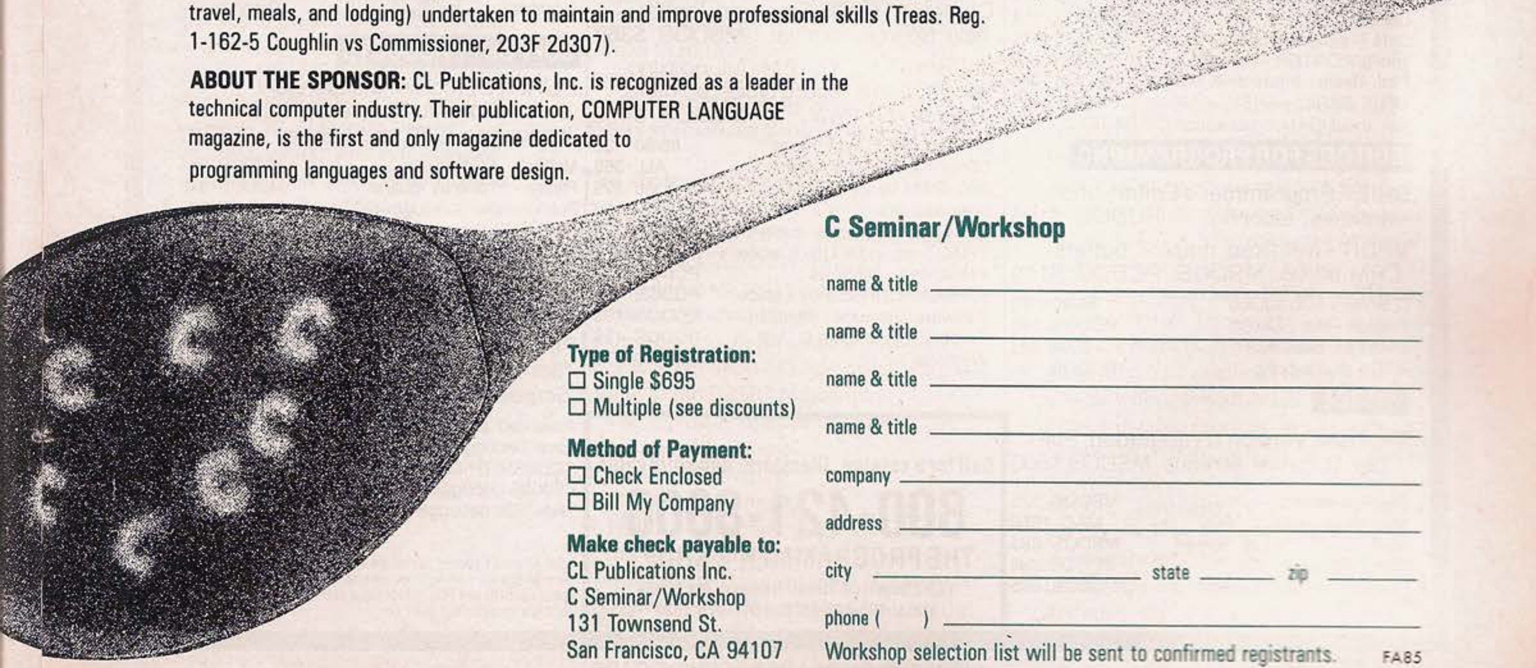

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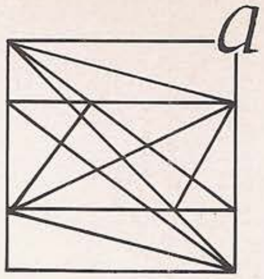
Part II: The ERGO Logic Editor

Logic at a Glance



By Jim McCarthy

In this installment of our description of the ERGO Logic Kit (see Part I in COMPUTER LANGUAGE, *July 1985), we will focus our attention on those parts of the kit that provide facilities for the creation and editing of decision tables, with an eye toward compilation. We will discuss the features available, why they exist, and what some of the compromises involved in implementing them were.*

It is reasonable to expect that these topics will be of most interest to programmers. Therefore the tenor of this article (including the examples), will be slanted in a technical direction.

However, those of you who may be more interested in the expert system class of application engendered by the ERGO Logic Kit would probably do well to bear with us, as the ERGO Logic Interpreter (described in detail in next month's installment) uses the same algorithms and techniques as the ERGO Logic Compiler for decision table parsing and rule management. Also, the same Logic Editor is used whether you're creating source code or executable tables. And finally, the rationale and philosophy of the ERGO Logic Kit are described in some detail, and these are applicable across all elements of the kit.

For information on how to acquire your version of the ERGO Logic Kit (at a nominal cost) see page 4.

The ERGO Logic Editor differs from general purpose electronic text editors and word processing programs in that it will be useful only when the class of input is logical in nature. No provision has been made for general text entry, for example. Also, ERGO makes no claims to be in that class of integrated software that includes multiple, generalized applications; however, this system is meant to be a multifunctional application within the domain of logic and logic programming, and the Logic Editor is at the heart of the manifold functions ERGO provides.

Because the Logic Editor was designed to work within the confines of a particular format used to encode and manipulate logic known as a decision table (see last month's article), many features of a highly specialized nature are provided.

The status display

Refer now to Figure 1. This is a representation of a Logic Editor screen. (Note: the C1 through C7 and A1 through A7 label entries and code will be described later.) Defining the elements of this screen will be the best way to give you a glimpse of the ERGO method of logic processing and a view of the ERGO philosophy.

The top three lines of the display are always used for one of:

- Status information
- Command menus
- Helpful information.

In Figure 1, the top three lines are devoted to the standard table status display. When this display is presented, the ERGO Logic Editor is in ready mode, that is, condition and action labels, stubs, and entries may be keyed in.

The top left element on the status display is the table name. This is merely any arbitrary, legal file name. Permitted characteristics of the file name are, of course, dependent on the host operating system's expectations.

On the right side of the screen, top line, is a location indicator. This describes the editorial spot where the cursor resides. The location will always be one of:

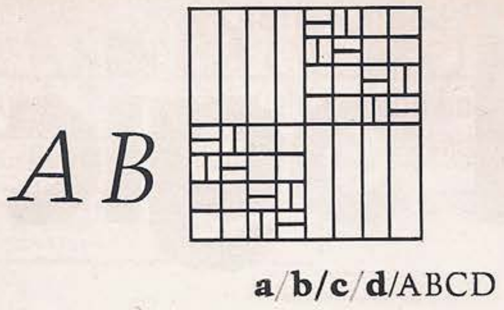
LABEL	r
STUB	r
MATRIX	r
ENTRY	r:c
ACT LABEL	r
ACT STUB	r
ACT ENTRY	r:c

where *r* equals the current row and *c* equals the current column. The reason a location indicator is required is that the Logic Editor permits you to scroll around a large, virtual table, and it can be reassuring to know where you are in the table and that the editor knows, too.

I suspect that this indicator will be only of modest use. This is because in decision table construction, as in software design generally, a key value is to keep the units you're working with small. As proficiency in table fabrication and parsing grows, the cursor will always be precisely where it appears to be in a table matrix, and the "virtuality" provided by the editor may well be a feature that atrophies.

Nonetheless, the feature seems appropriate: it is there when you need it as a beginner, and it is in line with probable

Illustrations: Barbara Luck



user expectations, given the extensive use of numerical and data-based spreadsheets that encourage you to scroll hither and yon.

Below the table name is the rule name indicator. This is useful for a variety of reasons. If you choose to, you can name each of your rules (entry columns). Then, as you move through the rules, creating, editing or otherwise relating to them, the mnemonics you assigned to the rules flash before you at this spot.

This can be tremendously important, because scrutinizing a column of y/n or a/b/c type entries does require a moment's (or several moments') reflection before the meaning of that column crystallizes in your mind. Much delay can be avoided with rule names. Also, the rule names become a sort of accountability feature: the name specifies in a natural language what the rule is, and you can balance that natural language specification against the more abstract depiction of the same rule in a logically encoded format in the rule column itself. That is, the rule name should be equal to the rule entries—they're merely two different ways of giving form to the same substance.

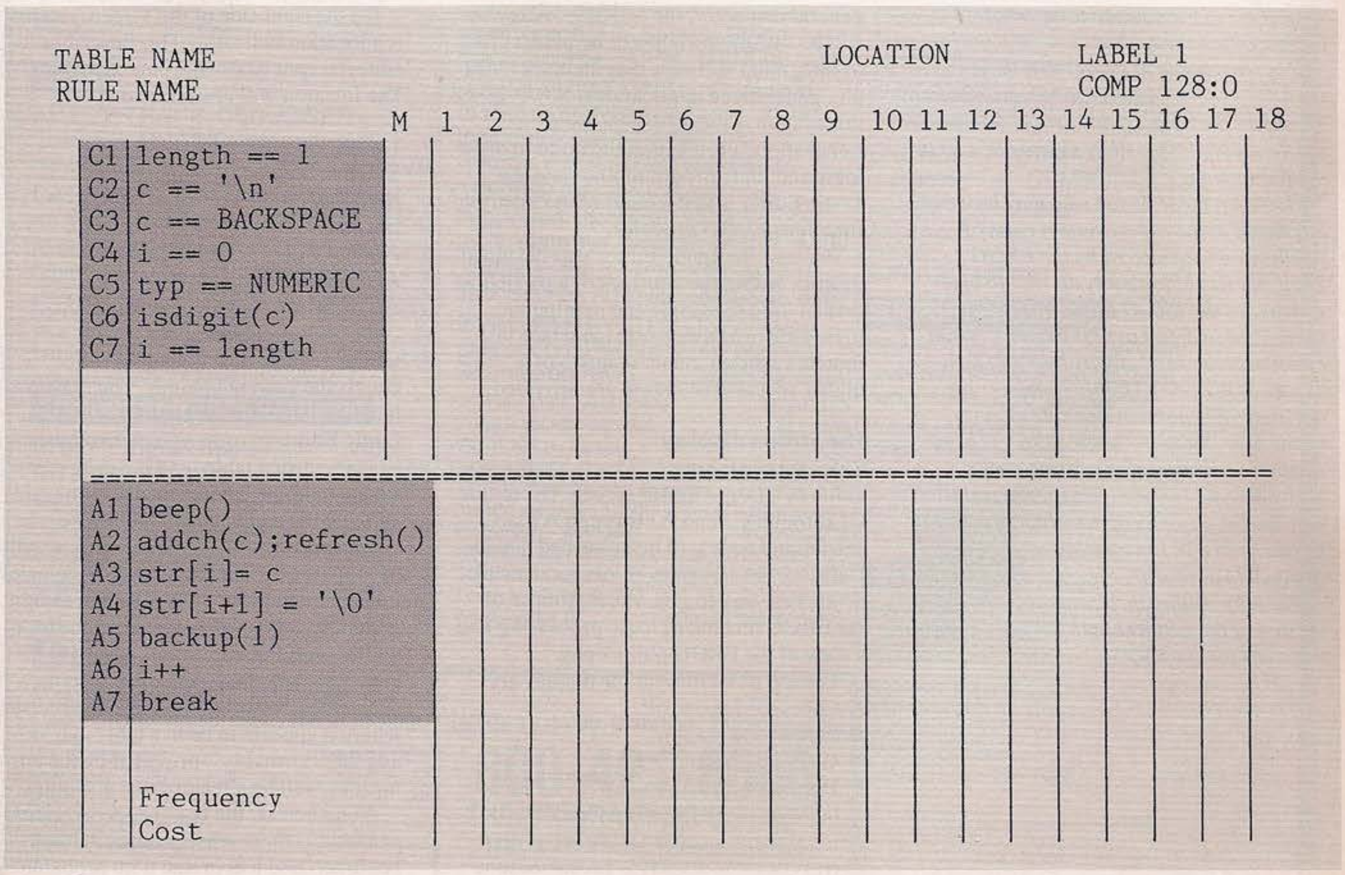
This is an important principle to grasp in understanding the aims of the ERGO Logic Kit. ERGO really just casts some arbitrary logical essence into different and varied forms. It can be handy to have your computer focus on the transformations while you tend to the information. This was most vividly shown by Lotus 1-2-3 with numbers and formulas transformed to the medium of business graphics. Using your computer to perform transformations will be a continuing theme with software in general and in this particular discussion of the ERGO Logic Kit.

A final use of the rule names is that they can become embedded comments in the code produced as output by the ERGO Logic Compiler, and they can form a part of the display presentation of the ERGO Logic Interpreter.

To the right of the rule name indicator is blank area that will display the matrix values, which will be discussed later.

To the right of this area is a key status indicator carrying the label "COMP:". This is the table completion indicator. It is expressed as the ratio of distinct simple rules that *should* be in the table (as computed by the matrix arithmetic) vs. the number that *are* in the table at any given instant.

A blank table will properly have 0:0 as the constituents of this ratio. By way of example, a limited entry (y/n) table with



```
TABLE NAME                                  LOCATION       LABEL 1
RULE NAME                                                  COMP 128:0
                  M  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18
  C1 length == 1
  C2 c == '\n'
  C3 c == BACKSPACE
  C4 i == 0
  C5 typ == NUMERIC
  C6 isdigit(c)
  C7 i == length

  ========================================================================
  A1 beep()
  A2 addch(c);refresh()
  A3 str[i]= c
  A4 str[i+1] = '\0'
  A5 backup(1)
  A6 i++
  A7 break

     Frequency
     Cost
```

Figure 1.

four conditions that is half completed will have as its completion ration 16:8 (16 = 2^8:8 = ½ of 16).

The user's continuous access to this little ratio is an important piece of the ERGO Logic Editor. This is because of the comfort humans generally gain when they know how far along they are in completing a task. The COMP ratio is instantly and always updated (at significant CPU cost, incidentally) as rules are entered and/or edited. The user's goal is to make those two numbers on either side of the colon match. With each little rule addition and with every clever rule specification that increases the righthand number or diminishes that on the left, the user is immediately rewarded with a certain visual indicator of his or her increasing success.

Much like a bookkeeper who must make both sides of the ledger balance or the householder reconciling the checking account, a good deal of task direction can be maintained by foreknowledge of the end points. A delectable bit of satisfaction can be had when all the numbers do at last line up, and you are utterly certain that you are done and you have a high degree of confidence that the work is correct. Achievement and victory, order out of chaos.

Viewed in this light, working with logic tables acquires many of the elements that make playing a game play instead of work. Even a modest increase in the amount of pleasure to be had in creating and analyzing logical systems could entice many more people into recording their experience in more directly useful, logical forms. Such a development would have unpredictable though possibly massive effects. So perhaps those dimensions of ERGO (or other comparably intended systems) that can be thought of as pleasurable are the most significant ones.

The first display segment on the third line from the top is labeled, simply, "M". This is the matrix column, holding the integer (2-9) that expresses the number of states a given condition can attain. This number defaults to two in the Logic Editor, as all logical problems of the class treated here can be reduced to a binary matrix, yes or no, 1 or 0. The Logic Editor encourages the use of extended entries (those with greater than a binary state) but does put an arbitrary cap of nine on the number of matrix values a single condition can attain.

The rest of the third line is given over to a rather mechanical enumeration of the rules. The alphanumerical sequence proceeds 1-99,A1-Z9,a1-z9,AA-zz. I do hope you never find yourself working on a table that requires (in its final form) more than 99 distinct rule expressions. You will have tackled a very formidable problem indeed.

Remember that a single complex rule can cover dozens, even hundreds, of simple rules. So while it is likely that you will encounter tables with greater than 99 simple rules, they will probably condense down to less than a dozen complex rule expressions.

The table image

The table image occupies the space starting with the fourth line of the display and continuing across and down the balance of the screen area.

The leftmost columns of the top half of the table are the label fields. By convention, one labels conditions C1-Cn, in numerical sequence. Sometimes other labels are appropriate, particularly directives to the compiler or the interpreter.

The next field is the stub, or description field. While the actual screen space allotted for each of the stubs is (by default) 12 characters in width, each stub field is actually a horizontally scrollable window into a line of 50 characters. You can set the number of characters that will be visible in this field.

When the ERGO Logic Kit is used as a programmer's tool, these stubs are presumed to contain syntactically meaningful target source language expressions. Of course, the user is free to type in whatever is desired, but it is possible to make the ERGO Logic Compiler output look pretty nonsensical and certainly uncompilable by a destination compiler.

Nonetheless, pseudocode type of expressions are often used here, as what is desired from ERGO is a module template, or architectural drawing as it were, rather than a compilable module.

The next array of fields on the top half of the table image is the matrix count for each condition stub. While the maximum matrix is only nine, I personally have yet to encounter a problem that both required more than nine matrix values and couldn't be more reasonably expressed in another way.

The condition entries themselves comprise the rest of the top half of the table. A description of legal table entries is in order.

Legality in a table entry is a function of the matrix of the condition to the left of that entry. If the matrix is only two, there are only three legal entries: y/n/— (the dash, of course, meaning "don't care"). If, on the other hand, the matrix is greater than two, say four, legal entries are:

a/b/c/d/A/B/C/D/—

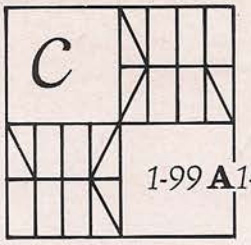
The lowercase letters read "is equal to (var)," the uppercase letters read "is NOT equal to (var)," and the dash continues to read "don't care."

The reason for including the "not equal to" expression is that it provides one more way for the user to keep the total number of rule expressions down. Consider: if you had a rule that held true in all cases but one, and there was no "not equal to" expression, you would have to explicitly key in (and document, and test, and maintain, ad infinitum) three affirmative rules (given a matrix of four) instead of a single negative rule.

It has been a nagging concern to me that I resorted to the terse a/b/c/etc. class of mnemonics for extended entries rather than some more comfortable natural language phraseology. For example, the phrases "low, medium, and high" make for eminent readability and clearly intensify the legibility of the table format.

Or perhaps the user would find more meaningful a construct like "always, often, sometimes, hardly ever, never." Of course, there is an infinite variety of descriptions that could be used that would be, in terms of sheer sensibility at least, superior to the single letter variable I have allowed.

The reason I chose a model with less



apparent communicative value was a pure and simple hunger for screen space. I decided, rightly or wrongly, that being able to see an entire table at once, without a lot of scrolling folderol, or waiting for a printer, or other less than optimal view port techniques, was ultimately more communicative, at a slightly higher level of abstraction, than the more full-blooded textual approach I might have implemented.

