VAST/f90
Fortran 90 Compiler

User’s Guide
Version 3.1

Pacific-Sierra Research
Document revision record

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Preface

This is a guide to the use of VAST/f90. VAST/f90 is a compiling system for Fortran 90. This manual is designed to give Fortran programmers an understanding of VAST/f90’s capabilities and effective use.

Fortran 90 is the new Fortran language standard (ISO and ANSI). This User’s Guide does not contain language reference information; for more information about Fortran 90, please refer to one of the many books that have been published on this subject.

An excellent source of information on Fortran 90 is the Fortran 90 Handbook (McGraw-Hill, 1992) by Adams, Brainerd, Martin, Smith, and Wagener. This book gives more background and examples than the standard, and still documents the complete language.

Special notices

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1. Introduction

Compiling Fortran 90

VAST/f90 compiles Fortran 90 by translating it into Fortran 77, which is then compiled by a local Fortran 77 compiler. Using VAST/f90 is simple; you can just use the supplied f90 driver to compile your programs. For example, if your program is myprog.f90, just use this command to compile it:

```bash
f90 myprog.f90
```

You can use whatever options you normally use for your Fortran 77 compiler and linker on the f90 command line; they are passed to the appropriate step in the compilation process automatically.

If you just wanted to run it through VAST/f90 and see the intermediate Fortran 77 code, use:

```bash
vf90 myprog.f90
```

or

```bash
f90 -c -keep myprog.f90
```

and look at `vmyprog.f`. This may be useful in debugging new code or in learning more about Fortran 90.

By default, VAST/f90 assumes that if the file suffix is `.f90`, the source is in free format, which is the new source form available with Fortran 90. If you have Fortran 90 programs that are in the old fixed format source form (comments starting with `C` instead of `!`, continuations via column 6 rather than with the `&`, etc.), use the `-ya` switch when you run `f90` or `vf90`, or use a `.f` file suffix. Example:

```bash
f90 -Wv,-ya myprog.f90
```

VAST/f90’s efficient translation into Fortran 77 insures that your Fortran 90 code will run quickly.

For more information about Fortran 90 to Fortran 77 translation, see Section 3. When translating from Fortran 90 to Fortran 77, VAST/f90 converts Fortran 90 array syntax into Fortran 77 DO loops; this process is discussed in Section 4.
Further Information

Section 2 describes in more detail how to invoke VAST/f90 with the f90 and vf90 commands, and you probably will want to look at this section, if nothing else.

If you are interested in the specifics of Fortran 90 compilation, read sections 2 (invocation), 3 (f90 to f77), 4 (array syntax to loops) and 5 (Fortran 90 examples).
2. Invoking VAST/f90

f90 command line

To use the supplied f90 driver for compiling Fortran 90 programs, just invoke it in the same manner as your existing Fortran 77 compiler. Put the options you normally use for your Fortran 77 compiler on the f90 command line (optimization level, etc.). If you need to pass options to VAST/f90 itself, you must prefix them with -Wv to distinguish them from normal compiler options. The f90 driver automatically links in the VAST/f90 library (libvast90.a), which contains various functions for handling Fortran 90. The f90 driver searches through the user’s path in order to locate libvast90.a.

f90 [f77_compiler_options] [-Wv, VAST/f90_options]
input1 [...inputn]

Example 1:

To compile file crunch.f90, requesting optimization of the translated Fortran 77 code (-O), and compilation only (-c):

f90 -O -c crunch.f90

The object file created will be in file crunch.o.

Example 2:

To run *.m (all modules) and sub.f90 through VAST/f90, with the input in fixed format mode (-ya), and compile the source output:

f90 -Wv, -ya *.m sub.f90

The executable output will be in a.out, as usual.

vf90 command line

VAST/f90 is executed by the command:

vf90 [-o output] [-l listing] [options]
input1 [...inputn]

output = compilable output file. The default output file name is the input file name prefixed by V. The extension of the default output file will be .f.

options = VAST/f90 options and parameters. See Section 3.
input1... =  Fortran source input files.

vf90 invoked with no arguments prints a short usage summary, including the VAST/f90 version number.

vf90 examples

Below are some examples of using the vf90 command to translate Fortran 90 to Fortran 77.

Example 1:

To run the Fortran 90 source file crunch.f90 through VAST/f90 and get a Fortran 77 source to compile:

\[ \text{vf90 crunch.f90} \]  
\[ \text{f77 Vcrunch.f libvast90.a} \]

The Fortran 77 output is sent by default to Vcrunch.f. No listing file is created. When linking the final output, you may need to link in the libvast90.a library.

Alternatively, you can just use the provided f90 driver (see prior section) in this manner (it automatically links in libvast90.a by looking in your search path):

\[ \text{f90 crunch.f90} \]

Example 2: (with modules)

To run global.m and progx.f90 through VAST/f90, use:

\[ \text{vf90 global.m progx.f90} \]

Module file names should be listed before the program units that reference them, because they must be processed first. Source output will be in file Vprogx.f.

Example 3: (fixed format)

To run fixform.f90 through VAST/f90, where the input file uses fixed format rather than the default free format:

\[ \text{vf90 -ya fixform.f90} \]
**File extensions**

The table below summarizes the file types that VAST/f90 may use or create.

<table>
<thead>
<tr>
<th>Extension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>.f</td>
<td>Fixed form Fortran source.</td>
</tr>
<tr>
<td>.inc</td>
<td>Fortran INCLUDE (Fortran 90 and extended Fortran 77) (usually used to hold common blocks).</td>
</tr>
<tr>
<td>.f90</td>
<td>Fortran 90 source (free form).</td>
</tr>
<tr>
<td>.m</td>
<td>Fortran 90 module: used in place of COMMON to hold global data, may also have internal routines that operate on the data.</td>
</tr>
<tr>
<td>.inf</td>
<td>File holding Fortran 90 interface block(s): number, intent, type and attributes of the arguments to a routine -- used to check connections between program units.</td>
</tr>
<tr>
<td>.vo</td>
<td>Fortran 90 module, compiled to VAST/f90 binary form; overwritten each time the module is compiled.</td>
</tr>
</tbody>
</table>

*module_name.inc* Modules are converted to common blocks. Each module results in an INCLUDE file being generated. This file is then used in the Fortran 77 translation. These files can be deleted after all routines which used the specific module have been compiled into object files.
3. F90 to F77

This section discusses aspects of compiling Fortran 90 using VAST/F90. This process is automatic, and does not require intervention on your part.

Translation of Fortran 90 array syntax to Fortran 77 loops is described separately in the section following this one.

The target of VAST/F90 is not limited to the Fortran 77 standard; instead, VAST/F90 targets extended Fortran 77 in most implementations. For instance, for clarity VAST/F90 on most platforms will generate loops that have no labels (DO/ENDDO), which is not standard Fortran 77 but is a feature of almost all modern Fortran 77 compilers. VAST/F90 will also generate Fortran 77 with INCLUDE statements, which are also available on most systems.

Optionally, VAST/F90 also can make use of the POINTER Fortran 77 extension (which is different from Fortran 90 Pointers, see discussion below).

VAST/F90 inspects the input source and flags Fortran 90 syntax errors.

**Options**

The table below shows the switches that affect the transformation of the input program. `–x` enables these switches (on), `–y` disables these switches (off).

<table>
<thead>
<tr>
<th>Switch</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Free format input source code</td>
<td>on</td>
</tr>
<tr>
<td>b</td>
<td>Free format output source code</td>
<td>off</td>
</tr>
<tr>
<td>c</td>
<td>CM Fortran input.</td>
<td>off</td>
</tr>
<tr>
<td>q</td>
<td>Translate derived types to VAX-compatible structures</td>
<td>off</td>
</tr>
<tr>
<td>3</td>
<td>Use the F77 Pointer extension in translated output</td>
<td>on</td>
</tr>
<tr>
<td>4</td>
<td>Assume potential overlap between pointers</td>
<td>on</td>
</tr>
<tr>
<td>5</td>
<td>Generate cpp file/line number directives in output.</td>
<td>*</td>
</tr>
</tbody>
</table>

As an example, `–xb` requests that the Fortran 77 output source file be free format.

Notes on transformation switches:

a. Input file is free format. Usually, Fortran 90 input files will be free format, and this is the default. If you have a fixed format Fortran 90 file that you want converted to Fortran 77, use the `–ya` switch to request fixed format input.
b. Output file is free format. The default is fixed format output for Fortran 77 files. If you want free format Fortran 77 output, specify -xb.

c. Input source is Connection Machine (CM) Fortran. VAST/f90 then assumes that the input source is 132 column fixed form, and the order of arguments on array intrinsics fit CM Fortran definitions. Note: the CM Fortran intrinsics FIRSTLOC, LASTLOC, DIAGONAL, PROJECT, and RANK are not supported in the current version.

3. By default, on most systems VAST/f90 uses the POINTER extension of Fortran 77 (provided by many vendors) in the F77 intermediate code. This switch can be turned off (-y 3) for systems that don’t have this extension. Also, for systems that do have the extension, performance of code involving POINTERS and ALLOCATABLEs often improves if this feature is turned off.

4. It is possible to mask a potential recursion between a pointer and another object by pointing at identical or overlapping areas in memory. This kind of recursion is rare in practice but it is unsafe for the compiler to assume it never happens. If it is known that it doesn’t happen in the input source, use -y 4 on the command line. This will decrease execution time and memory requirements for codes making use of pointers, particularly arrays.