There is massive value in viewing a logical system in its entirety. The uniquely human capacity for indentifying structures can be brought into play: obscure patterns emerge, insights flash, and new levels of understanding open suddenly in the mind of the attentive user.

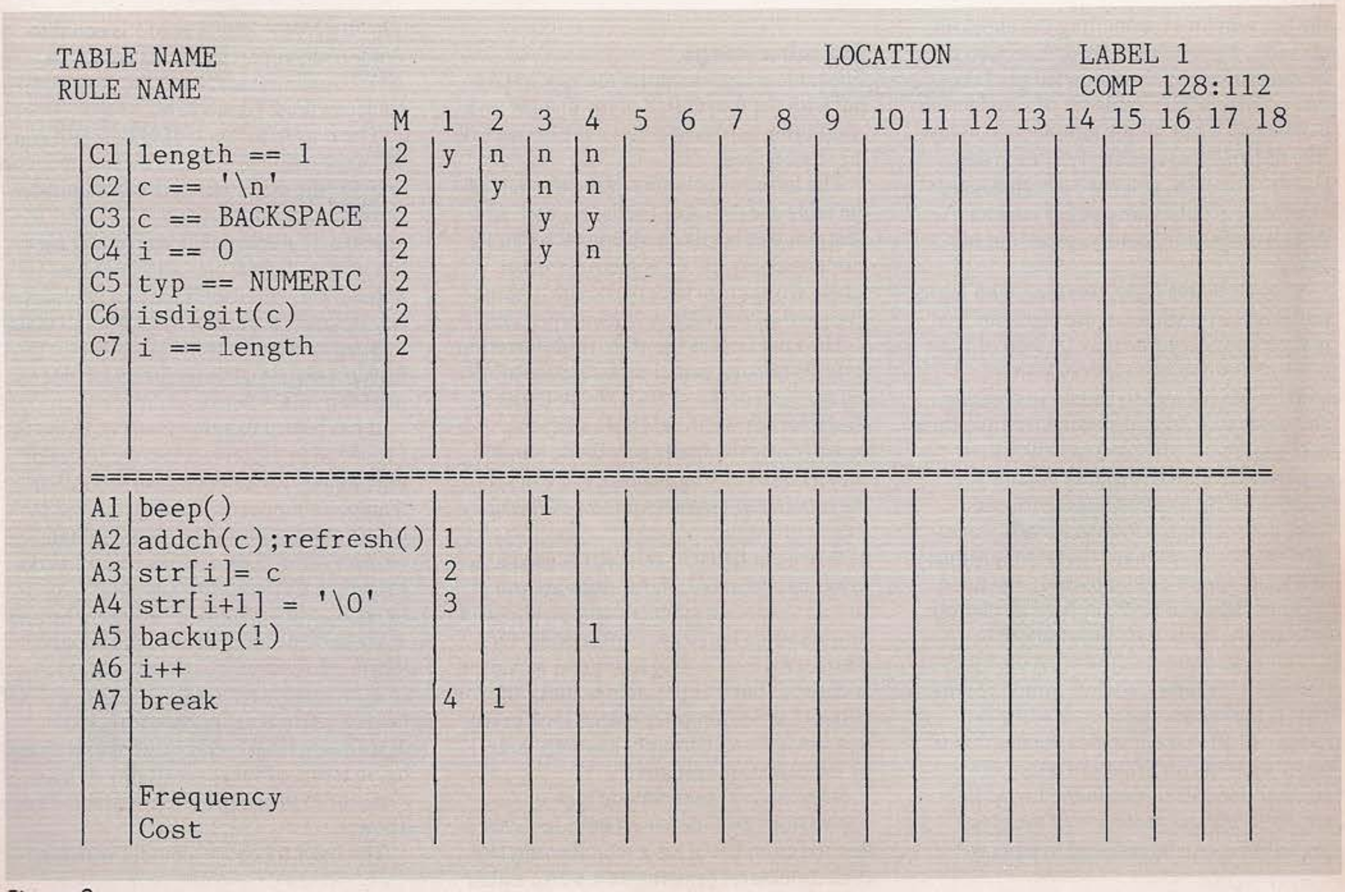
When you see that your logic looks like something, that there is an apparently natural design to what you suspected was a disordered and peculiar thought process, the balance shifts in your favor a bit. You begin to realize that this problem is soluble, it's merely a matter of arranging the patterns properly.

Though there may be moments of frustration ahead, your unconscious concerns about control and the doubtful outcome of your efforts abate, your self-possession is more profoundly realized, and the program becomes an instrument you can play. The intimations of pattern are the point of identification between the user and the logic. These can be revealed by the display of the Logic Editor, and the recognition of coherence can be most pleasant and informative.

As is often the case, manifest patterns are the fruit of abstraction, and an unfortunate by-product of abstraction is often a lack of clarity. To preserve the optimal degree of abstraction without inducing too much subtlety into the system, I decided to encourage the user to assign names to the a/b/c/etc. condition entry symbols.

My encouragement takes the form of reasonable default values for extended entries. These are available for display and alteration at the command level and pop up as appropriate on the status display to remind the user of the meaning of a particular condition entry variable.

Moving down the table image of Figure 1 and jumping across the horizontal bar



```
TABLE NAME                                      LOCATION        LABEL 1
RULE NAME                                                       COMP 128:112
                        M  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18
  C1 length == 1        2  y  n  n  n
  C2 c == '\n'          2     y  n  n
  C3 c == BACKSPACE     2        y  y
  C4 i == 0             2        y  n
  C5 typ == NUMERIC     2
  C6 isdigit(c)         2
  C7 i == length        2

  ==========================================================================
  A1 beep()                      1
  A2 addch(c);refresh()    1
  A3 str[i]= c             2
  A4 str[i+1] = '\0'       3
  A5 backup(1)                      1
  A6 i++
  A7 break                 4  1


     Frequency
     Cost
```

Figure 2.

c d

aaaaaaaa

that distinguishes the condition from the action portions of the table, we see more or less the same layout: labels, stubs, no matrix for actions, and action entries.

Action labels are generally A1-An, again keeping in mind that certain ERGO Logic Interpreter directives, discussed later, can appear here. Action stubs are treated the same as condition stubs, and legal action entries are numeric in nature.

These numbers in the action entries (0-9) indicate precedence of action. That is, in a particular rule, the actions are executed in numerical rather than physical sequence (if there are more than 10 actions under a rule, you can number all the actions greater than nine with the number nine, and they will be executed in physical sequence).

Below the action segment of the table are two rows that allow the assignment of numerics to rules. These two lines are labeled "Frequency" and "Cost."

The frequency line enables you to enter a sequence of numbers that suggest how often a rule might be expected to be invoked. I have deliberately avoided calling this row "Probability" because that really gets us into another matter altogether.

Although the subject of probability and decision tables is a fruitful subject to pursue, and all types of benefits can be accrued by the judicious use of probabilities, time and space do not allow for an excursion into that area at present. Suffice it to say that the use of probabilities in the ERGO Logic Kit is awaiting a fuller treatment.

The optional entry of numbers into this row enables the ERGO Logic Compiler to do some optimizations relative to execution speed of the code structure produced (see section called The ERGO Logic Compiler) and can be used to specify to the ERGO Interpreter how the decision tree(s) should be constructed. Also the interpreter can make best guesses when relative frequency is known.

The cost row provides the opportunity to enter some numbers that indicate the degree to which the respective rules impose a burden, whether in code cost, or actual fiscal cost, or gravity, or any class of what we might loosely term "liability." These numbers likewise come into play at compile and interpret time.

The entries to both of these rows may (probably will) be somewhat loose. For example, one need not worry that the frequency entries add up to 100. The use of the numbers is to establish a kind of relativity among the rules. That is, "Rule n is more frequent (or costly) than Rule f, and Rule f is more frequent than Rule g, etc." Thus, it is important that we know only a rough approximation of frequency or cost, which, after all, is the only type you are likely to have available in most instances.

The command menus

The slash (/) key invokes the ERGO command menu tree. At the highest level, the menu offers the following options, displacing the top two status display lines:

```
File Table Draw Grid Compile Interp
    Prefer Exit Quit
```

These options represent the major components of the ERGO Logic Kit. Selecting these options is accomplished by either striking the first letter of the option name or spacing through them with arrow keys or the space bar and hitting return when the proper command is highlighted. On the second line of the menu is either the appropriate submenu that will be invoked with the highlighted selection, or explanatory information relative to the highlighted command.

This menu-driven interface is obviously deeply indebted to Lotus 1-2-3, which, in its turn, owes much to Visicalc. While I make no claims that it is optimal, I really find myself without motivation to tamper with an interface that has proven more or less acceptable to millions of users over a relatively long period of time. Perhaps the single biggest barrier to overcome in deploying new software is training: users, dealers, distributors, etc.

By more or less cloning the interface that most people seem familiar with, perhaps much inertia can be overcome, and much more logic will be fruitfully encoded. Additionally, there was (and is) simply too much raw functionality to achieve, too many functions to invent, and too many things to do that haven't been satisfactorily done to devote energy to the creation of something that has.

Since we are now focusing on the editorial functions of the ERGO Logic Kit, the menu tree we will refer to is that which appears with the selection of the "Table" option from the main menu.

The getl table

We will do a small but probably useful example of a single table module to demonstrate how a programmer might make use of the ERGO Logic Editor. The specifications of our problem are such as are often encountered by programmers writing an interactive application.

We need a handy little input routine for miscellaneous *get*s from the console. We will pass this routine a string pointer, a type designator (*NUMERIC* or other), and a length indicator. *getl* (the name of our routine) must provide the following facilities:

- If the type is *NUMERIC,* accept only numbers from the keyboard; if anything else is entered (except as described later), ring the console's bell to indicate an error
- If the length expected is only one character, don't require that the carriage return be struck to indicate end of entry—rather, return to the calling program after the entry of a single character
- If the user has typed in *length* characters, don't accept any more (except a new line), instead, beep the console to indicate an error
- Accept a new line at any point to indicate end of entry
- Accept a backspace at any time, other than when the user hasn't entered anything yet, and call an appropriate backup routine
- Echo all legal output to the screen.

Since our ERGO Logic Compiler has an affinity to the C language, we will build the *getl* table from C language

CCCD

```
Condition specifications:

length of only one
'\n'
BACKSPACE
        except when i = 0;  /* no input */
NUMERIC typ
        require numbers for input
length exhausted

Condition code:

length == 1
c == '\n'
c == BACKSPACE
i == 0
typ == NUMERIC
isdigit(c)
i == length

Action specification:

ring the bell on errors
echo the characters typed
store the characters typed in the string provided
   implied is proper termination of the string
   and keeping track of where the current char is
backup on legal BACKSPACEs
return when finished

Action code:

beep()
addch(c);refresh()   /* 'curses' screen update */
str[i] = c
str[i+1]='\0'
backup(1)     /* function that manages a backup */
i++
break         /* we'll assume an infinite loop */
```

Listing 1.

A

expressions. We will assume that the variables passed to us are:

```
char str[];  /* destination string for */
             /* keyboard input */
int typ;     /* NUMERIC or other */
             /* input type indicator */
int length;  /* maximum number of */
             /*allowable characters */
```

The calling program will be held responsible if there is insufficient room in the string pointer or if the type or length indicator are radically wrong or out of bounds (such as a length greater than available memory or a zero or less then zero length). We will also assume two local variables:

```
int i = 0;     /* index pointer */
char c;        /* the current character */
```

to help us keep track of how far along in the string collection we are and what it is we have on hand in the current character.

The specification tells us to watch for the code (and its ramifications) as presented in Listing 1.

Entering the conditions and actions as described into the ERGO Logic Editor, we have the working table shown in Figure 1. Note the large number of simple rules yet to be created in order to attain complete mechanical perfection: 128. Let's see what we can do to cut that daunting number down to size.

We'll start with some of the easy rules that come to mind at once. For example, if $i == 1$, we always store the *char*, terminate the string, and return. Another easy rule is if $c ==$BACKSPACE and $i == 0$ —there's nothing from which to back up, so we beep the bell. Alternatively, we do back up whenever there's a BACKSPACE and *i* does not equal 0). Also, if *c* $==$ '*n*', then we're all done, no matter what.

We enter into the Logic Editor both condition and action entries that express this logic, as in Figure 2. Note that with these four complex rules (spaces are interpreted by the Logic Editor as dashes if there is an entry on the top condition row) we have completed nearly 90% of the table. Also note the *n* entries that were only implicit in our textual description of the rules (three paragraphs previous) at,

for example, entry 1:2 (condition 1, rule 2). This is commonly done to distinguish rules and to make manifest implicit exclusion.

Another interesting point here is the stair-step image of the logic. This also is common and represents (at least to my mind) a well-ordered analysis of the hierarchy of the logic. Such stair-step images are often produced by the sorting operations available in the Logic Editor.

Now let us assume that all the easy rules are accounted for. There remain 16 rules yet to be entered. This can be quite tedious work, and here is where the Logic Editor really lends us a hand by generating the missing rules for us either one at a time or all at once.

Selecting the *Missing* command from the table submenu, we can then have ERGO fill out all the missing rules for us. We add dashes as appropriate and use the ERGO disambiguate function to eliminate redundant columns.

The case of disambiguation presents an interesting problem: if two rules overlap, how is the Logic Editor to know which of the two is the superfluous rule? After all, it *must* pick one of them for elimination.

For this, the ERGO Logic Editor employs the following algorithm:

- Compare the column counts of the rules (which will be either the product of the matrices of the dashed entries, or if there are no dashes, 1)
- If one is less than the other, delete the rule with the lesser column count
- Otherwise, delete the rightmost rule.

Whenever a programmer automates behavior that normally requires judgement, extreme caution is indicated. The judgement automated here is that a rule with more information (that is, column count), is somehow better than its less informative neighbor and more deserving of continued existence.

Additional judgement is rendered that the ERGO user is working from left to right and the sequence of table creation we just used in our example will emerge as the standard way to create tables. Since the user will be entering his or her rules close to the left-hand boundary of the table and since ERGO adds its rules to the end, or the right side of the table, the rightmost should be the one to go.

The rationale for this particular set of judgements is that simple (nondashed) rules are cheap. The Logic Editor can generate them effortlessly, one at a time or in large groups. But a complex rule, with dashes or NOT entries, is a rule that has the human element. It has necessarily been born of some person's mind and is therefore more valuable (at least from the human viewpoint).

The real problem emerges when two human-generated rules experience friction. As a result of this tidy little algorithm, one of them will surely die.

Picture the following case: there are three rules, two complex and one simple:

```
1  2  3
y  y  y
n  n  —
—  y  n
```

Upon automatic disambiguation, the following events take place:

- R1 has a greater column count than R2, and therefore R2 is removed
- R1 and R3 match column counts, but R1 is the leftmost rule, so R3 is extinguished.

All this is well and good, I suppose, but the problem is that *I liked R2 and R3*: between them, they had a higher column count than R1, and I figured the Logic Editor would remove R1!

While *Undo* is a function that expresses the lack of intelligence in our software, I am afraid that it was this rule-gobbling disambiguate function (along with the system's blithe ignorance of operations the user orders up but *can't* really want) that caused me to create an *Undo* operation for the ERGO Logic Editor.

This is a brute-force *Undo*. With each radical table operation (*Delete/Insert/Sort/Disambiguate*/etc.), a total copy of the current table is made. This only goes to one level, and it takes time and space, but it does have the virture of restoring a table that has been botched.

An *Undo* function can also cover a multitude of sins. Excessive prompting and verifying, a practice not unlike the doctors' practice of defensive medicine, can be minimized; user temerity can be reduced; and the revocability of major operations encourages their use.

Not one to overestimate either ERGO's perfection or its ability to make clear what might happen next, I also extended the *Undo* command to *Undo* itself. That is, if I like what I have undone less than what I had done, I can undo what I have undone and do what I had done.

Next month we will complete the logic processing associated with the *getl* table, compiling and optimizing it in various ways. Also we will delve into the Logic Interpreter and develop a small expert system. ■

References

1. Pollack, S.L. "Conversion of Limited-Entry Decision Tables to Computer Programs." *CACM* 8,11 (Nov. 1965): 677-682.

Jim McCarthy is a member of the technical staff, research and development, AT&T-Teletype, in Skokie, Ill.

Try out the ERGO Logic Kit

You are invited to experiment with the ERGO Logic Kit.

I have two motives for distributing these parts of the ERGO Logic Kit. I hope that the software will be useful, and I am looking to "prove-in" both the software itself and the ideas that engendered it. You can communicate with me by sending letters to: Jim McCarthy, c/o *COMPUTER LANGUAGE*, 131 Townsend St., San Francisco, Calif. 94107, or via UNIX mail at : ihnp4!ttrdc!jm. I will attempt to respond to all communications I receive.

You should be aware that I am not placing the ERGO Logic Kit, or any part of it, in the public domain. With every diskette order that the *COMPUTER LANGUAGE* Users Group receives, I will receive $.10 as a license fee. You in turn will receive a license that allows you to do essentially whatever you desire with the software except sell it or otherwise distribute it. You are encouraged to return the completed license so that good records may be kept from the start.

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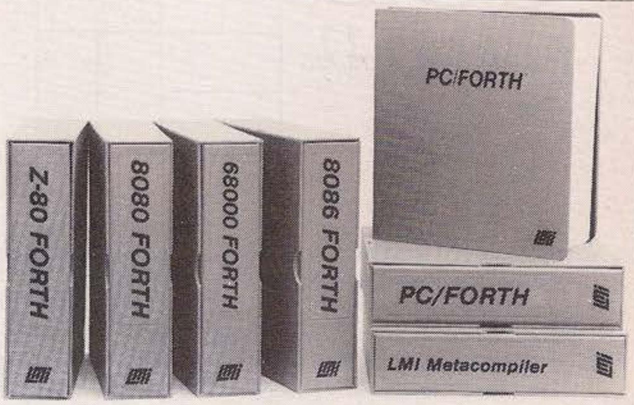

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dBASE II programs

By Tim Parker

Three application programs dominate the microcomputer field, both in home and business use: word processing, spreadsheet (financial) applications, and data bases. While discussion of products for the first two categories is wide open (witness the large number of word processing packages and spreadsheets that vie for attention), the data base end has been dominated by Ashton-Tate's dBASE line.

Though there are many other data bases, some of which may be better than the dBASE line, if ever there was a typical package for any of the three application programs, dBASE fits the bill for data bases. But whether dBASE is the best data base available is immaterial for our purposes here; we're more concerned with the growth of dBASE public domain support.