5. Many unix Fortran 77 compilers accept c preprocessor directives indicating source file and line number. VAST/f90 can generate these in the output as a way of relating generated source lines to original source lines. This allows runtime error messages and debuggers to refer to original source line numbers. Default is system-dependent.

The parameter -zrecur=nnn can be used to specify a recursion stack size different than the default of 100.

**System-dependent optimization**

On some workstation platforms, VAST/f90 applies superscalar optimization to the generated Fortran 77 code, for improved runtime performance. This feature is invoked by the -0 switch.

Typical optimizations include:

- Loop unrolling
- Loop fusion
- Loop collapse
- Cache blocking
- IF removal
- Expression optimizations
Debugging

VAST/90 can optionally generate cpp file/line number directives for those Fortran 77 compilers that accept them. (Option –x5.) This allows runtime error messages and interactive debuggers to refer to original source line numbers. However, as with any optimizing compiler, there may no longer be a one-to-one correspondence between input and output source statements, and variables may have been eliminated or transformed.

Overview of Fortran 90

Coding in Fortran 90 can produce much better structured and more readable code than was possible in Fortran 77. Features of Fortran 90 include:

- **Array syntax.** You can use triplet notation that allows the start, end and increment of an array section to be specified. In addition, there are many new array intrinsics available. *Where* statements allow conditional operations on arrays. Array syntax may be more readable than the equivalent loops.

- **Attribute form of declarations.** You can declare a list of variables to have the same attributes. Data types can be declared with the *kind* parameter.

- **New control statements.** There are *exit*, *cycle*, *case*, and *do while*. These allow you to avoid the use of confusing *goto* statements.

- **Derived types.** These allow structured data.

- **Modules.** These allow the grouping of global data (as well as procedures that operate on that data). Using modules, you can avoid the pitfalls of the old *COMMON* and *EQUIVALENCE* statements.

- **ALLOCATE/DEALLOCATE.** You can create and destroy data objects dynamically.

- **Interface blocks.** You can have optional arguments and keyword arguments to your procedures. Interface blocks also enable the compiler to check type and number mismatches on parameter lists and to improve the optimization of external calls. This helps to tie the program together more than was possible with older Fortrans.

- **Internal subroutines.** One level of local subroutines is allowed.

- **Pointers.** Variables can "point at" objects that are declared to be *targets.*

- **Recursive routines.** A routine may reference itself.

- **New intrinsics.** Several new intrinsics are available for string manipulation and other functions.

- **New source form.** Free format programs get away from the column-orientation of older Fortran.

- **New operators.** Symbolic relational operators are available.

- **I/O options.** You can now do non-advancing I/O, and you can specify the position of a file when you open it. These I/O features are the only part of Fortran 90 not currently available in VAST/90.

- **Compatibility with Fortran 77.** Fortran 77 programs are valid Fortran 90 programs, so Fortran 90 maintains compatibility with older code.

Examples of various Fortran 90 constructs can be found in Section 5.
Efficiency

When coding in Fortran 90, these are some areas to be aware of, if performance of executable code is a concern:

- **Pointers.** Overuse of pointers and targets may hide true dependencies from the compiler, and result in slower code.
- **Array syntax fusion.** The compiler generates more efficient code from array syntax when there are successive conformable statements. Within a group of array syntax statements, avoid intervening scalar statements or other non-array syntax. Avoid confusing subscripting or other constructs that may inhibit the compiler’s conformability analysis.
- **Passing array sections.** Passing non-contiguous array sections as procedure arguments can result in excessive data motion.
- **Allocate/Deallocate.** These operations may incur system overhead; avoid repeatedly allocating items that are used for only a short time.
- **Transformational intrinsic functions.** Certain of these, for example SPREAD and RESHAPE, may be relatively inefficient compared to DO loop equivalents.
- **Internal procedures.** Although these are intended as generalizations of the Fortran 77 statement function feature, current compilers do not always optimize references to them to the same degree as statement function references.
- **Array-valued functions.** Depending on context and implementation, array-valued function references may incur extra data motion overhead.
- **Recursion.** Generally inefficient in execution compared to non-recursive algorithms.
- **INTENT.** Use of interface blocks and the INTENT attribute for dummy arguments can help the compiler reduce unneeded operations when invoking externals.
4. Array Syntax

VAST/90 transforms Fortran 90 array syntax into Fortran 77 DO loops; this translation of array syntax to loops is also called scalarization. Array syntax is one of the more important features of Fortran 90, and this section looks at it in more detail.

Features

Features of the array syntax include:
- unsubscribed arrays
- vector-valued subscripts
- triplet (colon) notation
- multi-dimensional shapes
- WHERE/ELSEWHERE/ENDWHERE blocks
- array constructors
- array-valued intrinsic functions
- transformational intrinsic functions
- array inquiry intrinsic functions

Array syntax expressions can appear anywhere that expressions are allowed in Fortran 77. (In some statements these would need to involve reduction operations to wind up with a scalar value).

VAST/90 analyzes conformability of all input array expressions to insure that they meet the rules of the language.

Array expressions

Fortran 90 allows the use of array sections via the triplet notation, which allows a start, end and stride to be specified. Here are some sample expressions:

\[
\begin{align*}
a & \quad \text{entire array} \\
a(n1:n2:n3) & \quad \text{start: end: stride} \\
aa(:,:, :) & \quad \text{entire array} \\
aaa(1:9:2, 97:9:-1, 5) & \quad \text{2-dimensional section} \\
a * b & \quad \text{element by element product} \\
a(1:10) + a(9:0:-1) & \quad \text{element by element sum} \\
sin(b) & \quad \text{element by element sine} \\
\text{sum}(a) & \quad \text{sum of array elements}
\end{align*}
\]

Conformability

Two array sections are conformable if they have the same shape or if one of them is a scalar. Arrays must be conformable if they are combined in an expression.
The shape of an array section is described by the rank and extents, where rank is the number of dimensions and extent is the number of elements in a given dimension.

```fortran
real:: a(100), aa(100,100), aaa(100,100,100)
...
a = 2.*aa(1,1:100) conformable
a = sca conformable
a = aa(1:1,1:100) non-conformable
aa = sin(aa + sca) conformable
aa = aa + aaa non-conformable
```

Masked operations

WHERE statements are used to indicate conditional array operations. The operations are done for each element corresponding to a true element in the WHERE clause.

```fortran
real, dimension(100):: a, b, c
!
where ( a .ge. 0 ) b = sqrt(a)
!
where ( a .eq. b )
   c = 0.
elsewhere
   c = 1.
endwhere
```

Intrinsic functions

There are several categories of functions that can operate on arrays in Fortran 90. Elemental functions are scalar functions which may be applied to arrays; these functions are shape preserving — their result is the same shape as their input(s). Examples of these are sin, cos, and sqrt.

Transformational functions have the ability to change the shape of the result array. Examples of these are sum, product, and reshape.

Inquiry functions depends on a property of the array rather than the value; they return such attributes as shape or size of an array.

Here are some of the array intrinsic functions:

- **SUM** (ARRAY[, DIM][, MASK]) Sum of array elements (also PRODUCT)
- **MAXVAL** (ARRAY[, DIM][, MASK]) Maximum of array elements (also MINVAL)
- **ALL** (MASK [, DIM]) Mutual 'AND' of array elements (also ANY)
- **COUNT** (MASK [, DIM]) Number of true array elements.
DOT_PRODUCT (VECTOR_A, VECTOR_B)  Inner product of the vectors.

MATMUL (MATRIX_A, MATRIX_B)  Matrix multiply, or vector matrix. multiply

TRANSPOSE (MATRIX)  Transpose the elements of the matrix.

PACK (ARRAY, MASK[,VECTOR])  Where MASK is true, put elements of ARRAY into a 1-dimensional array.

UNPACK (VECTOR, MASK, FIELD)  Where MASK is true, put elements of VECTOR into a multi-dimensional array

MERGE (TSOURCE, FSOURCE, MASK)  Result is TSOURCE where MASK is true, FSOURCE where it is false.

SPREAD (SOURCE, DIM, NCOPIES)  Replicate SOURCE along dimension DIM.

RESHAPE  Rearrange elements of SOURCE into a new array.

MAXLOC (ARRAY[,MASK])  Find indices of max element of ARRAY (also MINLOC)

SHAPE (SOURCE)  Extent of SOURCE in each dimension.

SIZE (ARRAY[,DIM])  Number of elements of ARRAY.

CSHIFT (ARRAY, SHIFT[,DIM])  Circular shift of elements of ARRAY.

EOSHIFT (ARRAY, SHIFT[,BOUNDARY][,DIM])  End-off shift of elements of ARRAY.

**Indirect addressing**

Arrays can have vector-valued subscripts, as shown below; here aa has array section ia(:) as one of its subscripts.

```fortran
real, dimension(100,100):: aa, bb
integer, dimension(100):: ia
!
bb = aa(ia(:,:))
```

**Array constructors**

Array constructors can be used to initialize arrays.

```fortran
dimension a(9)
!
! array constructor example
```
a = (/1, 2, 3, 4, 5, 6, x, y, z/)

Translation:
  a(1) = 1
  a(2) = 2
  a(3) = 3
  a(4) = 4
  a(5) = 5
  a(6) = 6
  a(7) = x
  a(8) = y
  a(9) = z

---

**Fusion**

VAST/f90 is able to generate code for whole blocks of array assignments together (fusion). This results in much more efficient code than a line-by-line compilation, as temporaries and subexpressions can be used across statements.