Public domain dBASE programs tend to come in two varieties: utilities and standard applications, such as mailing lists. Although the dBASE public domain programs don't really match those of a custom programmer's efforts for a particular need, most of the material is of reasonable quality. In many cases, these programs are quite adaptable for several uses.

Discussing dBASE requires considering a number of categories, including a comparison of dBASE II and dBASE III. dBASE II began as a standard program in the 8-bit CP/M world and was rapidly adapted to 16-bit machines. dBASE III soon followed, taking greater advantage of 16-bit capabilities. In fact, dBASE III is probably one of the most copied programs available, with the possible exception of WordStar and VisiCalc.

But while dBASE III is relatively new, there is far more available for dBASE II, so we'll concentrate on the latter. There is also the matter of target machine: 8- or 16-bit. Both programs will run on either because the code is transportable, but the issue here is disk availability and formats. Unless you have one of the excellent series of multiformat programs such as UNIFORM, your machine is probably limited to one or two formats.

To begin our discussion of dBASE II, let's delve into the world of Big Blue and the IBM format public domain dBASE II. Most of the programs to be considered in this column surfaced originally as CP/M versions but now have been transferred to the MS-DOS format.

When tackling IBM disks, the first reference I inevitably check is the PC-SIG catalog. Several IBM disks have dBASE material available, some dedicated, some mixed in with other programs garnered from bulletin boards, CompuServe, and the like. As mentioned earlier, these programs tend to fall into two categories: completed applications and utilities and "boilerplate" routines that can be rapidly patched into code for a particular purpose. The latter are probably more useful for programmers.

An excellent example of the so-called boilerplate routines appears on PC-SIG vol. 109. One routine checks whether dates entered into a program are valid or not. This routine ranges from simple (checking for invalid characters) to more complicated (checking for November 31) to the most complex (whether February 28, 1984, occurred).

One fairly common approach for checking dates is to convert to Julian days, use algorithms to check correctness, and then reconvert. Alternatively, recent years can be checked by comparing matched substrings of the date function with a list of correct values. This is the approach taken in DATE.PRG (or .CMD on 8-bit), written by Douglas Haman. This routine is self-contained and the results easily imported and exported. The date entered or passed to the routine is broken down into month, day, and year substrings and the results matched against a list of valid characters.

The routine is not particularly short, involving several nested *DO* loops and a mess of *CASE* statements, but it does the job. Documentation is nonexistent, but it is unnecessary for all but inexperienced dBASE users. The code is structured just as the manuals suggest and requires only slight modification to fit easily into a program, but some programmers might want to rewrite sections to match their programming style. As a quick and dirty routine, it saves time in thought and coding.

Another problem that often occurs when displaying data base fields on the screen is a wraparound of the field when it is lengthy. Most programmers get around this by limiting the fields requiring this sort of space (such as a comments field) to 60 characters or so and having multiple fields devoted to the space (COMMENT1, COMMENT2, etc.) on separate lines. However, there are times, such as when a lot of fields are in use, when it is necessary to have a long field. When displayed on the screen or printer, a long field will break at an arbitrary place depending on the display space available.

dBASE does not have word-wrap or anything similar. Usually it is necessary to try to arrange the displays so that a break does not occur in the middle of a word. A program by Melissa Gray on PC-SIG vol. 139 allows a long field to be broken at a blank character or some other allowable line break character, such as a dash, semicolon, comma, equal sign, or backslash, and wrapped onto the next line. This program, called PRINTXT1, is one of three files available on the disk. The other two are a documentation file and a procedure file.

Records to be printed are trimmed so that extra space is deleted and blank records not displayed. A series of variables require initialization before the routine is used, depending on the context.

The coding itself is not particularly elegant and can probably be compressed quite a bit if desired. The author admits that it is a beginning effort. Regardless, it does the job it is intended to do and solves the common dBASE problem of wrapping.

PC-SIG vol. 143 has a program that should be of interest to dBASE users. COPYFLD, written by Kenneth Eagle, provides a more powerful *JOIN* command function and allows a third file to be created by appending transferred fields rather than using dBASE's *JOIN* command. Further, two or more fields in the source data base can be compressed into one field in the target data base. A documentation file is provided, but the program is documented well enough to be figured out without it.

The program displays prompts for the name of the source file and destination file. (In a completed application, this process can be bypassed with macros.) Prompts for the fields to be copied to and from are then displayed. The program is somewhat lengthy but checks for errors. Indexed files are used throughout. Depending on the case, both the target field and the field that is to be copied from must be the key index.

I used the COPYFLD program quite a bit for testing when creating a large inventory data base program involving 12 data bases. (Most were combinations of other data bases but for different purposes and broken up for speed—a necessary constraint in this particular project.) No problems were encountered, and some tedious and frustrating work was eliminated. This program would be very useful for large data base programmers working in dBASE II.

Vol. 128 in the PC-SIG library includes several dBASE utilities. Programs that determine the day of the week and set the system time and the date variable from the system date are useful routines that can be included in other coding. COMSTRIP is a quickie routine that strips comment files from other dBASE II programs. The advisability of such a move is left to the user, but where size is a factor such a move is probably necessary.

A series of completed applications are available on PC-SIG vol. 126. The disk contains seven different program series: a form letter generator, a mailing list manager, two backup routines, a library routine, a state and zip code checker, and a conversion program, with documentation.

Warren McKenna's BACKUP is CP/M-based and relies on the *QUIT TO* command to use PIP (the peripheral interchange program). It can be adapted to MS-DOS by using the *COPY* command instead, but the structure of MS-DOS when compared to CP/M may not allow the program to work as easily. It adapts to the CP/M version through a relatively short routine that utilizes file transfers, but it cannot handle files larger than disk capacity.

For large files, SUPERBAK (by an unnamed contributor) uses hard disk backup onto floppies. Though the program is longer it works well, allowing the user to name the input and output files or data bases. This routine works in CP/M or MS-DOS, although you have to insert a *RESET* statement in CP/M versions whenever disks are changed.

SUPERBAK prompts the user for the capacity of the floppies to be used and requires the number of characters per record to be inputted. (This can be read directly from the records if the coding is changed slightly.) Restoration from the backups is also easy. This routine can be readily incorporated into another program by using the *BACKUP/RESTORE* option on a menu and looping through a *DO* to this program.

STATEZIP is a program (author unidentified) that checks for valid state abbreviations and correct zip codes. It includes a data base with (surprise!) 52 entries listing state abbreviations and two fields three digits wide with the high and low valid zip codes.

The program is a self-contained procedure and can be trimmed to fit most programs. Variables may have to be renamed for usage optimization—especially for variable passing—but the program is quite well laid out and concise enough to be useful in any program incorporating zip codes.

In use, the program asks for the data base to be checked. This process can be avoided if the program is included in a larger routine. The data base to be checked is called the SECONDARY file, while the STATEZIP used as a reference is the PRIMARY file. After the program has been executed, you can edit the erroneous data or print out the bad values for future reference.

MAIL is a series of programs that allows a mailing list to be generated and printed on labels and form letters to be used in conjunction with the mailing list. Mailing lists, as many custom programmers know, are one of the most frequently requested and easiest programs to devise. Keeping a few basic versions on the shelf

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*Could not successfully compile the program.

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1.0	3.6	14.7	21.6	22.3

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CIRCLE 76 ON READER SERVICE CARD

is something a dBASE programmer shouldn't pass up, as these can quickly be tailored to a customer's requirements. MAIL does a fairly good job of creating lists but lacks any editing functions for list maintenance. These have to be added by the user.

MAIL's design follows the form letter approach and uses a standard letter format that can be edited with a word processor or dBASE itself. The letter salutation and headers are contained in a file with the dBASE commands for merging with the rest of the data base, while the body of the letter is in a separate file, saved as question mark statements.

The mailing list itself is straightforward, with fields for a title or salutation, surname and given name, address, company and title, and state and zip code. The entry process is simple but has no real power for editing, manipulation, or checking entries.

The label generator is routine, and the printout uses a predefined format. It would be nice to have variable spacing, width control, and fields printed, but these would make the program more complex. Also, selective printouts of matches with defined fields (such as all California residents or people of ABC company) would be appreciated by most mailing list users.

The routines work as they should, but the program as a whole is rather rudimentary, suitable for small uses but definitely requiring programmer modification for any large-scale usage. The series as a whole seemed remarkably like the mailing list and form letter routines included in the sample programs with dBASE II, particularly in terms of capability.

A more sophisticated mailing list and form letter generator are included on the same disk under the name ML2. This program, written by Wil Wakely for the San Diego Computer Society, is far superior in all respects to MAIL, except for the user whose major concern is simplicity.

ML2 allows the user to edit entries. The data base is composed of fields for name and address, home and work phone numbers, and three fields—SORT, EXPIRE, and TYPE—for membership lists or categorizing data base entries.

Form letters use the same format as the previously mentioned programs, with a word processor used to create the body and the letter read into the print routine. The label printing routine allows multiple labels to be printed only in the standard (3 ½-in.) label size.

A disk library index manager was contributed to this volume by Dr. M. Timin. This application allows the creation of a subject index to a disk file library, with brief descriptions of passages referred to in a separate data base. The user can search throughout the data base contents for a string match or a particular subject. For those with extensive disk libraries, this may be of some interest.

PC-SIG vol. 102 has a complete series of programs designed for advertising agencies. These are the sample programs included in the dBASE II manual, but revised, modified, enhanced, and entered on disk for general use. While there may be limited demand for this particular type of program, it can be adapted easily to other situations and shows the construction of a medium-sized application.

Provisions for entering bills (and paying them), time sheets, deposits, check maintenance, media insertion orders, client billing, and various status reports are included. The program also has job-costing potential.

In addition to the products listed here, much more dBASE material is available on the PC. Many of the programs mentioned in this column, as well as some not yet listed by PC-SIG, also are available from the New York Amateur Computer Club's PC/BLUE Library. Many of these programs are available in CP/M format from several sources, including SIG/M, CPMUG, and public domain libraries around the country.

Next month we will be publishing a list of sources for public domain material, including addresses, prices, and (where possible) phone numbers. One such source is available from Dynacomp. This company has released a catalog that includes several public domain library sets in addition to its line of commercial software. This catalog (#28) is available for $1.

Apple software is represented on 50 disks culled from the over 100 available in other collections, such as the Public Domain Exchange. Priced as low as $2.95 in quantities of 10 or more, this is probably the cheapest public domain library I know of for the Apple.

PC/BLUE and PC-SIG libraries are also available for purchase or rent. Thirty-two disks, representing their better volumes, have been culled from PC/BLUE. Individual disks are $5.95 each, while the full disk collection is $119.95. (Rental of a 32-disk collection for 10 days is $39.95.)

The PC-SIG collection is made up of 98 disks and can be purchased in its entirety for $399.95 or rented for 10 days for $99.95. Individual disks are $5.95.

CP/M is represented by a nine-volume collection available for $39.95 (10-day rental) or $153.95 (purchased) with a book of documentation published by People Talk. (The book is available separately for $17.95.) Individual disks are $4.95.

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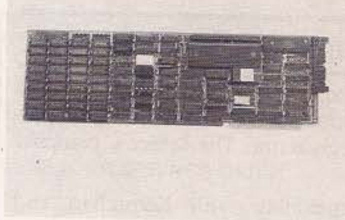

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By Doug Millison

Each month Product Bingo features the latest in new software and hardware products of interest to COMPUTER LANGUAGE readers. Send new product information to Doug Millison, Product Bingo, COMPUTER LANGUAGE, 131 Townsend St., San Francisco, Calif. 94107.

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APL a day, chapter 2

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AT&T users will develop business applications under UNIX with the **Philon** family of **FAST/** compilers, including **FAST/C, FAST/BASIC-C, FAST/BASIC-M, FAST/COBOL FAST/FORTRAN, FAST/PASCAL,** and **FAST/RPG.** Prices were unavailable at press time.

Philon, 641 Ave. of the Americas, New York, N.Y. 10011, (212) 807-0303.

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Programmers can convert Applesoft BASIC programs to Apple Pascal with **P-tral**, from **Woodchuck Industries Inc.**, for the Apple II family. Introductory price $125.

Woodchuck Industries Inc., 340 W. 17th St. #2B, New York, N.Y. 10011, (212) 924-0576.

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TGL Inc., 4400 Sulphur Springs Rd., Corvallis, Ore. 97330, (503) 745-7476.

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CIRCLE 78 ON READER SERVICE CARD

An industry look at 15 Forths

By Michael Ham, Michael McNeil, Stephen Martin, and William Lindow

In any review of Forth packages, the reviewer faces a frustration unknown to reviewers of languages such as BASIC and FORTRAN. Because Forth is an extensible language, its users can add new commands to it at any time—indeed, programming in Forth precisely consists of adding commands to address a specific task. Thus the lack of a particular command or feature in a Forth package must be measured against how difficult it would be for the user to add that command or feature.

In keeping with Forth's guiding philosophy of simplicity, most vendors avoid including nonessential commands as part of the package if the user can easily create them. Each command takes up room in the system and adds to the bulk of documentation. If the command clearly is needed by a large number of users, well and good; but if the command would be used only in special circumstances and is relatively easy to build, it probably is better to let the user add the command when (and if) it is needed. Thus the presence or lack of a particular command is not necessarily of any real significance.

So on what basis does a potential user choose a Forth?

One criterion is speed. The top of the Forth dictionary consists of words written in Forth—the same sort of extensions to the language that the user provides. But the very innermost words within any Forth dialect are written in machine code. Their structure and polish to some extent determine how fast the Forth will be at traditional benchmark tasks. The more words written in machine code, the faster (and less portable) the particular Forth system is likely to be.

It is worth pointing out, however, that the only true benchmark of performance is a job mix of tasks specific to the user's own applications. And because one of those tasks is programming, overall speed should also be measured from the inception of the idea to the arrival from the completed program of real output—that is, real-world speed concerns not only internal performance once the program is complete but also the ease with which one can program in a particular Forth.

Thus a second key criterion for language selection is the quality of the documentation. Is it clear, comprehensive, and readable? And for those instances in which a user cannot make out what is meant, is there telephone support? Is the vendor available to answer specific questions?

Another factor affecting the ease of using the Forth is the richness of the set of extensions provided by the vendor. For example, considerations of speed suggest that in an application program the developer may want to write some parts of it in machine code. Forth does not use a separate assembler and linker, the procedure is to begin the definition with *CODE* instead of *:* and then enter the name of the word followed by its definition written in assembly language instead of Forth. The definition ends with *ENDCODE* instead of a semicolon.

The usual development procedure for speed-critical applications is to get the entire program running in high-level Forth and then systematically replace the most frequently encountered Forth definitions with assembler definitions. Since 95% of a program's time typically is spent within 5% of the code, this procedure allows the programmer to gain assembly language speed with very little assembly language programming. Users whose applications demand extremely fast processing speeds will want a Forth that includes an assembler. (It is worth pointing out that most Forths are fast enough for many users to write all their code in Forth without having to dip into assembly language at all.)

The Forths reviewed here generally include an assembler and an editor. Look also for other extensions that might be important to you—a special capability in graphics might be something you prize, or a need to work with files generated within a particular operating system.

Another important criterion is vendor support, which is expressed in several ways. One important kind of support is the fixing of bugs. Forth systems, particularly early in their evolution, are like any other programs: they exhibit occasional bugs that arise only in particularly obscure encounters with the operating environment. If the vendor is responsive to reports of such problems, the vendor's Forth will quickly become reliable through its trial by fire in real-world encounters. This evolution presupposes an ongoing effort on the part of the vendor.

An aspect of vendor support already touched on is in the number of extensions provided to the basic Forth package. Allied with this kind of support is the degree to which the vendor responds to customer requests and suggestions. Some vendors are extremely open to ideas for extensions and improvements, which is reflected in the polish their systems exhibit. For example, the editor in PC/Forth v. 2.0 used its own unique set of control-key commands. Acting on a user suggestion, Laboratory Microsystems revised the editor in v. 3.0 and installed WordStar control-key commands, to the great benefit of users accustomed to those commands.

Some vendors also act as a clearinghouse for user-developed software and suggestions. The electronic bulletin board systems installed by those vendors not only carry answers to technical questions but also allow users to upload and download source code of various routines, written in the vendor's Forth.

Another consideration, particularly if you plan to develop programs across a variety of computers, is the degree to which the vendor provides the same Forth on different machines. It obviously helps the developer tremendously if the bulk of the source code can be ported directly to another machine.

Developers are also apt to be keenly interested in the royalty fee and licensing arrangements for programs written in a particular Forth. Indeed, anyone who writes a program that may have more than one user should check the conditions under which the program can be shared. Some of the licensing agreements require the payment of a significant licensing fee even if you merely want to share with a local users group some program you developed. (Of course, it is perfectly legitimate to pay no license fee or royalty if you sell or give your program to those

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CIRCLE 33 ON READER SERVICE CARD

who already own that Forth, since they can use it on their own systems.)

It should be noted that many system features may seem positive or negative according to the individual's point of view. To the experienced Forth programmer, lack of long memory addressing operators, for example, is not particularly a liability for a given system. When needed, the individual can add operators such as these to the language in five minutes or so, including testing. In the mean time, the programmer appreciates the lean and trim nature of polyFORTH, say, which provides a larger programming space than its small-model memory addressing might lead one to imagine.

Many experienced Forth programmers—fluent in Forth and not really wanting or expecting to deal with other environments—will value the approach taken by polyFORTH and other systems where a common non-DOS Forth environment is created and maintained across a number of different processors. On the other hand, the individual who desires to coexist along with non-Forth programs in a shared DOS data environment will find this approach to be a handicap.

Although all these systems claim to follow some Forth standard or other, modifications to the benchmark programs were necessary in almost every case, mostly to semistandardized words such as 2DUP, 2*, etc. The file interface varied

The community of Forth users

Forth has come up from underground. The language was conceived and developed on the job, far from the normal programming language incubation site of academia or research and development institutes.

Charles Moore stated that his goal in developing the language was simply to make himself a more productive programmer (see *COMPUTER LANGUAGE*'s ComputerVisions, Premier issue, pp. 69-70, and Designer's Debate, March issue, pp. 19-24). He developed Forth gradually, over a period of several years in various programming jobs for underfunded enterprises that were trying to wring the maximum of performance out of the minimum of machines. Forth's simplicity, compactness, speed, and extensibility resulted from its development in the rough-and-tumble world of real-life applications.