Fusing statements together in this way involves examining the dependencies the array assignments represent and the conformability of successive array expressions, and determining that such fusion will not cause different answers to result.

In the example below, the loops cannot be safely fused. If the second statement referenced a(9:19) instead, then VAST/f90 would fuse both statements into the same loop.

a(10:20) = b(10:20)
c(10:20) = a(11:21)

Translation:
  do j1 = 1, 11
      a(j1+9) = b(j1+9)
  enddo
  do j1 = 1, 11
      c(j1+9) = a(j1+10)
  enddo

Some statements are split into two loops when being converted, as in this example:

\[
c(10:20) = c(9:19) + c(11:21)
\]

Translation:
  real r1(11)
  do j1 = 1, 11
      r1(j1) = c(j1+8) + c(j1+10)
  enddo
  do j1 = 1, 11
      c(j1+9) = r1(j1)
  enddo
Multi-dimensional array syntax is fused where possible into nested loops. When dependencies force fusion to be abandoned along a dimension, other dimensions may still be fused.

The example below demonstrates fusion of array syntax statements into nested loops. The third statement is not conformable and is not fused with the first two.

```fortran
real, dimension(100,100,100):: ccc, ddd, eee
!
! the next two statements are conformable
ccc(3:m+2,3:k+2,3:l+2) =
  1  2.*ddd(4:m+3,4:k+3,4:l+3) + x
eee(m:1:-1,k:1:-1,l:1:-1) =
  1  sqrt(eee(m:1:-1,k:1:-1,l:1:-1))
!
! the next one is non-conformable with the previous
aaa(1:10:2,:,10:1:-1) =
  1  cos ( bbb(14:5:-2,100:1:-1,1:10) )
!
end
```

Translation:
```
  do j3 = 1, l
    do j2 = 1, k
      do j1 = 1, m
        ccc(j1+2,j2+2,j3+2) =
           1  2.*ddd(j1+3,j2+3,j3+3) + x
        eee(m+1-j1,k+1-j2,l+1-j3) =
           1  sqrt(eee(m+1-j1,k+1-j2,l+1-j3))
      enddo
    enddo
  enddo
```

```
  do j3 = 1, 10
    do j2 = 1, 100
      do j1 = 1, 5
        aaa(j1*2-1,j2,11-j3) =
           1  cos(bbb(16-j1*2,101-j2,j3))
      enddo
    enddo
  enddo
```

---

**Examples**

Shown below is an example of the translation of array syntax statements involving the use of transformational functions.

```fortran
real, dimension(100,100,100):: aaa, ccc
real, dimension(100,100):: bb
!
! sum with 'mask' and 'dim' parameters
!
bb = sum ( aaa, dim=3, mask=(ccc.le.0) )
```
Translation:
\[
\begin{align*}
&\text{do } j3 = 1, 100 \\
&\quad \text{do } j2 = 1, 100 \\
&\quad \quad \text{bb}(j2,j3) = 0 \\
&\quad \quad \text{do } j1 = 1, 100 \\
&\quad \quad \quad \text{if } (\text{ccc}(j2,j3,j1) \leq 0) \\
&\quad \quad \quad \quad \text{bb}(j2,j3) = \text{bb}(j2,j3) + \text{aaa}(j2,j3,j1) \\
&\quad \quad \quad \text{enddo} \\
&\quad \quad \text{enddo} \\
&\quad \text{enddo}
\end{align*}
\]

Here is an example of WHERE statement translation. In the first statement, the transformational intrinsic function SUM must be calculated in a loop outside of the WHERE clause.

All of the statements excluding the first one are fused into one large loop.

\[
\begin{align*}
&\text{real, dimension(100)}:: a, b, c, d, e \\
&! \text{one line WHERE with transformational} \\
&! \text{where } (\text{sum}(a) > a) \text{ d } = e \\
&! \text{WHERE block structure} \\
&\quad a(1:n) = \sin(b(2:n+1)) \\
&\quad \text{where } (a(1:n) > 0) \\
&\quad c(1:n) = 2.0a(1:n) \\
&\quad \text{elsewhere} \\
&\quad \quad c(1:n) = 2.0e(n:1:-1) \\
&\quad \quad d(1:n) = b(1:n)*d(1:n) \\
&\quad \text{endwhere}
\end{align*}
\]

Translation:
\[
\begin{align*}
&\text{r1 } = 0 \\
&\text{do } j1 = 1, 100 \\
&\quad \text{r1 } = \text{r1 } + a(j1) \\
&\text{enddo} \\
&\text{do } j1 = 1, 100 \\
&\quad \text{if } (\text{r1 } > a(j1)) \text{ d(j1) } = e(j1) \\
&\text{enddo}
\end{align*}
\]

The example below shows transformational intrinsics used in scalar statements. The array calculation is done in a loop and the value used in the scalar statement.
! Need to 'migrate' dotproduct and sum
!
if ( dotproduct(a(1:l),b(1:l)) .gt. 0 ) then
  a = x
elseif ( sum(a).eq.x ) then
  b = x
endif

Translation:
  r2 = 0
  do j1 = 1, 1
    r2 = r2 + a(j1)*b(j1)
  enddo
  r3 = 0
  do j1 = 1, 100
    r3 = r3 + a(j1)
  enddo
  c
  if (r2 .gt. 0) then
    do j1 = 1, 100
      a(j1) = x
    enddo
  elseif (r3 .eq. x) then
    do j1 = 1, 100
      b(j1) = x
    enddo
  endif

Finally, the example below shows the use of several keyword arguments on a transformational function.

real, dimension(100,10,100):: out
real, dimension(100,100):: a
!
! spread
!
  out = spread ( a, dim=2, ncopies=10 )

Translation:
  do j3 = 1, 100
    do j2 = 1, 10
      do j1 = 1, 100
        out(j1,j2,j3) = a(j1,j3)
      enddo
    enddo
  enddo
5. Fortran 90 Examples

Cycle and Exit

EXIT requests termination of the current loop, CYCLE requests the next iteration.

```fortran
loopi: do i = 1, n
    loopj: do j = 1, m
        if ( d(i,j).eq.0 ) exit loopi
        if ( d(i,j).eq.1 ) cycle loopj
        a(i) = b(i) + d(i,j)
    end do loopj
end do loopi
```

CASEs

Cases allow a more structured test than block IF constructs.

```fortran
IF ( ARG1 /= 0 ) THEN
    SELECT CASE (ARG1)
    CASE(1)
        ARG2 = ARG3
    CASE(2)
        ARG2 = ARG1
        ARG3 = ARG1
        SELECT CASE(ARG3+ARG2)
        CASE(3)
            WRITE(6,*)' WRONG '
        CASE(4)
            WRITE(6,*)' RIGHT '
        END SELECT
    CASE(3)
        ARG3 = 3
    CASE DEFAULT
        ARG2 = 0
    END SELECT
ENDIF
```

Derived Types

 Derived types allow structuring of data. Nested derived types are allowed; derived type definitions can include references to other derived types.

If you want derived types translated into VAX-compatible structure declarations, instead of lower-level arrays, use the -xq switch.
type stats
    integer, dimension(5) :: rbi, hrs
end type stats

! type team
    character*10 player
    integer number
    type (stats) statistics
end type team

! type (team) roster(9)
!
iloop: do i = 1, 9
    write(6,50) roster(i) % player
    if ( roster(i) % player == ' ' ) cycle iloop
    do j = 1, 5
        write(6,60) roster(i) % statistics % rbi(j)
        write(6,70) roster(i) % statistics % hrs(j)
    end do
end do iloop
!
50 format(2x, ' player: ',a10)
60 format(2x, ' rbis: ',i3)
70 format(2x, '  hrs: ',i2)
end

ALLOCATE/DEALLOCATE

ALLOCATE/DEALLOCATE allow dynamic allocation of data items.

subroutine alloc_demo
!
    real, dimension(80,90) :: a
    complex, dimension(80,90) :: b
!
    real, dimension(:,,:), allocatable :: c
    complex, dimension(:,,:), allocatable :: d
!
    allocate (c(20,90), d(20,90))
!
    c = cos (a(:,20,:))
    d = b(:,20,:)**2
    a(:,20,:) = c*c - abs(d*d)
!
    deallocate (c, d)
!
end

Automatic Arrays

Fortran 90 automatic arrays allow dummy argument, module, or common variables in the dimensions of local arrays in subroutines and functions. These arrays are allocated by the compiler on entry to the subprogram and deallocated on exit.
SUBROUTINE AUTO1 ( B, N )
REAL A(N), B(N)       (A is an automatic array.)
READ (9,*) A
B = SQRT(A) + B
WRITE (10,*) B
RETURN
END SUBROUTINE AUTO1

Intrinsic functions

VAST/f90 recognizes all Fortran 90 intrinsic functions and the keywords allowed for each of them. A library (libvast90.a) is supplied for new intrinsic functions, and should be linked into the final program (it is automatically linked in by the f90 driver).

MODULEs

Modules allow collections of global data without the storage association of COMMON blocks; modules can also contain code related to the data.