As rumors about Forth's capabilities began to percolate throughout the microcomputer community, those intrigued were frustrated by the lack of access to any packages. FORTH Inc. was already in existence, but the cost of its system made it prohibitive to hobbyists who just wanted to learn the language. In the late 1970s, the Forth Interest Group, led by Bill Ragsdale, Kim Harris, and others, developed a public domain version of Forth for a variety of microprocessors and established an organization to bring together hobbyists and developers interested in the language. Building on the fig-Forth effort, a number of commercial vendors added polish, extensions, and support to the package, leading to today's relatively rich Forth environment.

Because Forth is a simple language to port, it is frequently the first language up on a new machine (as MacForth was on the Macintosh). And because Forth has so much power despite its simplicity, a variety of companies and products place their faith in Forth. Simon & Schuster's Typing Tutor III, Scarborough Systems' MasterType, a variety of programs from Electronic Arts, and many small dedicated devices, such as pocket translators and embedded control chips, all do their magic via Forth.

The Forth Interest Group continues to act as the main national Forth clearinghouse of information and activity. Membership is $20 per year and includes a subscription to the bimonthly *Forth Dimensions*. (Forth Interest Group, P.O. Box 8231, San Jose, Calif. 95155, (408) 277-0668.) Every fall the Forth Interest Group has a convention of Forth users and vendors. The convention this year will be September 20 and 21 in Palo Alto, Calif.

Another publication of interest to Forth programmers is *The Journal of Forth Application and Research*, published quarterly by The Institute for Applied Forth Research Inc., 70 Elmwood Avenue, Rochester, N.Y. 14611.

Books on Forth are available from fig and from many of the Forth vendors reviewed in this issue. The standard beginner's book is *Starting Forth* by Leo Brodie. Other good introductions are *The Complete Forth* by Alan Winfield and *Mastering Forth* by Anita Anderson and Martin Tracy. Intermediate texts include *Thinking Forth* by Leo Brodie and *Forth Tools and Applications* by Gary Feierbach.

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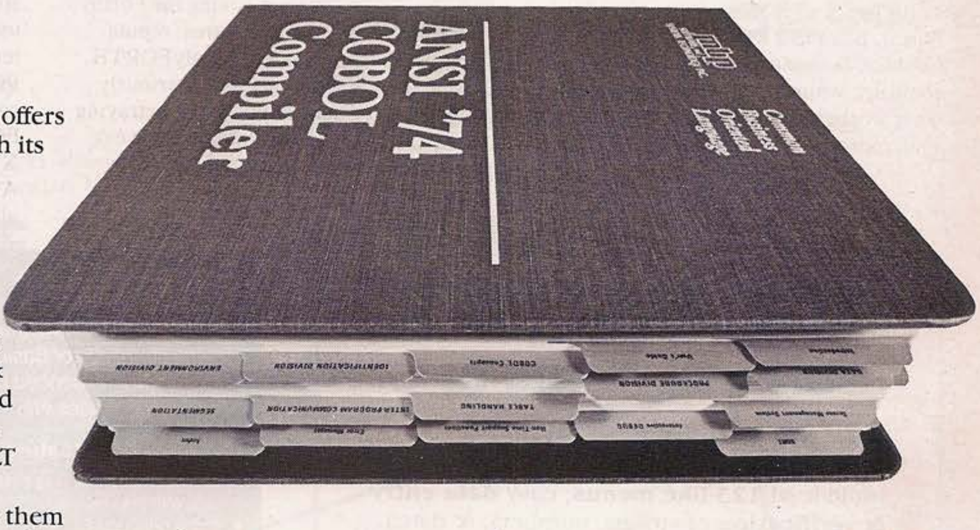

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drastically, with phrases opening the benchmark source file ranging from OPEN BNCHMARK.FTH to #0 FCB BNCHMARK SCREEN-OPEN to "BNCHMARK.SCR" SCREENS OPEN IS DEFAULT.

Finally, it should be pointed out that most of the Forths reviewed here are in a state of continuing development and refinement. If you are interested in any particular packages, you should contact the vendor to get current information.

IBM PC FORTHS

The IBM PC has attracted the attention of numerous Forth vendors who offer a broad line of products tuned to take advantage of the various special features of the IBM and compatible products. This review discusses the capabilities of IBM Forths from 11 vendors, in alphabetical order by vendor name.

FORTH Inc. polyFORTH II

FORTH Inc. was founded in the early 1970s by Charles Moore (the initiator of Forth), Elizabeth Rather, and Edward Conklin. Rather and Conklin still run the company, while Moore has gone on to other work, including the development of a microprocessor that runs Forth as its native language. From the beginning, FORTH Inc. has emphasized simplicity, compactness, and speed, avoiding anything that might be taken as a frill. The company's product philosophy could be summarized as lean and mean.

FORTH Inc. ported its Forth to processor after processor until polyFORTH systems today run on Intel 8080, 8086, DEC PDP/LSI-11, Motorola 6809 and 68000, RCA 1802-1805, NCR-32, and NC-4000 processors, FORTH Inc. also does a large amount of contract programming work in polyFORTH, specializing in jumping into software engineering projects in a state of crisis, replacing the existing operating systems and applications with customized polyFORTH, and using the speed and compactness of its Forth (along with its programmers' familiarity with it) to save the day.

The polyFORTH systems all include multitasking. They are multiuser when desired and fast-compiling and compact even by Forth standards. polyFORTH commands a high price among the Forths reviewed, based on its features, reputation, and performance. Yet polyFORTH on the IBM PC presents some curiously old-fashioned and creaky traits, betraying its age and history and perhaps the weak points in a product philosophy of spareness.

Forth would not be the language it is if Moore had not insisted on going his own way and holding fast to simplicity and compactness as guiding principles. However, in interpreting this overall strategy, FORTH Inc. has nearly always found that the simplest approach for any given implementation is to seize the entire machine and use Forth as its own operating system. Even when a computer has I/O routines in ROM, FORTH Inc. generally prefers to interface directly with machine hardware. While this approach does provide a simple and compact structure for the operating environment and squeezes amazing capabilities and speed into small machine computers, it also has the drawback that the resulting programs are incompatible with data produced by other (nonForth) programs and cannot run in a common environment with other programs the users may have.

This kind of simplicity has also led to compatibility problems as the hardware has evolved. While other programs were somewhat insulated from the hardware by using the manufacturer's operating system, the native polyFORTH for the IBM PC could not run on the XT when the XT came out. Then the version of polyFORTH that had been modified for the XT would not run on the PCjr or the AT. Another example: polyFORTH's standalone interface to the DOS file system,

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designed for DOS 1.x, could not be used to access DOS 2.x files, even on disks lacking a subdirectory structure. Thus the FORTH Inc. approach forces Forth to be agile in dancing to the hardware manufacturer's tune and tempo. polyFORTH also is not compatible with the Forth-83 Standard; the system is essentially Forth-79 Standard.

The problems in compatibility and marketing are slowly moving FORTH Inc. toward safer methods of interfacing to its computers. Two level 3 polyFORTHs are reviewed here; one is the traditional stand-alone polyFORTH for the IBM PC and performs its I/O by direct interface to the hardware.

The other polyFORTH system reviewed is even more integrated into the PC environment because it resides in an MS-DOS COM file and performs its I/O via DOS calls. Thus this system presumably is capable of running on any MS-DOS computer. Even this polyFORTH, however, displays minimal integration into the DOS environment and remains much closer to the polyFORTH world than the DOS world. For its disk I/O, MS-DOS polyFORTH simply accesses an image of the native polyFORTH system disk that has been transferred, block by block, into a DOS file. polyFORTH still does not seem to be really at home under MS-DOS.

FORTH Inc. says that the fully native polyFORTH for the IBM PC will be continued. A soon-to-appear upgrade of the native product will include an expanded (stand-alone) DOS file-handling package with the ability to create a DOS-bootable COM file containing a native application. Accompanying current versions of polyFORTH are various utilities, such as an 8086 assembler, command-type block editor, and polyFORTH's own file system and data base manager, which allow files and record structures to be declared and manipulated.

Developers should note that FORTH Inc. requires no royalties or license fees for program products written in polyFORTH, provided that the end user has no access to the underlying Forth. If the user can access the underlying Forth (under any circumstances), a fee is required. For serious development work, FORTH Inc. sells a level 4 version of the product (at $3,200) that includes the complete system source code and a target compiler that allows the customer to tailor the complete system to his or her own situation. The system, consistent with its minimalist philosophy, does not have any tools for creating binary (precompiled) overlays. An easy-to-use command is included for creating bootable and precompiled programs.

polyFORTH documentation is very complete. Two large manuals that come with the polyFORTH system are the 432-page *polyFORTH II Reference Manual* and a 91-page *Intel 8086 CPU Supplement* to the reference manual. Also included is Leo Brodie's *Starting FORTH*, an excellent introduction to Forth in general and polyFORTH in particular. Commissioned in 1981 by FORTH Inc., *Starting FORTH* has become a Forth standard in its own right.

Harvard Softworks HS/FORTH

Harvard Softworks' name reflects its Massachusetts origins, though the company is currently located in Ohio. Its HS/FORTH (v. 2.05) includes several features unusual among the other Forths in this review. HS/FORTH as booted is a Forth-79 Standard system, but it includes a Forth-83 Standard compatibility mode under which it conforms to the Forth-83 Standard. HS/FORTH runs on various machines that run MS-DOS since its standard system I/O goes through DOS.

The HS/FORTH system is moderately integrated into the MS-DOS environment. The program is stored as a DOS COM file and allows access to files via the mechanism of DOS 1.0 file control blocks. Not only is HS/FORTH capable of inter-

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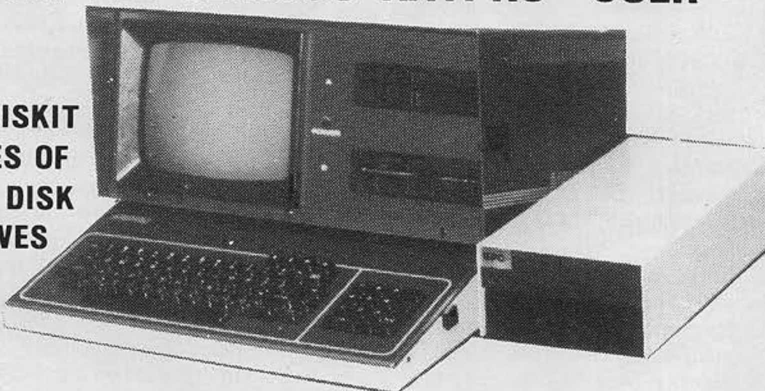

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preting text files, all the system source is distributed in that format. Optional packages allow interpretation of files and non-DOS disks containing Forth blocks. HS/FORTH does not support DOS 2.x path names.

HS/FORTH possesses a highly segmented memory organization, allowing it to take advantage of the 8088 processor's method of memory management. Stacks, tasks, high-level definitions, machine code, vocabulary word headers—everything is placed in a separate memory segment. Thus headers can be easily discarded by simply using a *BEHEAD* command, giving it either a single word or a range of words; this provision frees up memory for bigger applications.

HS/FORTH is accompanied by various utilities: assemblers (which include syntax checking) for the 8088, 80186, and 8087 processors, an editor, and a program development toolkit. The system includes an example of multitasking, but multitasking is not built in. IBM features, such as a speaker, are supported through special commands; for example, half a dozen commands control sound.

Harvard Softworks requires no royalties or fees for packages written in HS/FORTH that are distributed as bootable COM files if they do not contain the HS/FORTH definition lists (which are easily removed with the *BEHEAD* command). If the application allows the end user to enter commands to the interpreter (even though the user cannot define new commands), the royalty is $1 per copy, with a maximum of $500 per program product.

SOTA: A CP/M Forth

In addition to the recently released SOTA CP/M Forth, CP/M Forth products are also available from Laboratory Microsystems Inc., MicroMotion, and Unified Software Systems.

SOTA Computing Systems is the only company to bring out a new CP/M product: a fig-Forth model. fig-Forth antedates even the Forth-79 Standard, and most vendors have upgraded from this early system. The company plans publication in September of a Forth that can be easily configured to conform to fig-Forth, Forth-79 Standard, or Forth-83 Standard.

SOTA is primarily concerned with the implementation of various interpreters and compilers on mainframe computers. This Forth is SOTA's first experience with the retail and mail order market. If the manuals are any guide, I believe SOTA will be successful.

The SOTA manual set contains five sections. They are all printed on a dot-matrix printer, probably because they use many icons. One problem with the dot-matrix print is the striking resemblance between a boldface slashed-zero and a black blob. Each section has a table of contents, but none are indexed.

The first manual is the six-page fig-Forth *Installation Guide*. It provides a step-by-step procedure for installing fig-Forth with a detailed description of what is happening at each step. Icons are used where necessary for clarity.

The *Users Manual* describes the vocabularies for Forth execution, Forth compilation, the editor, and the Z80 assembler. In addition, the system messages and disk error messages are described. Each word is accompanied by an icon that specifies whether the word is compile mode only, a defining word, an immediate word, a run-time routine, and/or a SOTA extension. In addition, the pronunciation of the word is given (of some importance since some words contain symbols or consist of symbols), and its effects and any restrictions on its use are described. The Z80 assembler vocabulary has many examples to clarify the context of each word. This manual is 88 pages.

Brief tutorials are provided for the editor and for the assembler. The editor tutorial is only three pages long and contains only one example. The screen editor commands and the mechanics of the editor operations are briefly discussed.

The assembler tutorial is designed for people already familiar with Z80 assembly language programming. It contains references to a Forth tutorial manual to be released in September. Even though it is only eight pages long, it does contain many good examples.

The *System Guide* gives very detailed information on interfacing I/O devices to TRS-80 models 1, 3, and 4. It also discusses the video screen, printer, keyboard, and disk driver.

If SOTA's planned documentation efforts for a beginner's tutorial and a programmer's guide are as good as these manuals, then this may be the best documented CP/M Forth system. SOTA's licensing agreement allows the developer to distribute programs written in this Forth with no payment of royalties or license fees, provided the end user has no access to the underlying Forth.

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The HS/FORTH manual is 300 pages, with updates mailed to registered users. Harvard Softworks offers telephone support during the business day.

Laboratory Microsystems PC/Forth

Laboratory Microsystems Inc., a long-term vendor of high-quality Forth products, has released version 3.0 of its PC/Forth, a Forth-83 Standard system. Version 3.1 was about to appear at press time. PC/Forth runs on the IBM PC and AT, with versions also available for the HP-150 Touchscreen, the HP-110 Portable, and the Wang Professional. These various systems use the same command set but are hardware dependent for maximum performance.

PC/Forth is well integrated into the MS-DOS environment. All disk I/O uses DOS files and source code is stored in files, either in the traditional Forth format of 1K blocks or as text files that are loaded with the *INCLUDE* command. Text can be in ASCII files or even in some word processor formats (such as WordStar document files).

The file system interface is based on DOS 2.0 UNIX-style file handlers rather than the user-maintained file control blocks required by earlier versions of DOS. As a result, files may be referenced by their path names and the current directory changed at will.

PC/Forth is organized within a 64K address space, although another LMI package, PC/Forth+, is available that uses a 32-bit stack and can address all of memory for both data and operations. PC/Forth and PC/Forth+ use the same command structure and can compile each others' source code, though the different stack width may require you to make some minor modifications in the program.

In PC/Forth, *long* operators can read and write data to high memory, either directly to and from the disk or to and from low memory. The *long* operators use segment addressing, with Forth commands available to retrieve segment addresses. (Separate segments are also used for the stacks.) To optimize memory usage, system utilities are stored in precompiled form as binary overlays. Commands are provided so that users can also easily create relocatable binary overlays for their own program modules. These modules can be accumulated as a library of run-time routines that can be called as needed.

The screen editor is fast and complete, with control key commands in the WordStar dialect. The screen editor requires a fair amount of memory, which is why it is a binary overlay. For program development, a supplemental small editor would be useful.

The PC/Forth documentation is the best packaged of the Forth systems reviewed. Published in a sturdy IBM PC-style binder and box, the 383-page *PC/Forth Language Reference Manual* has the usual chapters describing the source editor and assembler. In addition, the manual contains a very complete 259-page description (glossary) of all Forth words needed by an applications programmer; there is also a more limited glossary of words of interest to the system programmer. All words are listed in the index. Further chapters describe the use of binary overlays, how to create turnkey applications, and how to use the MS-DOS interface.

A variety of add-ons are available for PC/Forth, including a very strong graphics extension, a debugger, a native code compiler that compiles Forth source code down to machine code, and a metacompiler that allows users to restructure the system according to specific needs and strip headers from application packages to gain more room and more program security.

Laboratory Microsystems requires no royalties or license fees for program products written in PC/Forth, provided that the end user has no access to the underlying Forth. LMI does request that developers submit a copy of the product and get explicit permission before distributing programs written in PC/Forth.

Laboratory Microsystems maintains an on-line bulletin board during nonbusiness hours on which users can leave requests for technical assistance. Answers are normally posted within 24 hours. In addition, telephone support is available during morning business hours.

MicroMotion MasterForth

MasterForth (v. 1.0) is a high-quality Forth software development system for the IBM PC developed by long-term Forth vendor MicroMotion and designed to be entirely compatible with the Forth-83 Standard. MasterForth is well integrated into the DOS environment. The program is stored as a DOS COM file and allows access to files by way of DOS 2.0-style file handlers. Files may be referenced by their full directory path names and the current directory changed at will.

Certain deficiencies exist in the DOS interface. To be opened or created, for example, a file must have an extension (the up-to-three-character portion of a file name following a period. No direct accommodation is made for interpretation of text files, though the *STREAM* package allows reading text files and the *EVAL* function permits interpretation of a string so that a user could write a word to read source code from text files. System source is distributed in the form of files of Forth blocks.