MODULE NAME
   REAL A(10), B, C(20,20)
   INTEGER :: I = 0
   INTEGER, PARAMETER :: J = 10
   CHARACTER*(J) STRING
!
   CONTAINS

   SUBROUTINE ONE
      A = 1
   END SUBROUTINE ONE

END MODULE NAME

Variables can be renamed on the USE statement to have a different name within the referencing procedure.

USE NAME, ONLY: B
INTEGER A(400)
CALL ONE

Modules can reference other modules.

MODULE JQ
   REAL JX, JY, JZ
END MODULE
MODULE KQ
   USE JQ, ONLY : KX => JX, KY => JY
   ! KX and KY are local names to module KQ
   REAL KZ       ! KZ is local name to module KQ
   REAL JZ       ! JZ is local name to module KQ
END MODULE
POINTERs

Here is an example of Fortran 90 pointers:

```fortran
real, pointer:: x, z
real, target:: t
!
x => t    ! pointer assignment
x = x + 1.0
z => x
z = x + 2.0
print *, z
```

Pointers can also be used with ALLOCATE/DEALLOCATE to allocate instances of derived types, for instance.

Fortran 90 has the NULLIFY statement, which allows the pointer to be nullified. The pointer can also be tested by the ASSOCIATED intrinsic function to see if it is currently attached.

Attribute declarations

Fortran 90 allows a new form of declarations in which multiple attributes can be specified for a given item or items in a single declaration. In addition, the KIND attribute can be specified, which controls the data length of the intrinsic type (real can be single or double or extended precision, for instance).

The KIND parameter is interpreted by VAST/f90 to be the number of bytes typically used to represent such a quantity.

```fortran
INTEGER, INTENT(IN) :: ARG1
INTEGER, INTENT(OUT) :: ARG2
INTEGER, INTENT(INOUT) :: ARG3
LOGICAL, DIMENSION(5,5) :: MASK1,MASK2
CHARACTER (LEN=10) CHARACTER_STRING
REAL, DIMENSION(-5:+5) :: X,Y,Z
REAL (KIND(0.0D0)) A_DECLARATION
REAL, PRIVATE :: XPRIV, YPRIV, ZPRIV
```

Initial values can be specified in the declarations in a new way as well, as seen below.

```fortran
COMPLEX :: CUBE_ROOT = (-0.5,0.866)
INTEGER, PARAMETER :: SHORT = 2
INTEGER (SHORT) K
REAL, PARAMETER :: ONE = 1.0, YY = 4.1/3.0
INTEGER, DIMENSION(3), PARAMETER :: ORDER=([1,2,3])
```

In addition, constants can be postfixed with a kind identifier (using an _, as in 1.0e6_8.
User-defined operators

With Fortran 90, the programmer can define new operators which can be used in place of function calls to perform operations.

In the example below, the user-defined operator .USER. stands for several function calls.

```fortran
INTERFACE OPERATOR( .USER. )
INTEGER FUNCTION INT_USER(I,K)
INTEGER, INTENT(IN) :: I,K
END FUNCTION INT_USER

REAL FUNCTION REAL_USER(R,S)
REAL, INTENT(IN) :: R,S
END FUNCTION REAL_USER
END INTERFACE

INTEGER I,K,L
REAL Q, R, S
LOGICAL L1, L2, L3
L = K .USER. I
Q = R .USER. S
```

Overloaded operators

With Fortran 90, you can "overload" existing operators such as +, -, *, etc. by defining different operations for them for different data types. You can even add meaning to the assignment operator(=).

You cannot overload an operator which is already defined intrinsically, as in integer + integer or logical.and.logical or real = integer.

In the example below, the .AND. operator is redefined for integer arguments.

```fortran
INTERFACE OPERATOR( .AND. )
INTEGER FUNCTION INT_AND(I,K)
INTEGER, INTENT(IN) :: I,K
END FUNCTION INT_AND

REAL FUNCTION REAL_AND(R,S)
REAL, INTENT(IN) :: R,S
END FUNCTION REAL_AND
END INTERFACE

INTEGER I,K,L
REAL Q, R, S
LOGICAL L1, L2, L3
L = K .AND. I
Q = R .AND. S
L1 = L2 .AND. L3
```

The example below shows redefinition of the assignment operator.
INTERFACE ASSIGNMENT ( = )
  SUBROUTINE BIT_TO_NUMERIC(N,B)
  INTEGER, INTENT(OUT) :: N
  LOGICAL, INTENT(IN) :: B(:)
  END SUBROUTINE BIT_TO_NUMERIC

  SUBROUTINE NUMERIC_TO_BIT(B,N)
  LOGICAL, INTENT(OUT) :: B
  INTEGER, INTENT(IN) :: N
  END SUBROUTINE NUMERIC_TO_BIT

END INTERFACE

LOGICAL LL
INTEGER BB
BB = LL
LL = BB

Optional arguments

In order to use OPTIONAL arguments, you must have an interface block (either
in line or from a USED MODULE or an INCLUDE). Optional arguments allow calls
to be made with arguments missing. Each optional argument must be declared
OPTIONAL in the interface file and in the called routine. In the called routine, the
optional argument can be tested for with the PRESENT intrinsic function.

SUBROUTINE UNO ( Z )
REAL Z
INTERFACE
  SUBROUTINE DOS ( EXTRA, TEMP, RESULT )
    REAL, INTENT(IN) :: EXTRA, TEMP
    OPTIONAL EXTRA
    REAL, INTENT(OUT) :: RESULT
  END SUBROUTINE DOS
END INTERFACE
CALL DOS ( RESULT = Z, TEMP = 272.0 )
PRINT *, Z
RETURN
END SUBROUTINE UNO

Internal Procedures

Internal procedures are set off by the CONTAINS statement. Only one level of
internal procedure is allowed in the F90 Standard, so you cannot have internal
procedures within internal procedures. However, module procedures may have
internal procedures.

SUBROUTINE ONE
  N = 2
  CALL TWO
  N = 3
  CALL THREE
!
CONTAINS
  SUBROUTINE TWO
    PRINT *, N
  END SUBROUTINE TWO
!
  SUBROUTINE THREE
    PRINT *, N
  END SUBROUTINE THREE
!
END SUBROUTINE ONE

Recursive routines

With Fortran 90, routines can call themselves if they are declared as recursive.

```
recursive integer function fact ( j ) &
  result (factx)
if ( j.eq.1 .or. j.eq.0 ) then
  factx = 1
else
  factx = j * fact(j-1)
endif
end
```

I/O Extensions

This version of VAST/90 does not translate the few I/O enhancements available in Fortran 90. The extensions are:

- File positioning on OPEN
- Non-advancing I/O
- Additional edit descriptors

VAST/90 issues diagnostic messages whenever these unimplemented F90 features are encountered.

Other Fortran 90 features

Among other features in Fortran 90 are:

- The RESULT clause in Fortran 90 allows a different returnvalue variable for a function.
- Unit name on END statement.
- New symbolic comparison operators <=, etc.
Restrictions

Following is a list of restrictions and unimplemented features.

- Use of `SEQUENCE` with derived types, including:
  - Equivalence of derived type with non-conformable derived types or other variables.
  - Sequence derived types arrays in COMMON cannot be accessed in all possible ways.

```fortran
  type abc
    sequence
    integer, dimension(10) :: a, b
  end type
  type(abc) da
  common /.../ da(10)
  ...
  da(j)%a(11) = ...
  [one might think this refers to da(j)%b(1)]
```

- TRANSFER intrinsic.

```fortran
  type uh_oh
    sequence
    real x, y
  end type
  type (uh_oh) bad(100)
  complex c
  c = TRANSFER (bad(50), c)
```

- Nonadvancing input. (Nonadvancing output is translated using the $ edit descriptor, where available.)

- For some systems, list-directed I/O to internal file. (This is legal f90 but not f77; some f77 compilers allow, some don't.)

- For some systems, character array pointers. (Depends on f77 compiler.)

- Non-f77-pointer mode (-y3): doesn't handle character pointers or misaligned data.

- Recursion is limited to a stack size, with default of 100. The stack size can be increased or decreased with the -Zrecur=value option.

- NAMELIST I/O for derived types.

- DELIM= on OPEN statements.

- RECL= on OPEN statements for sequential access files.
- Use of array elements in specification (i.e. dimensioning) expressions.

- Recursive ENTRYS.

- SIZE of expression involving implied DOs with certain kinds of variable upper bounds.

  ```fortran
  subroutine sub(n)
  isize = SIZE( (/(i,i=1,j),j=1,n)/ )
  end subroutine
  ```

- Seven-dimensional array in recursive routine.

- Automatic character objects in recursive routines.

- DATA statement with vector subscript.

  ```fortran
  integer, parameter :: v(3)=(/3,2,1/)
  integer a(3)
  data a(v(:)) /1,2,3/
  write(*,*) a
  ```

- Certain user character functions with dynamic length.

- Use of certain intrinsic functions in dimensioning expressions of dummy arrays and character variables.

  ```fortran
  subroutine sub(a,n,m)
  dimension a(max(n,m),100)
  end subroutine
  ```

- Some arguments to INQUIRE(IOLENGTH=):
  - dummy arguments
  - implied DOs
  - derived types
  - expressions involving functions

- Function argument to recursive procedure, if the function can be different at different levels of the recursion.

- DATA-ing of derived type variables in BLOCK DATA; handled only if no components are arrays or structures.

- Indirect recursion.

- For some systems, possibly a few of the new edit descriptors e.g. B, depending on what extensions the f77 compiler allows.
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