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General information

Manufacturer and product	Forth standard	Editor	Assembler	Debugger	Kernel source	Manual pages	Disks	Multitasking	Access to extended memory	Access to DOS files	Interpret text files	Redirection works	Double integer	Triple or quad integer	Single floating point	Double floating point	Hardware floating point
IBM PC																	
Forth Inc.																	
polyFORTH II IBM	79[1]	yes	yes	no	0[2]	960	2[3]	yes	no	yes[13]	no	no	yes	no	no	no	yes
polyFORTH II MSD	79[1]	yes	yes	no	0[2]	906	2[3]	yes	no	yes[14]	no	no	yes	no	no	no	yes
Harvard Softworks HS/FORTH 2.05	83	yes	yes	yes	no	299[9]	1	yes	yes[19,21]	yes	yes	yes[16]	yes	no	no	no	yes
Laboratory Microsystems PC/Forth 3.0	83	yes	yes	no	no	380	1	yes	yes[19,22]	yes	yes	no	yes	no	no	no	no
MicroMotion MasterForth 1.0	83	yes	yes	yes	no	325	1	no	yes[19,22]	yes	yes	yes[16]	yes	no	0	0	no
Mountain View Press MVP-FORTH 1[5]	79	yes	yes	yes	yes[2]	204	8	no	yes[19,22]	yes	no	no	yes	no	no	no	yes
Next Generation Systems NGS Forth 2.1.1	79[7]	yes	yes	yes	no	208	2	no	yes[19,21]	yes	yes	no	yes	no	no	no	no
No Visible Support Software F83 2.1.0	83	yes	yes	yes	yes	10	1[4]	yes	no	yes	no	no	yes	no	no	no	no
Shaw Laboratories TaskFORTH 8088 v. 1.00A	83,79	yes	no[6]	no[6]	no	—[9]	1[15]	yes	yes[21]	yes	no	no	yes	yes	no	no	no
Sunset Technology ST-FORTH 1.3	83	yes	yes	no	yes[2,10]	148	1	no	yes[20,21]	yes	no	no	yes	no	no	no	no
Ubiquitous Systems u4th 1.0	83[11]	yes	no	no	0[12]	429	1	no	no	yes	yes	yes[17]	no[18]	no[18]	no	no	no
Unified Software Systems UNIFORTH	83	yes	yes	yes	0[2]	500[9]	3	yes	yes[21]	yes	yes	no	yes	no	yes	yes	yes
Macintosh																	
Creative Solutions MacForth 2.3	79	yes	yes	yes	no	509	2	no	yes	yes	yes	N/A	yes	yes	no	yes	yes
MicroMotion MasterForth 1.0	83	yes	yes	yes	no	325	1	no	yes	yes	yes	N/A	yes	no	0	0	N/A

0 = Option.
N/A = Not applicable.

1. polyFORTH is also *Starting FORTH* compatible.
2. Source is written in Forth and Forth assembler.
3. One of the two disks with polyFORTH is on-line documentation which corresponds with the source.
4. F83 is distributed with all source present in compressed files. Uncompressed, they take two disks.
5. Includes the additional MVP-FORTH PADS and the PADS options.
6. Available in advanced package.
7. Also includes a fig-Forth compatibility option.
8. Includes a print spooler utility, but not generalized multitasking.
9. We haven't seen part or all of the manuals for these systems.
10. Can look at but not compile.
11. u4th is somewhat compatible with the Forth-83 Standard, but with a number of variances from it.
12. Source to u4th is written in the C language.
13. A Forth utility interfaces directly to the DOS file system, allowing files to be accessed.
14. A single file named FORTH.SCR is opened and allowed access as Forth blocks. The new version has an extended DOS handling function.
15. Two for the advanced package.
16. Handles I/O redirection from the DOS command level but not from within Forth.
17. u4th allows I/O redirection both at the DOS command level and from within Forth.
18. Double and higher integers are available only on CPUs where the natural word size matches—even then access uses 16-bit Forth operators (*, etc.), a non-Standard feature.

Codes for accessing extended memory:

19. Long character fetch and store operators such as LC@ and LC! (names and functions differ).
20. Access using a RAM disk and the Forth block buffers.
21. Access by way of a segmented memory model organization.
22. Uses binary overlays for code (doesn't increase access to memory but improves memory usage).

Table 1.

utilities, such as the editor, assembler, debugger, and beheader, as binary overlays. Provision is made for the user to create custom overlays. Two additional memory optimization mechanisms are available: declaring certain code to be transient (allowing it to be discarded without affecting resident code compiled later) and declaring the headers of words transient while the code stays resident (allowing word headers to be discarded after all references have been compiled).

MasterForth is also well optimized for execution speed. It is organized internally according to a structuring scheme known as direct-threaded code. Most Forths today use indirect-threaded code or even token-threaded code, which have their own advantages (typically requiring less space) and disadvantages (slightly slower execution speed).

Developers should note that a one-time license fee of $1,000 is required for each program product, even if the program is distributed at no cost.

MasterForth is accompanied by the 110-page *MasterForth Reference Manual* and by the 224-page textbook *Mastering FORTH* by Anita Anderson and Martin Tracy. *Mastering FORTH* is a well-written introduction to the Forth-83 Standard, and the book describes itself as exactly matching the MasterForth system. The reference manual includes details particular to MasterForth: file interface, utilities, system internals, and a description (glossary) of system words.

Miller Microcomputer MMSFORTH

Since this company was in between versions at the time of this review, the revised version of MMSFORTH was not available for review. What follows is a brief description of the new version.

Miller Microcomputer Service's MMSFORTH (v. 2.4), like polyFORTH, takes over the machine completely and is incompatible with DOS and DOS-based files. Having complete control offers some advantages in terms of diskette capacity and video control but brings up the compatibility problems previously discussed. For example, if you are using a nonstandard hard disk or equivalent, such as the Bernoulli Box, you would have to write your own driver. Iomega provides a driver with the Bernoulli Box, but it (of course) is written as a DOS-based program.

Within these limitations, MMSFORTH is a responsive language. It is not a Forth-83 Standard, but it adheres generally to the Forth-79 Standard. The package has a long history, tracing back to TRS-80 model 1. Indeed, MMS continues to support MMSFORTH on TRS-80 models 1, 3, and 4; the MMS TRS-80 Forth is, within hardware limitations, the same as the IBM MMSFORTH reviewed here. The continued development of MMSFORTH has brought it to a high level of polish. The tie-on packages include not only Forth utility files but also support software such as a word processor, a data base system, and a telecommunications package. Thus the restriction to what amounts to the MMS operating system is not so severe as it might otherwise be.

The documentation is comprehensive, with all commands defined in an alphabetic list; command names are also grouped by function, and the commands a beginner should master first are identified in boldface. The manual is in a large, three-ring binder and is indexed.

The package includes an assembler and a breakpoint routine. Source is provided for extensions and the upper half of Forth but not for the innermost kernel. The program is restricted to 64K, but words to use upper memory for data storage are provided.

Double-precision integers come with the basic package. Arbitrary precision integers (you specify the number of bytes) and floating points (with 8087 support) are included on optional utility disks. On IBM computers, floating point operators can utilize the ROM routines.

Bootable and precompiled applications are easily prepared via a *CUSTOMIZE* word. Binary overlays are not supported directly but are examples in source code on the utility disk.

Developers should note that a corporate site license is required for producing pro-

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grams from MMSFORTH, along with a license fee of $500 for 50 units or a one-time fee of $5,000 for an unlimited number of units. The fee applies whether programs are sold or distributed at no cost and is for distributing a run-time version of MMSFORTH (the end user having no access to the underlying Forth, only to the application program).

The normal price is for a one-person, one-computer license; a corporate site license is an additional $1,000 for unlimited users and copies within a single building. Additional buildings are $500 each.

Mountain View Press MVP-FORTH
Mountain View Press sells a wide variety of Forth systems, documents, and materials; some of these are from other publishers, some are published by Mountain View Press. The house-brand Forth is known as MVP-FORTH. Always a capable, well-documented Forth system, it now calls itself a virtual system (MVP-FORTH's terminology for binary overlays), allowing certain utilities to be read, already in precompiled form, from disk into the system's 64K addressable memory.

MVP-FORTH (v. 1.3) is not an Forth-83 Standard, though it is compatible with the Forth-79 Standard. Mountain View Press states that its Forth kernel will be unchanged in the future.

MVP-FORTH is available with two optional system components known collectively as the MVP-FORTH Professional Applications Development System (PADS). The first component of PADS is a package of Forth programming aids. The other optional PADS component is a unit made up of the metacompiler and virtual loader systems.

The Forth programming aids are a set of routines designed to speed program development and extract subroutines or an entire application program for cross compilation. Included in this optional package are a translator, which provides one-to-one translation (a form of decompilation, not recompilable) of high-level Forth words in memory; a callfinder, designed to find all calls to a specified word or set of words; a decompiler, capable of decompiling back to compilable source on disk; and a subroutine decompiler, which may, for example, extract a working subroutine in source form to disk, together with all its variables, constants, and called subroutines.

The metacompiler system supports a range of operations varying from recompiling the MVP-FORTH kernel after modifying some of the words to creating an entirely different system. The virtual loader system provides a technique for precompiling subsystems (overlays) in upper memory and storing them on disk until needed.

MVP-FORTH is at an intermediate stage of integration into the DOS environment. The system disk contains a DOS file system, with the Forth system appearing therein as a COM file. However, the remaining diskettes supplied with the MVP-FORTH system contain no file system but are organized simply as Forth blocks. Several of these diskettes contain a stand-alone boot image of MVP-FORTH.

The MVP-FORTH system is reasonably well documented, with a 56-page *MVP-FORTH Virtual System* manual, a 55-page *Forth Programming Aids* manual, and a 23-page *PADS Metacompiler and Virtual Loader Systems*. Of the PADS options, the *Floating Point System* manual is 28 pages long, the *Graphics Manual* is 13 pages, and the *MS-DOS File Interface Supplement* is 29 pages. Also included is a system source listing. In addition, Mountain View Press has published several books on MVP-FORTH, including a detailed reference on the MVP-FORTH system. MVP-FORTH, PADS, and the PADS options are distributed on a total of eight single-sided, double-density diskettes.

With the exceptions of the metacompiler system and the programming aids, the MVP software is in the public domain. Thus no royalties or license fees are required for products produced in this language.

Next Generation Systems NGS Forth
Next Generation Systems' NGS Forth, like some of the other Forths, utilizes seg-

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ment addressing to make full use of the IBM memory space, even though the program is restricted to 64K.

NGS Forth places the stack in a separate segment and allows the extra segment to be set to point to data elements in extended memory. This makes better use of the 8088's 1MB addressing space without incurring the overhead of full large-model organization of the system.

NGS Forth provides a good degree of DOS integration although at the DOS 1.0 file control block level. NGS Forth is capable of accessing both Forth blocks and DOS text files and can convert from one to the other. NGS Forth is also capable of interpreting text files directly. It does not support DOS 2.x path names.

NGS Forth is not Forth-83 Standard. Normally it is Forth-79 Standard, but it also has the option of switching to a Forth Interest Group look-alike mode for a measure of compatibility with fig-Forth, an early standardized Forth.

NGS Forth's 208-page manual is published in an IBM PC-size binder. It contains sections describing the operation and structure of NGS Forth, a glossary of system words, and an index. Appendices describe specific tools, such as line and screen editors, an assembler, and debugging aids. The system supplied for review was v. 2.1.1, while the accompanying manual was for v. 1.1; we are unable to say what system features were added or changed for v. 2.

Next Generation Systems requires no royalties or license fees for the distribution of programs written in NGS Forth provided that the user has no access to the underlying Forth.

No Visible Support Software F83

Those who use and appreciate Forth must give much credit for its early growth to those public-spirited founding members of the Forth Interest Group who in the late 1970s organized implementation teams to bring up their newly defined fig-Forth on major microprocessors. The fig-Forth systems were then placed in the public domain. The availability of inexpensive Forth systems where there had been none made it possible for people to learn about and use Forth. fig-Forth defined its own standard and may be considered the first standard Forth to achieve widespread use.

Many fig-Forth systems are still in use. However, the Forth-79 Standard defined a Forth of greater power and capability than fig-Forth. A further blow to fig-Forth was struck by the drafting of the Forth-83 Standard.

To blaze a trail into the Forth-83 Standard world and stimulate commercial vendors to adopt the new standard, Forth collaborators Henry Laxen and Michael Perry revived the ideals of fig-Forth to create the Forth-83 Model Implementation, commonly known as F83. F83 systems are available for 8080, 8086, and

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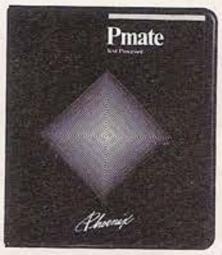

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68000 processors running CP/M and 8088 processors running MS-DOS. The version reviewed here is 2.1.0.

Like fig-Forth, F83 is in the public domain. Laxen and Perry have published the following policy statement: "In order to promote widespread distribution and use of this model, we have placed it in the public domain. We encourage its use, reproduction, extension, and improvement, especially the latter two."

F83 is a Forth-83 Standard and is supplied with all system source, including a metacompiler. The system is multitasking and comes with various utilities: an assembler, a *Starting FORTH*- compatible editor, a decompiler, and a source-code locator facility.

As implied by the vendor name, F83 has no vendor support and is supplied with no documentation other than the system source itself and a couple of text files containing hints. As Laxen and Perry state, "All [systems] are available as is, with no support, handholding, questions answered, warranties, guarantees, assurances, refunds, or any recourse whatsoever."

F83 is moderately integrated into the DOS environment, providing operators to open and access DOS files at the DOS 1.0 file control block level and storing its source in files of Forth blocks. F83 includes no facilities for interpretation of text files and does not support DOS 2.x path names.

The MS-DOS version of F83 is distributed on a single double-sided, double-density diskette containing a number of Huffman-encoded files. When unpacked, these files expand to fill two additional floppies, a procedure requiring approximately one hour.

Benchmark results (sec)

Manufacturer and product	Loop	Subtraction test	Multiply test	Divide test	Move	Compare test	Sieve 1	Sieve 2	Sieve 3	Sieve 4	Sieve 5
IBM PC											
Forth Inc.											
polyFORTH II IBM	1.118	3.641	4.473	4.723	3.679	4.456	54.898	36.907	66.026	66.384	74.070
polyFORTH II MSD	1.063	3.470	4.250	4.463	3.471	4.235	52.502	35.214	62.855	63.195	70.510
Harvard Softworks HS/FORTH 2.05	1.204	3.284	4.134	4.594	3.636	4.131	47.818	33.841	53.530	56.934	61.522
Laboratory Microsystems PC/Forth 3.0	0.779	3.400	4.265	4.621	3.223	3.991	52.209	33.419	62.078	64.608	71.573
MicroMotion MasterForth 1.0	0.638	2.691	3.573	9.584	3.305	3.214	45.028	29.570	53.583	54.520	60.809
Mountain View Press MVP-FORTH 1	1.098	3.570	4.461	4.589	3.801	4.214	55.010	—[1]	64.680	65.709	72.671
Next Generation Systems NGS Forth 2.1.1	0.992	3.471	4.389	4.620	3.541	4.041	53.485	35.383	64.783	63.984	71.529
No Visible Support Software F83 2.1.0	1.172	4.462	7.619	37.367	4.463	5.206	67.796	43.923	79.863	80.430	89.008
Shaw Laboratories TaskFORTH 8088 v. 1.00A	0.893	3.553	4.338	5.691	3.471	4.233	55.147	35.202	64.597	65.986	73.130
Sunset Technology ST-FORTH 1.3	0.850	3.470	4.303	5.130	3.471	4.049	54.754	34.498	64.808	64.511	71.953
Ubiquitous Systems u4th 1.0	—[2]	—[2]	—[2]	—[2]	—[2]	—[2]	—[2]	—[2]	—[2]	—[2]	—[2]
Unified Software Systems UNIFORTH	0.779	3.426	4.281	4.462	3.371	4.061	54.145	34.128	63.807	65.141	71.826
Macintosh											
Creative Solutions MacForth 2.3	0.700	2.100	5.100	N/A	2.900	2.500	34.400	21.300	41.400	45.900	50.900
MicroMotion MasterForth 1.0	0.400	1.400	1.700	N/A	1.900	1.900	25.200	16.800	29.700	30.200	32.900

N/A = Not applicable.

1. Running Sieve 2 crashes MVP-FORTH.

2. Lacking a XENIX system for the IBM PC, u4th could not be tested or benchmarked.

Note: The benchmark routines used in this review are essentially identical with those used in a recent article in *BYTE* by Ernie Tello ("Software Review: polyFORTH and PC/FORTH," November 1984, pp. 303-314). The loop, subtract, multiply, divide, move, and compare tests originally appeared in *FORTH Dimensions* (issue III/1, p. 11). The various Eratosthenes Sieve programs are derivatives of the Sieve of Eratosthenes algorithm appearing in the September 1981 *BYTE*, which Tello selected for his review. Sieve 1 is the basic Sieve of Eratosthenes algorithm. Sieve 2 is an improved Eratosthenes Sieve by Don Colburn. Sieve 3 is an Eratosthenes Sieve described as "optimized." Sieve 4 is a Sieve which makes use of a *CREATE DOES>* character array. Sieve 5 is a Sieve described as using an "optimized array." Timings on the MS-DOS systems were performed by combining a count maintained by the 55-millisec timer interrupt with low-order bits read directly from the IBM PC's 8253 chip, reset to mode 2. Although up to microsecond resolution is theoretically available using this technique, in practice resolution to about a millisecond was attained. Stand-alone polyFORTH resets the 8253 to interrupt every millisecond; in this case, polyFORTH's built-in timer utility—also estimated to have approximately millisecond resolution—was used.

Table 2.

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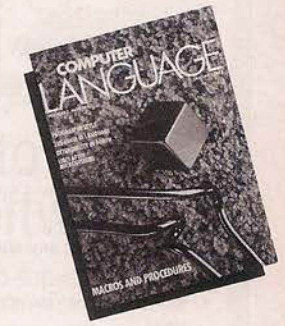

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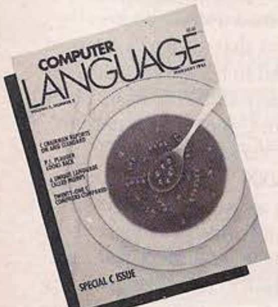

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Shaw Laboratories TaskFORTH

George Shaw has long been a major contributor to the Forth community; he is a member of the Forth Standards Team and was one of the elected referees who completed the Forth-83 Standard. Shaw Laboratories Ltd. has now released a new version of its TaskFORTH system that conforms to the Forth-83 Standard as well as allowing Forth-79 Standard and *Starting FORTH* compatibility modes.

TaskFORTH (8088 v. 1.00A) is moderately integrated into the MS-DOS environment; it runs under DOS as an application program, provides the ability to access DOS files (at the DOS 1.0 file control block level), and stores its source in files of Forth blocks. However, no capability is provided for interpretation of DOS text files and DOS 2.0 path names are not supported. TaskFORTH is capable of accessing absolutely-addressed disks that lack a DOS file system.

On top of DOS files (or absolutely addressed disks), TaskFORTH provides the capabilities of its own hierarchical file system and data base manager, allowing further internal structuring of DOS files. The file system supports both fixed contiguous and dynamic allocation with random, sequential, and keyed file access. Additional file types, record structures, and access methods can be defined and integrated into the system. Records can be divided into and accessed by named fields.

TaskFORTH is multitasking and allows multiple users as well. When an image of the TaskFORTH system is saved into a file, every task is provided with a vector allowing it to execute its own programs from a cold start. TaskFORTH's multiprogrammer is an efficient, round-robin scheduler; any task can do anything a user can. The only limit on tasks is the amount of available memory.

Various utilities accompany the TaskFORTH system—a video editor, an assembler, a decompiler, a disassembler, performance monitoring tools, and an interactive high-level debugger capable of debugging multiple tasks. A range of single-, double-, and triple-size fixed-point arithmetic operations are supported and optimized for speed.

Documentation for the new version of TaskFORTH was unavailable at press time and could not be reviewed.

Sunset Technology ST-FORTH

ST-FORTH (v. 1.3) is compatible with the Forth-83 Standard and is at an intermediate stage of integration into the MS-DOS environment. The program is supplied as an MS-DOS COM file and has the ability to access DOS files by way of DOS 1.0-type file control blocks. Words are provided to allow access to sequential and randomly structured files. However, ST-FORTH considers its normal method of source storage to be non-DOS absolutely addressed floppy disks containing blocks, similar to the access of the stand-alone systems such as polyFORTH and MMS-FORTH.

The ST-FORTH system includes a video editor, assembler, high-level decompiler, source code locator, system memory map, and other useful tools. In an unusual feature, ST-FORTH is supplied with all source for the system (including the kernel), organized as a single 267K file of blocks. Also included is a RAM disk that allows access, via the disk buffers, to memory beyond the normally addressable 64K.

ST-FORTH is accompanied by the 156-page *ST-FORTH Users Reference Manual*, which describes the system components and includes a description (glossary) of all words in the system.

Ubiquitous Systems u4th

u4th (v. 1.0) is a Forth-83 Standard that runs on the IBM PC under the XENIX operating system. XENIX, a version of AT&T's UNIX, was developed by Microsoft and ported to the IBM PC by The Santa Cruz Operation. We were unable to obtain XENIX for the IBM PC by press time and so cannot provide benchmarks; however, we deemed u4th to be a well-developed product that deserves a report.

u4th is designed to be a highly portable product. Like many UNIX systems, it is written entirely in C. u4th reportedly runs on processors as various as Intel 80286 and Motorola 68000, with the only source changes being in a couple of statements. Another design objective was fastest execution speed consistent with portability. u4th documentation claims the system is slower only by a factor of approximately two than fast assembly language Forths. Internally, u4th uses direct-threaded code.

Highly integrated into the UNIX environment, u4th allows access to all types of UNIX files and provides fully recursive I/O redirection within its own process. Interpreting Forth source from a text file is performed simply by redirecting input to come from that file; similarly, output to files can be performed by redirecting the output. u4th allows commands to be automatically passed through to UNIX ("forking a shell") if the input can't be found in the Forth dictionary. UNIX-style filters can also be run without leaving the u4th environment. It's worth noting that many of these capabilities are available to programs operating in the MS-DOS environment.

Due to limitations in the XENIX C compiler, u4th currently is available only by using small-model 64K addressing. Upgrades to large model will be made available to current customers "when such support can be offered." Large-model u4th will run with 32-bit stacks, a

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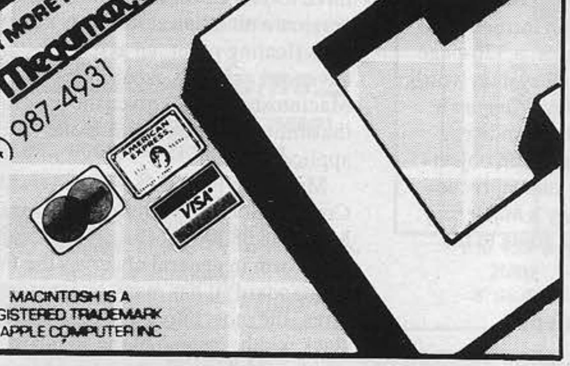

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variation from full compatibility with the Forth-83 Standard. Other differences from the Forth-83 Standard include definition of system words in lowercase, and only optional, high-level support for accessing files of Forth blocks.

The u4th product provides all system source, including the kernel, and makes use of UNIX's make program to control kernel recompilation. Since u4th stores its source in ordinary UNIX text files (which UNIX can manipulate through many well-designed utilities) and commands can easily be passed through to UNIX, u4th recommends using a UNIX text editor—such as the popular vi—for program development. For editing files of Forth blocks, u4th provides a video editor with a command set modeled after a subset of vi.

u4th documentation consists of the *u4th User's Manual*, consisting of 60 pages of "essential information," an introduction to u4th, and advanced topics; a 326-page description (glossary) of all system words (in the style of the *UNIX Programmer's Manual*); and 43 pages of appendices, including a 24-page appendix on object-oriented Forth. The u4th manual recommends Anderson and Tracy's *Mastering FORTH* as a supplemental guide to the Forth-83 Standard Forth.

Unified Software Systems UNIFORTH

Unified Software Systems is now completing conversion of its Professional Series UNIFORTH to the Forth-83 Standard. Because of this, we were unable to test the new Professional Series; instead, we ran our benchmarks on the UNIFORTH Sampler System, a public domain subset of the Professional.

A brochure describing the new UNIFORTH Professional System states that it includes both a line and video editor, an assembler, a decompiler, and a debugging trace facility. The Professional System is also a prioritized multitasking system. Software and hardware floating point support are standard, using IEEE format, and options such as a plotting package, EPROM programmer, and cross compiler (otherwise known as a metacompiler) are available. UNIFORTH does not support the creation of binary overlays or DOS 2.x path names.

Unified Software Systems requires no royalties or license fees for any program developed in the public domain sampler system or for any program developed in the Professional Series, provided the user has no access to the underlying Forth and the headers are stripped out using a word provided for that purpose.

Documentation for the new Professional Series UNIFORTH was unavailable at press time so we are unable to report on it. The UNIFORTH brochure states that all UNIFORTH systems come with a manual set designed to lead you painlessly from the basics to the heart of FORTH. The manual set is divided into the *User's Guide* and *Programmer's Guide* and totals more than 500 pages.

Professional Series UNIFORTH was scheduled for release this summer. UNIFORTHs for a number of other processors and operating systems are also reportedly available.

MACINTOSH FORTHS

Creative Solutions MacForth

MacForth was the second language available for the Macintosh, coming shortly after the release of MS-BASIC for the Mac. MacForth was the first language for the Mac that offered the ability to create stand-alone applications without the need for an interpreter. MacForth comes in three levels. Level 1 is an integer-only version without an assembler. Level 2 adds floating point, an assembler, and advanced graphics capabilities on the Macintosh. Level 3 gives the programmer the ability to create stand-alone applications.

MacForth is the Macintosh version of Creative Solutions' MultiForth for the Motorola 68000 processor. Although MacForth in general observes the Forth-83 Standard, it has many nonstandard features, the most important of which is the stack width: instead of the standard 16-bit width (which accommodates addresses up to 64K), the MacForth stack is 32 bits wide. Thus double-precision numbers use 64 bits instead of 32 bits. This provides a considerable range for fixed-point (integer-only) calculations.

The editor provided with MacForth operates in its own window. Standard Forth 1K blocks (16 lines of 64 characters each) are used to store source code; the mouse and pointer can be used with Macintosh cut-and-paste methods for very quick source code editing. If an error has occurred during compilation, the editor will present the block containing the error with the cursor at the exact spot where the error happened. Code compiled with the trace feature turned on can be debugged when executed. In this mode each word called will be displayed along with the stack contents at the time. Control-A can be used at any time to halt execution of a MacForth program.

Numerous extensions are provided with MacForth. With level 1, MacForth windows and menus can be created in the Macintosh environment, and lines, rectangles, and ovals can be drawn from the Macintosh toolbox routines. Level 2 adds region and polygon capabilities for creating and manipulating complex graphics. MacForth allows the coordinates of a window to be defined by the user.

The developer provides on-line support via a CompuServe special interest group. Access to this group is for registered users; the only fee is a surcharge on the

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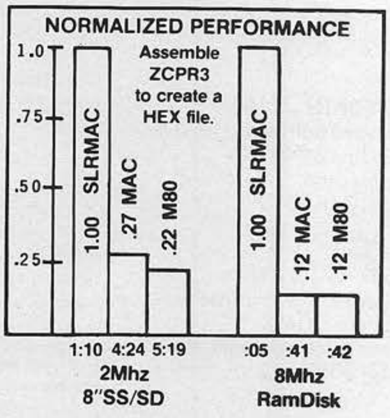

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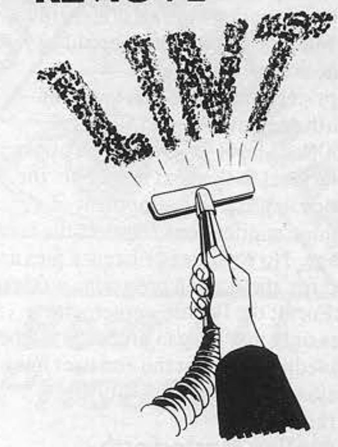

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The benchmarks were all done with level 2 MacForth, but there should be no differences between levels.

The prices for the various levels of MacForth are: level 1— $150, level 2—$250, and level 3—$499. The upgrade from one level to the next costs only the difference in price. Development of stand-alone applications requires the level 3 package. No royalties or license fees are charged for application programs written in MacForth; the license agreement requires only that the use of MacForth be acknowledged and that the end user have no access to the underlying Forth.

MicroMotion MasterForth

MasterForth is a Forth-83 Standard for the Macintosh and is essentially identical to MicroMotion's MasterForth running on other computers. An assembler is provided with this package. The manuals for MasterForth consist of a copy of the book *Mastering Forth*, which is a generic guide for MicroMotion Forth products, and a small book that points out specifics of MasterForth for the Macintosh.

The editor provided with MasterForth operates from within the main window. Standard Forth 1K blocks are used for source code. MasterForth's editor does not use the Macintosh mouse; instead, control key sequences move the cursor and cut and paste lines of text. These sequences can be tedious to learn and awkward to use for programmers accustomed to the Mac's standard interface.

Macintosh toolbox routines are called by using traps. Examples are given, but doing such things as creating windows and menus with this system require access to Apple's huge *Inside Macintosh* document. The example code is sparse, so this system cannot be recommended for the novice. As an example of the level of expertise required, note that MasterForth addresses only 64K of memory. To address 512K, Macintosh's memory requires the use of the Mac's memory manager. Source code is provided for accessing the extra memory, but the programmer probably needs a good working knowledge of 68000 assembly language.

The stack used by MasterForth is the standard 16-bit width, with 32 bits for double precision arithmetic. As can be seen by the benchmarks, MasterForth is faster then MacForth, but the limitations of the MasterForth system should be taken into account. It should be noted also that Forth code is usually compact; more can be done in 64K than one accustomed to other languages would expect.

The ability to take snapshots of the MasterForth system and create stand-alone applications is provided in the package. To distribute copies of programs written with this system requires a $1,000 royalty fee for each program. ■

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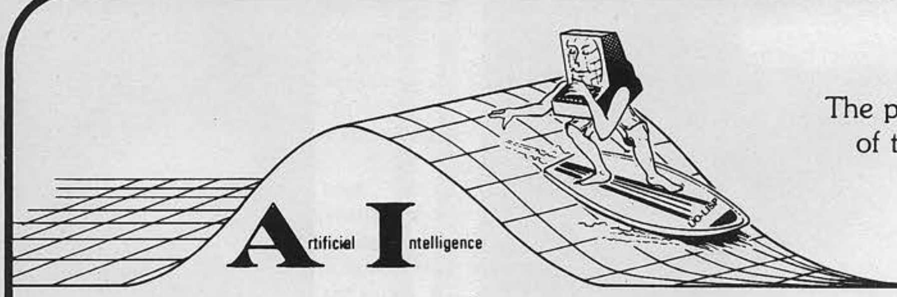

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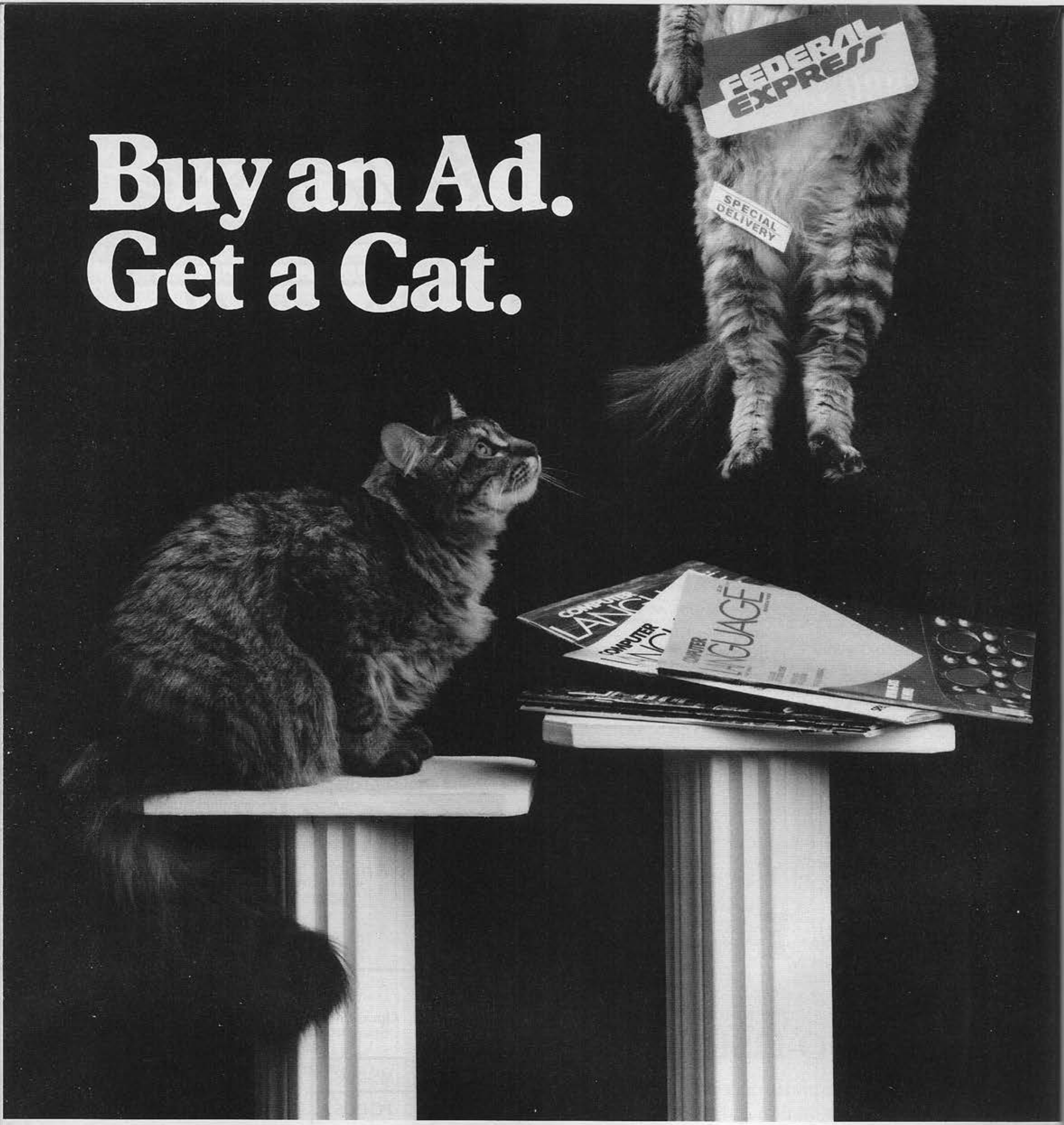

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Knowledge systems for the IBM PC, Part II

By Ernie Tello

In this second and final installment of *COMPUTER LANGUAGE*'s coverage of current PC expert systems, we'll look at the packages falling into the following categories: intermediate-level systems, rule-oriented mathematical modeling systems, and advanced systems.

Table 1 contains general information on all products listed in Part I and Part II of this article.

INTERMEDIATE LEVEL SYSTEMS

Expert Systems ES/P Advisor

Although Expert Systems International's ES/P Advisor is a PROLOG-based tool, as opposed to an extension package like APES (reviewed in Part I), it is a fully configured consultation and development environment that does not require the user to know PROLOG. But for those who already do or are willing to learn, there are some substantial rewards waiting. Although ES/P Advisor is not merely a high-level programming language or extension to PROLOG, it allows any legal programs or functions in the PROLOG-1 dialect to be added freely to its knowledge bases.

This system seems to have been designed specifically for the creation of on-line manuals and how-to applications that take a user step by step through a process covering many different situations. It consists of two separate programs: the consultation shell, or end-user environment, and the knowledge base compiler. The run environment stands out for its well-designed use of windows and color displays and a large number of commands that allow the user to take the initiative in a consultation.

ES/P Advisor's knowledge representation language is powerful and is able to have variables assigned a value through input from a user and then be quoted in subsequent text displays. The inference engine is a backward chaining system that allows the knowledge system developer to assign goals.

Though this system is powerful, the knowledge base files are not particularly easy to read because they are structured according to the order that things will appear in rather than a logical order. Rules are not all in one section but can appear throughout the source file. I have not found this a particularly easy development environment. In many ways the KRL compiler is very strict about syntax idiosyncracies, and yet in others it allows files to compile that subsequently will not run properly. This puts the developer back in the situation of conventional programming languages, where consideration of the tools themselves diverts attention from the problem to be solved.

One of the best features of this system is the interface to the PROLOG language itself. An interface to PROLOG-1 or PROLOG-2 is also available from Expert Systems International as a separately purchased option. This feature gives ES/P Advisor an open-ended architecture that allows a skillful PROLOG programmer to embed programs into the system to augment the inference engine or interface it with external hardware.

PROLOG can be incorporated into ES/P Advisor in two ways:

- As a rule that is used to deduce a value of a knowledge base parameter
- As a pseudo-paragraph, a procedure that is invoked after a qualifying condition is satisfied.

In either case, ES/P Advisor itself does not provide any error trapping for PROLOG code. The PROLOG programs that are entered must be fully debugged beforehand or errors will crash the system. So although in principle it is not necessary to purchase the ESI PROLOG interpreter to add code to ES/P, in practice it seems essential for debugging any complex PROLOG routines.

This system is appropriate where there is adequate programming expertise available. While it is well suited to developing generic applications for resale, it is not easy enough to use to be appropriate for rapid prototyping. For programmers with expertise in PROLOG, this could be a relatively inexpensive environment in which powerful expert systems, within certain limits, could be built.

General Research TIMM-PC

The Intelligent Machine Model (TIMM) from General Research Corp. is the first knowledge engineering system available for microcomputers that handles problems where the user may not know all the necessary and vital information for a problem.

The main features of this system are a preprocessor for knowledge bases that describes the way key attribute variables behave and a partial match search routine based on the nearest neighbor algorithm. As we will see later in the discussion of the fuzzy logic of REVEAL, few real-world problems have the either/or, on/off digital logic on which computers are based. Systems that can be made to operate on the basis of a quantified similarity rather than exact congruent matching are more flexible and potentially more useful in a world where things usually change subtly and by degrees.

By incorporating a preprocessing module, TIMM allows the knowledge engineer to tell the system ahead of time how a particular variable is supposed to behave. Three types of variables are allowed: unordered, linearly ordered, or circularly ordered.

With unordered attributes, TIMM makes no assumptions about how the values can vary. In contrast, linearly ordered values assume that the permissible values will fall into some linear sequence. For example, with an attribute such as skill level, we could define the permissible values as novice, junior, senior, and expert, with each having its place in an ordered sequence. On the other hand, a variable such as month-of-delivery is considered circularly ordered because the values go through a 12-month sequence and then start over again.

Knowing in advance how an attribute can vary is one thing that gives TIMM the ability to fill in missing knowledge. For example, if it has already been given the information that junior-level and expert-level people have a certain skill, then TIMM would consider it a good assumption that senior-level people have that skill also, because senior-level falls between junior-level and expert-level in the linear sequence. By adopting this strategy on a mass scale, it is not hard to see how TIMM could frequently fill in missing information when making inferences. The other facility TIMM uses to operate when all the facts aren't available is based on the partial match algorithm mentioned earlier.

TIMM is made up of 10 separate programs that are available from a common menu. Here is the main menu as it appears on the screen:

```
1. Build
2. Train
3. Exercise
4. Modify
5. Inquire
6. Generalize
7. Check Consistency
8. Check Completeness
9. Compress
10. Convert Knowledge Base
```

The Build program allows you to enter all the choices and factors for your problem and to specify how the factors will behave. With Train you can develop the rules that the knowledge system will contain.

The example conditions are presented much as they would appear in rules. Each part of the example becomes visible as one of a cumulative list of conditions, with the choice entered last in the list. A prompt asks whether you wish to enter the examples or have the system do it for you. If you know many of the rules you want to incorporate in the system then you can enter them as examples. If you let the system choose the values for you, then it randomly picks values for each of the factors based on the possible values you have assigned them.

The Exercise program is where you actually run a knowledge system. It is here that TIMM can try to draw conclusions without having all of the values it asks for. The Modify program is the editing program that allows you to make changes in the actual constraints of the application. The Inquire program allows you to inspect the system to see what it contains. One option gives you the decision structure, meaning the entries you made in the Build program. Another allows you to see a listing of all the rules.

The Generalize program is one of the more interesting ones in the system. It uses the information so far on the system to make hypotheses to the user, who responds favorably or unfavorably and determines whether or not the idea becomes a rule. The rest of the programs are straightforward utilities. The presence of inconsistencies here does not mean logical contradictions. Perfectly viable knowledge bases can have several inconsistencies.

The main limitations of TIMM are that it only allows up to 25 end choices in a knowledge system, it has no provisions for variables or mathematical calculations, and it has no external interface. There are plans, however, to continue to extend this program. The manufacturer should be contacted for information on the latest release.

There are a number of very interesting ideas implemented in TIMM, and I for one hope the authors continue to enhance it and add all the features needed to make this a complete system with all the capabilities of the most advanced systems.

Level Five Research Insight Knowledge System 2

Level Five Research Inc.'s Insight 2 looks and feels like Insight, the $95 product by the same company that was described in Part I of this series, but it is a far more powerful system worth considering as a professional development tool.

The two products share identical end-user interfaces, but Insight 2's is not a separate, stand-alone program. Everything is integrated into a single program available from a menu. Included are a WordStar-like text editor, a data base editor, a compiler, and a run-time environment. Unfortunately, I can't say a great deal about the editors because they were not finished in the prerelease version tested.

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In addition to the functions described by K&R, MIX C includes the more exotic functions like *setjmp* and *longjmp*. Source code is also included.

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As I write this, Insight 2 still has a ways to go until it is finished, but it is clear what this system will become, and it is impressive. Once again, Level Five Research is offering a lot of value for the money. So what does this higher-end package offer over the entry-level version? In addition to the production rule language, DBPAS, a built-in mini-Pascal that allows you to write programs, can be called directly from a PRL knowledge base. You can also call external programs written in other languages, but if you're willing to bite the bullet and use Pascal you have the built-in ability to pass parameters from the knowledge system to the program and back again.

With Insight 2 it is now possible to compose the actual text of questions rather than rely only on the automatic question-generation facility alone. Multipaged text displays are provided which are activated when certain rules fire. Displays can also use bar graphs to convey their information. A goal selection facility allows more knowledgeable users to skip the preliminaries and jump directly to the subdomain of a particular problem. A *pursue* facility also is included for exploring "what if" possibilities and determining the likelihood of certain situations occurring.

The PRL in Insight 2 has been expanded to include arithmetic operations within rules. The system can use as much memory as you have in your machine. Other additions include full support of object-attribute-value triples; external programs, such as data base programs and custom programs that can be executed with the *ACTIVATE* command; knowledge bases that can be chained together; and techniques for implementing inference procedures that essentially operate like a forward chaining inference engine.

A sample dBASE II data base interface is included in the appendix of the documentation. The demo DBPAS program makes all the variable and data base record declarations. It also implements a procedure that opens a data base file, indexes through it, and lists the record information in various ways.

An *APPEND* procedure makes it possible to update the data files by adding new records. Since this is done in the DPAS language, a subset of Pascal that interfaces directly with Insight 2 knowledge bases, an entirely open-ended situation is present. Those adept at the language can do many of the things that would ordinarily be done with Pascal. But in this case, these functions may be used to integrate existing data bases with the Insight 2 knowledge engineering environment. Although this interface is clearly biased toward one programming language, much as ES/P Advisor is toward PROLOG, it offers one of the most powerful extendable environments at a reasonable price.

RULE-ORIENTED MATHEMATICAL MODELING SYSTEMS

Lotus/Software Arts TK!Solver

Most of the systems reviewed here are not overly impressive in their math capability, but TK!Solver by Lotus/Software Arts is a clear exception. This unusual package is clearly an expert arithmetic problem- and equation-solver. But what it is or can be besides is not as easy to determine.

Certainly, TK!Solver is not an expert system tool of the usual production system type, being somewhere between a spreadsheet and a symbolic math solver. But it is clearly a far cry from a mathematical expert system of the caliber of the MACSYMA system developed at the Massachusettes Institute of Technology, Cambridge, Mass. Yet the potential for TK!Solver applications by a sophisticated developer goes well beyond mere run-of-the-mill math and engineering problems.

The basic environment has eight main information modules or sheets: variable, rule, list, global, unit, table, plot, and user function. Each acts as a separate window onto a data set that drives the two problem solvers: the direct solver and (in

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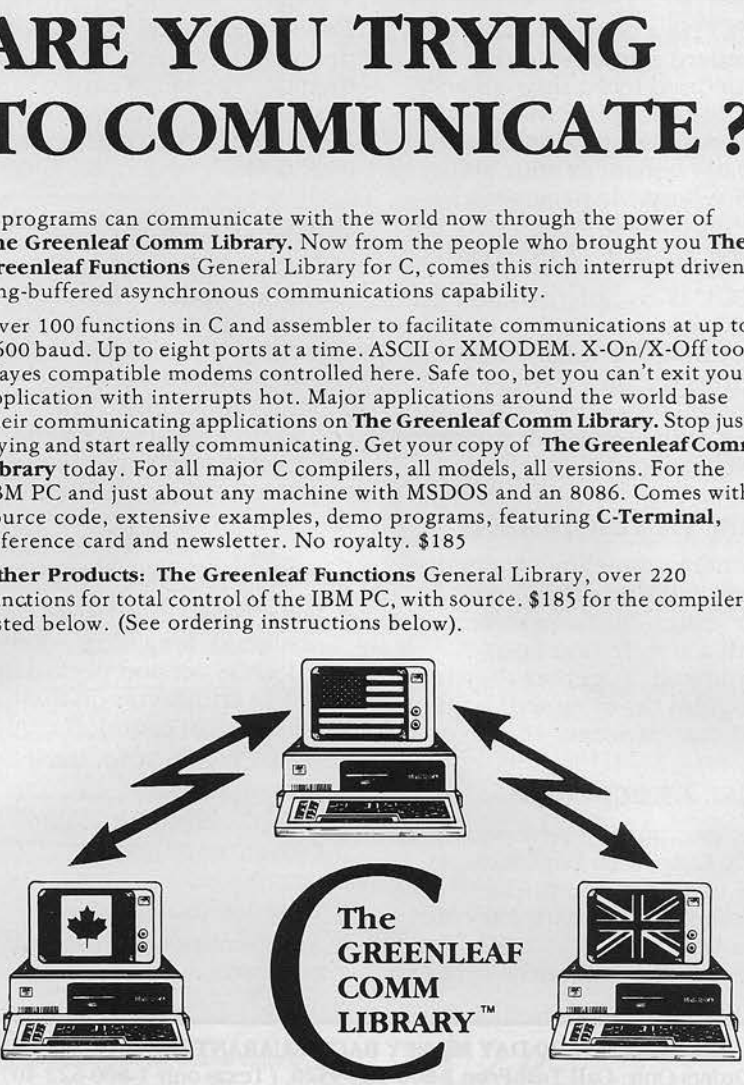

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case the first fails) the iterative solver.

The emphasis of this design, as opposed to that of a spreadsheet, is on seeing clearly what goes in and what comes out in the calculation of answers. No attempt is made to provide a permanent storage matrix, as with a spreadsheet. The formula, or rule, sheet is kept separate from the sheet that contains the variables and their values. Rather than trying in vain to describe in general terms how this works, it will be much easier to give an example of TK!Solver at work on an interesting problem.

The example comes from *The TK!Solver Book*, by Milos Konopasek and Sundaresan Jayaraman, the developers of the system. It gives solutions to the so-called Einstein Twins Paradox. More exactly, it is a model based on the equation for time dilation as predicted by special relativity. Listing 1 shows the rule sheet and the variable sheet.

The items under the Name column are all the variables used on the rule sheet. They appear automatically here by virtue of being entered on the rule sheet. Problems are solved by entering values in the Input column for all the variables except the one being solved for. You recalculate and TK!Solver tries to find the answer with the direct solver. If it can't, you then call on the iterative solver. As you can see, with the input and output columns on either side of the variables column, the focus is on what goes in and what comes out of the model. Among other things, TK!Solver is actually a highly interactive, input/output-oriented simulation modeler.

The rules used here are not the *if . . . then* type used in production systems but are equations or formulas that follow the variables rather than applying to the cell locations. There is no way to set up consultations with TK!Solver where the user is asked questions. And there is no querying about how or why it gives the answer it does. Someone who needs to constantly get numerical answers to complicated problems may prefer this format, because it offers a hands-on interactive style with everything clearly laid out. If the ultimate point is to get the problem solved, then the consultation paradigm may not always be as satisfactory as TK!Solver's plug-in approach.

Although TK!Solver was not specifically designed to accomplish multiple condition statements and logical reasoning, Konopasek and Jayaraman have demonstrated methods for allowing this. These techniques are esoteric but fascinating, and most importantly, they work.

A good example of this, also from *The TK!Solver Book*, is on the color coding of resistors. By typing in the color names for each of the bands on a resistor in the input cells, the application can take in these names for color combinations and spit out the value of the resistance in ohms and the manufacturer's tolerance in percents. And by backsolving, the process can be reversed, returning the color code pattern when the resistance and allowable tolerance are provided.

It is quite conceivable that someone might build a small production rule knowledge system for the color coding and decoding of resistors. But why go through all the questions and reasoning when, with a system like TK!Solver, you can just plug in the pattern and immediately get your answer? It is clear that TK!Solver is quite limited in some ways and doesn't have the tools to handle powerful symbolic processing problems. But it is good to recognize that TK!Solver's simpler input/output paradigm may be the best approach to an important class of problems.

```
Rule sheet

S  Rule
-  ----

*  Ts = Te * sqrt(1 - v^2/c^2)

--------------------------------------------------------------

Variable sheet

St  Input      Name     Output  Unit   Comment
--  -----      ----     ------  ----   -------

L              Te               yr     time on earth
      10       Ts               yr     time in the spaceship
L      0       v                m/s    spaceship velocity
    299790000  c                m/s    velocity of light
```

Listing 1.

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The last TK!Solver application example I will discuss is one that employs logical inference to diagnose automobile problems. Here new user functions are added to TK!Solver by assigning "true" to 1 and "false" to 0 and using numeric means to develop the relations for all the logical operators. In this example, input values for the variables of various conditions of parts of a car are entered and then other conditions are concluded. In one case, the car was described as fit at the same time that two tires were noted as punctured. An error message was displayed.

Though this is a toy example, it shows that, similar to Expert Ease, TK!Solver can do input/output modeling exclusively with qualitative attributes. However, since no questions are generated with this system, there is no guarantee that the user will put in just the relevant number and choice of input values to fire the responses that will help. The more complex the problem, the more the consultation paradigm is justified in providing users with guidance and explanations to stop them from getting lost.

Based on actual examples, I have seen that the following types of problems can be solved with TK!Solver: nonlinear equations for two unknowns, linear regression, curvilinear regression, random number generation, numerical differentiation and integration, and some symbolic differentiation and optimization.

The most decisive advantage TK!Solver has over spreadsheets is that, in principle, it can solve for any variable immediately. To do this with a spreadsheet, extensive editing and even an entire new spreadsheet might be required. Compared with BASIC, or nearly any other programming language, TK!Solver is far quicker and easier to use. Also, like production systems, it is very easy to modify and expand. It is completely modular in the sense that a large number of independent models can be merged into action at once.

Generally, TK!Solver is easy to use, but a user has to know what he or she wants and how to get it. It seems to be the kind of system where the same person would typically be both user and developer. Provisions for a DIF file interchange ensure compatibility with a broad range of existing software. Though not a general problem solver, TK!Solver may be the closest thing to it on microcomputers. This system is a rare combination of power and ease of use.

McDonnell-Douglas REVEAL

So far very few products really make a serious attempt to bridge the gap between expert system technology and the more familiar business information and decision support systems. But REVEAL, by McDonnell-Douglas, does this in some very interesting ways, crossing over several application boundaries at the same time. A powerful relational data base system is combined with an approximate reasoning facility, based on fuzzy sets, that incorporates aspects of natural language processing, expert systems, decision support systems, and modeling and simulation. While this may sound like quite an accomplishment, it is not too hard to see the sense in which it is true.

At first glance, it might seem that the last thing we want is fuzzy reasoning. However, digital technology frequently imposes the false precision of an all-or-nothing logic where it simply doesn't belong. The best example of this is in specifying quantitative criteria for data base queries, production rules, discrimination and transition networks, etc. There are times when something is just over the line on several counts, but the combination makes it a highly attractive option. Conventional software usually misses this entirely, whereas a competent manager or analyst seldom would. Trying to make up for this with conventional production rules can get very cumbersome, but fuzzy sets provide an easier way out.

With fuzzy sets, true or false is no longer an on-off affair but a continuous function with differing numeric values. The numbers measure the degree to which something is true—not the probability that they are true but the extent to which they are true. The idea is that some options are not 100% sound (100% true) and some not 0% sound (0% true). It is often true—to at least a certain extent—that a given option is a sound one.

With a system like REVEAL, if a rule or query states "All the options with a reasonable profit," the word "reasonable" is defined as a relatively continuous function. The records involved are assigned a value representing the degree to which they satisfy the criterion. With this approach, all the usual set relations—such as intersection, union, and so on— can be given a functional meaning. A key relation, though, is that one set logically implies another.

To provide for saying something like "If a company has very high profits, then it has very high sales," REVEAL uses the maximum-minimum rule of compositional inference to implement its fuzzy implication. This means following two provisions: the degree of truth of the consequent set (in this case high profits) cannot be of a higher value at any point than that of the antecedent set (in this case high sales); and the value selected from the consequent set to be the implied amount is the most possible or maximum value for any given antecedent value. So in the column of values of the sales corresponding to a given profit value, the one selected is the largest one. One difficulty with this approach is that since the logical relation is replaced with a mathematical curve, there is no way to portray that profits imply sales while sales do not necessarily imply profits.

REVEAL's architecture is complex but well integrated. At any given time, the full environment is referred to as the context. This context contains four things:

- Data tables that form the raw material on which the rest of the logic will operate
- The data dictionary, which consists of user-defined constants and variables
- A program in the REVEAL language which can be a normal algorithmic procedure or a policy consisting of approximate reasoning based on fuzzy set logic
- A command file with control parameters which provides a given sequence of operations that occur as a batch operation.

The REVEAL user environment operates like an interpreter with a large number of command modes. The main parts of this environment are the editor (a fairly powerful command-driven line editor), the programming language, the command file processor, the data handler, the approximate reasoning facility, and the report and graph generator.

Model programs, label sets, and command files are edited in the editing mode. Included in the editing subcommands are the usual editing functions, as well as a *PARSE* command that toggles syntax checking on and off, a *STACK* buffer for temporarily clearing the editor workspace, and *VERIFY*, which switches verification messages on or off. I did not see any character or block editing functions in the editor, however.

REVEAL's programming language is block-structured and reflects its FORTRAN heritage. However, as previously mentioned, this language is interpreted. In addition to the usual string and constant identifiers and logical, arithmetic, and inequality operators, REVEAL includes built-in functions and series identifiers for referring to the rows in data arrays. Branching to labels, repeat looping, and conditional expressions are also supported. Special functions include data handling, mathematics, finance, string variables, integer arithmetic, data moving, and external file operations. As you can see, REVEAL is a very complete language that is quite suitable for providing data manipulation, modeling, and calculation.

Besides the regular programming language, REVEAL has command file parameters and policy statements that can incorporate the fuzzy sets. Command files automate model processing by batching operations that would ordinarily be done by commands from the keyboard. Branching within a command file and nesting with other command files also are supported.

To use the policy facility, you first declare a vocabulary. Each vocabulary set is identified by its name. As soon as a set is declared it contains a default of hedges and noise words and one qualifier, named *TRUE*. The default hedge words are *ABOUT, ABOVE, BELOW, NOT, QUITE*, and *VERY*, with the synonyms *AROUND, NEAR; MORE THAN;* and *LESS THAN*.

Each of these default words represents a continuous fuzzy truth function that acts as a modifier on the truth curve of what comes after it. It is possible to nest hedge words indefinitely, as in *VERY VERY, NOT QUITE*, and even *QUITE LOW BUT NOT VERY LOW*.

To help construct statements that read like colloquial English, noise words are also defined in a vocabulary but are treated as if absent. The default noise words for each new vocabulary are *MY YOUR OUR THEIR*, *HIS HER ITS*, *A AN HE*, *THIS THAT THESE THOSE*, *SHOULD WOULD COULD*, *MIGHT MAY MUST*, and *THAN TO*.

In addition to the hedges and noise words, new fuzzy qualifiers such as *HIGH, LOW, STRONG, WEAK*, and so on can be defined with custom truth functions that allow policy statements which reflect both the way we speak and think and the contours of real situations. Resulting policy statements would include statements such as:

```
IF PROFITS*.5 IS LOW THEN COSTS
    SHOULD BE SOMEWHAT
    LOWER
IF PROFITS IS NOT LOW THEN PRICE
    SHOULD BE MUCH HIGHER
```

Once the statements that define a policy are formulated, they can be applied to a given model and can be evaluated by executing the *APPLY* command from within a given model or from the command level. In this way, sensitivity analysis, modeling, and forecasting can all be done by forming policies and command processing files that schedule processing operations.

For many problems, particularly in the business world, the REVEAL environment provides the net result of a relational data base and equation modeling with fuzzy sets and a natural language front end with far more efficiency than if these things were done literally. In a sense, it is such a direct approach to solving a certain range of problems that it might be unnecessary to use a more unwieldy environment when REVEAL can do the job. For a broad range of knowledge-based business problems requiring a combination of both numerical and symbolic processing, REVEAL is an attractive option to consider.

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Engineering Inc. is one of the few LISP-based systems currently available for PCs. KES was originally released on the DEC VAX running under UNIX, the CDC CYBER, and the Apollo workstation. It dates back to a system developed at the University of Maryland by James Reggia and Barry Perricone. The PC version is ported to IQLISP, a subset of the INTERLISP dialect. One of the advantages of having the LISP interpreter is that experienced programmers can add to the system the features they consider important.

KES is really three separate programs: KES.PS, KES.BAYES, and KES.HT. Each has a different type of inference engine and can develop entirely different expert systems. One of the most attractive features of this package is the ability of any of the three models to call on the others as often as needed. This makes KES the first hybrid system available for microcomputers. I have not tested this feature, however, and cannot guarantee that it is usable in the PC environment.

One of the more substantial advantages of the KES environment is the powerful array of commands available to the end user. *Justify* is the main command used to ask the system to explain its results. As with many of the other commands, options are specified by what is typed immediately after issuing the command. You can ask the system to justify either the main result, other particular results, or all of the values that have an attribute of the same name. For example, you might type:

```
justify problem = dirty carburetor
```

in an auto repair application to ask KES to provide the basis for its result. In this case, KES might respond:

```
reasons for this statement:
    age of car = 7
    type of noise = backfire (by rule:
        DIRT 1.0 )
```

Further information can then be requested by the general purpose *display* command. In this case, you could make use of the *display <rule>* option by typing *display DIRT*, which would show the rule that was used to arrive at the conclusion.

Another area where KES shines is in math. In addition to standard inequality and arithmetic operations, including exponentiation, KES also has absolute value, common and natural logarithms, and sine and cosine functions that can be calculation attachments to attributes.

KES.PS is the system's rule production module. This is a fairly standard backtracking inference engine. A typical knowledge base using this module would include a section in which the attributes are declared, a section for stating the rules, and an actions section where the goals that guide rule processing are stated. Text messages can be provided at any stage of a consultation.

The KES.BAYES module incorporates an inference procedure for statistical pattern classification that is based on the well-known Bayes' theorem. It is appropriate for problems where there is a large amount of data that can be expressed in the form of probabilities, such as when available experts, based on their experience, can provide knowledge about the likelihood of various states of affairs. The inference engine first asks for all the input attribute values. Then, using the probabilities in its knowledge base, it calculates the probability of possible outcomes by plugging values into the Bayesian probability equation. The output of a typical consultation will consist of the formatted printing of probability values for various outcomes.

This type of inference module clearly is applicable to problems where such probabilistic knowledge base data is attainable and it is appropriate for the outcome to be expressed in probabilistic terms. This type of inference mechanism is often associated with the PROSPECTOR system, where a similar approach was used for estimating the probability of valuable mineral deposits.

The KES.HT module, which uses frame representation and a hypothesis and test inference mechanism, is the most

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Dallas, Texas-based Artelligence Inc.'s OPS5+ is a production quality implementation of OPS5, the rule-based language used to write R1 (XCON), the first commercially successful artificial intelligence program. Written in C, OPS5+ is a high-level language designed to implement forward-chaining production systems.

This enhanced version of OPS5 runs on the IBM PC or XT and compatibles such as COMPAQ. It supports up to 1,500 production rules on a 640K IBM PC and requires 256K of memory. Window-based application development tools are utilized, and the multiple windows allow separate types of information to be kept in separate areas of the screen. The source code and interactions (program I/O) are handled in the large window, while informative messages, the system state, and the command menu appear in surrounding smaller windows.

OPS5+ utilizes mouse/menu interaction for greater development speed and ease of use. In order to use the full development environment, IBM color-card or Hercules graphics and a Mouse Systems or VisiCorp mouse are needed. All user routines written in C are supported, as is full IEEE 32-bit floating-point math, with 64-bit calculation accuracy. *BUILD* action and a *BACK* command (which allows the user to back up for up to 32 steps) also are supported.

OPS5+ combines the flexibility and features of interpreted versions of OPS5 with the speed of a compiler. An example of this system's extended capabilities can be seen in the *PAUSE* command. Invoking *PAUSE* allows the user to temporarily leave OPS5+ and edit another program or use a feature of the operating system and then return to OPS5+ with no loss of state.

The documentation for this product includes descriptions of OPS5 and the OPS5+ system and several case studies. In addition to consulting and maintenance services, Artelligence also offers user seminars and has the hardware to support graphics-based development systems. OPS5+ is available to the public for $3,000 and to educational institutions for $960.

OPS5+ was not yet available for review at press time; a midsummer release was planned. The product information provided in this sidebar was supplied by the manufacturer.

By Kathy Kincade

interesting and unique of the three KES modules. Since it is the only one of its kind I have seen so far on a microcomputer, it is worth elaborating in some detail. This knowledge system module is devoted exclusively to knowledge bases that diagnose such problems as equipment malfunctions and medical disorders.

The main ingredients of the KES.HT knowledge bases are: outcomes, called disorders; attributes, which are divided into manifestations (the undesirable symptoms which should not be occurring); and setting conditions, which also fix the situation but are not necessarily an indication that something is wrong. These attributes are represented in the knowledge bases by a frame template, as in this spill detection example from a sample system:

```
Name: type of spill
Is : attribute
Type: mlt
Marked: evoking
Synonyms:
    contaminants
inferred: yes
possible values:
    sulfuric acid
    carbonic acid
    chromogen R23
    hydroxyluminum
current value:
    sulfuric acid <m>
    carbonic acid <m>
    chromogen R23 <m>
    hydroxyluminum <m>
External: *none*
```

The hypothesis and test module perform their inferencing by following this procedure:

1. Get a symptom attribute from the user as suggested by the current FOCUS.
2. Retrieve the relevant causes from the knowledge base.
3. Reset the SCOPE to reflect the new input.
4. Reset the FOCUS to cover the new symptoms.
5. Repeat until no further symptom attributes are needed.
6. Assign a rating to each possible explanation.
7. A final score for each explanatory attribute is calculated on the basis of its setting score and match score. This is converted to a verbal statement of its probability of being the cause.

Because of the possibility of developing complex architectures that incorporate all three of the inference mechanisms in a single expert system, KES offers some powerful advantages over other currently available tools for PCs. The main drawback of this system is its huge size, stemming from the fact that it was ported to the PC from a minicomputer implementation. I would not suggest running it on anything less than an IBM PC or AT with at least

General information

	Statistics			User interface			Knowledge structure									Development aids			
Manufacturer and product	Memory required	Memory used	Number of rules	? generation	Explanation	Windows	Facts[4]	Variables	Multivariables	Math functions	Certainty factors	Text animation	Example driven	Extendable	Chaining	Rule editor	Compiler	Trace	External interface
Decision modeling software																			
Decision Support Software Inc. Expert Choice	256K	all	N/A	no	no	no	N/A	yes	yes	no	yes	yes	yes	yes	N/A	N/A	N/A	N/A	N/A
Lightyear Inc. Lightyear	192K	most	500	no	yes	yes	N/A	yes	yes	via Lotus	no	no	no	yes	N/A	yes	yes	no	no
Extension packages																			
Programming Logic Systems APES	128K	40K	1,200	yes	yes	yes	yes	yes	yes	yes	no	yes	no	yes	yes	yes	no	yes	yes
Mountain View Press Inc. Expert-2	64K	24K	120	yes	yes	no	no	yes	yes	yes	no	no	yes	yes	yes	yes	no	no	yes
Rule induction systems																			
Expert Systems Inc. Expert Ease	128K	all	255[1]	yes	no	no	yes	yes	no	no	no	no	yes	no	yes	no	no	no	no
KDS Corp. KDS	512K	some	16,000	yes	yes	yes	yes	no	no	N/A	yes	yes	yes	yes	yes	yes	yes	no	yes
Small production system tools																			
Level Five Research Inc. Insight 1	128K	all	2,000	yes	yes	no	no	yes	no	no	yes	yes	no	no	no	no	yes	yes	no
EXSYS Inc. EXSYS	256K	all	unlimited[2]	yes	yes	yes	no	yes	yes	yes	yes	no	no	no	yes	yes	no	yes	yes
Intermediate level systems																			
Expert Systems International ES/P Advisor	256K	some	unlimited[3]	yes	yes	yes	yes	yes	yes	yes	no	yes	no	yes	yes	no	yes	yes	yes
General Research Corp. TIMM-PC	640K	all	500	yes	yes	no	yes	yes	yes	no	yes	no	yes	yes	yes	yes	yes	yes	yes
Level Five Research Inc. Insight 2	448K	all	2,047	yes	yes	no	yes	yes	yes	yes	yes	yes	no	yes	yes	no	yes	yes	yes
Rule oriented mathematical modeling systems																			
Lotus/Software Arts TK!Solver	128K	66K	32,000	N/A	yes	yes	yes	yes	yes	yes	no	N/A	yes	yes	yes	yes	yes	yes	N/A
McDonnell-Douglas REVEAL	640K	all	—	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no	yes	yes	yes	N/A
Advanced systems																			
Software Architecture & Engineering Inc. KES	640K	512K	unlimited[1]	yes	yes	no	yes	no	no	yes	yes	yes	no	no	yes	no	yes	yes	yes
Teknowledge Inc. M.1	192K	all	200	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes

N/A = Not applicable.
1. Expandable to 18 matrices.
2. Total memory limited.
3. Virtual memory system.
4. Refers to ability to make fact statements in knowledge base.

Table 1.

640K RAM. Anything less than this and the system would run sluggishly and have to garbage collect rather frequently. When the long-awaited IQLISP compiler and a significantly updated version of this system are released, KES could become one of the most powerful expert system development tools available for a moderate price.

Teknowledge M.1

M.1 is a PROLOG-based knowledge engineering tool from Teknowledge Inc. that offers several advanced features. Like ES/P Advisor, it was written with PROLOG-1, an implementation of Edinburgh PROLOG produced by Expert Systems International.

The knowledge representation language is very full, allowing even the user interactive commands to be called from within a knowledge base. There are various provisions for controlling how the inference engine operates on a knowledge base that add power and efficiency to knowledge systems built with M.1. The environment for user consultations with finished applications is very polished and includes a multiple window panel display, but it requires specific programming to provide the end user with the most helpful features.

Because of its PROLOG heritage, M.1 essentially uses a backward chaining inference engine. You give it a goal and it searches the rule base for rules with that goal as a consequence or *then* part. It then tries to prove the rule's premise true or to make the premise true. To remove a lot of redundant searching, there is a cache for storing conclusions. Normally, M.1 enters results in this cache as it finds them.

However, some facilities allow both the user and the application developer to interact directly with the cache. At any time, a user can call upon M.1 either to save to the disk whatever is currently in the cache or to load a cache file from the disk. The knowledge engineer can also do this from within the knowledge base and can specify certain items to be automatically inserted in the cache. The advantage of this is that the conclusions are there when needed, so M.1 doesn't waste time searching for them in the knowledge base. It is also possible to design knowledge systems so that alternative fact models can be loaded from the disk to try "what if" scenarios by applying the same rule set to different sets of factual values or assumptions. It also makes it possible for very large applications to be broken down into a set of smaller, more manageable modules.

If M.1 doesn't find a value in the cache or in a fact in the knowledge base for an expression it needs to reach its goal, and if there is no provision for calculating this value from rules it already knows, then it will automatically ask the user for the value it needs or use the text provided by the knowledge engineer to pose the question.

M.1's knowledge base language has three types of entries: facts, metafacts, and rules. A metafact is an entry that tells the M.1 inference engine to behave in a certain way. For example, the "question" metafact instructs M.1 to ask the user a question using a specific text to obtain a specific value.

One very useful and powerful feature of this knowledge-based language is its ability to use variables anywhere and in any of the three entries. Thus it is possible to create very efficient knowledge bases. Generic rules can be written in terms of variables and the facts can be supplied like lookup tables for the rules. Not only does this keep the rule base small, but a variety of fact bases often can be used as alternate models with the same rule base. This provides a degree of modularity not often found in knowledge engineering systems.

Another very useful feature of M.1 is its ability to allow you to vary its syntax by defining new operators. Thus it is possible for rule statement expressions to look as much like English phrases as the developer wants. For example, if you have an expression in the knowledge base like "end-of-consultation," it can easily be changed to a more readable form, such as "the end of the consultation," by defining the right prefix, infix, and postfix operators. Normally, you would develop your application in the less friendly form and then, after completing it, define all the operators needed to make it read more like ordinary English.

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M.1 now has an interface arrangement that allows functions to be called from an external library through the use of an external metaproposition. Assembly language, or any compiled programming language that conforms to the standards of the supported interface, can be used to prepare external functions. The interface requires an additional simple assembly language routine called *USER*, which forms the bridge to M.1. An object code module, M1AUX.OBJ, is linked with the *USER* module and the external functions to form the M1AUX.EXE file. This file is loaded when M.1 boots, giving it access to the external functions.

This gateway also allows up to eight arguments, either numbers or atoms (strings), to be passed both to and from M.1. Each external function is accessed by an integer that is the function identifier assigned to it. There can be up to 200 functions, each with a unique function identifier. These functions can access external data collection hardware as well as external data bases and even other machinery and computing devices.

The major limitations of M.1 are its speed (which is not overpowering), its 200-rule limit, and its use of only a backward chaining inference engine. But other than speed, none of these are absolute limitations. It is not a problem to design knowledge systems with M.1 that would consist of a network of component files, all 200 rules or less, that directly call and load one another as the need arises.

Such a system has many possible architectures. They range from one where the first knowledge base file is really a discrimination net that determines which of a large number of other expert systems to load to more complex networks of interrelated knowledge files. Also, powerful techniques using recursive procedures, cycles, list processing, and metarules and metapropositions can permit the design of knowledge systems that get some of the same results as forward chaining and other types of inference engines.

All in all, M.1's power is very impressive for its size, even though its price limits it to a rather select clientele. ■

Texas Instruments Personal Consultant

One expert systems tool we still have not received as this article goes to press is Personal Consultant from TI. It is available for the IBM PC and compatibles as well as the TI Professional. Briefly, it is a LISP-based, backward-chaining expert systems shell of the familiar Mycin type. It offers function key commands and an English-like syntax for rule explanations and allows the inclusion of custom routines written in IQ LISP.

Personal Consultant is available for MS-DOS releases 1.1 through 2.1, requires 512K RAM and, according to the TI brochure, can accommodate up to 400 rules. The price is $3,000. Personal Consultant comes packaged with the latest release of IQ LISP.

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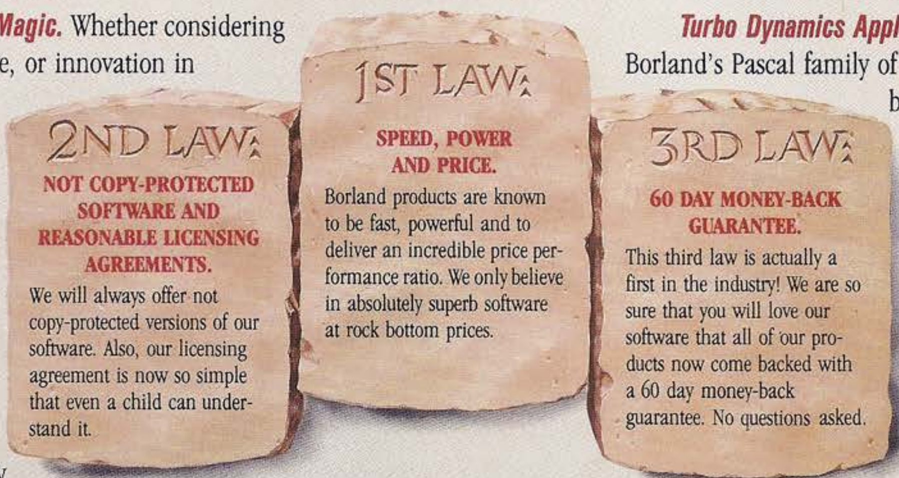

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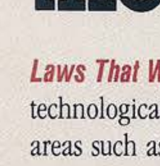

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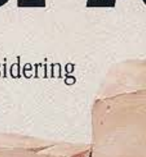

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