Automatic Arrays (1)

Local arrays with bounds specified at run-time are called automatic arrays

Bounds may be taken from an argument, or a constant or variable in a module

```
SUBROUTINE aardvark (arrsize)
  USE sizemod     ! this defines the var "worksize"
  INTEGER, INTENT(IN) :: arrsize
  REAL, DIMENSION(1:worksize) :: array_1
  REAL, DIMENSION(1:arrsize*(arrsize+1)) :: array_2
```

Automatic Arrays (2)

Another very common use is a “shadow” array
i.e., one that is the same shape as an argument

```
SUBROUTINE pard (matrix)
  REAL, DIMENSION(:,:) :: matrix

  REAL, DIMENSION(UBOUND(matrix,1), &
        UBOUND(matrix,2)) :: matrix_2, matrix_3
```

Automatic arrays are very flexible.

Explicit Shape Array Args (1)

We cover these because of their importance
They were the only mechanism available in Fortran 77
Generally they should be avoided

In this form all bounds are explicit
They are declared just like automatic arrays
The dummy should match the actual argument
Making an error will usually cause chaos

Only the very simplest uses are covered

Explicit Shape Array Args (2)

You can use constants

```
SUBROUTINE expl_shape (matrix, array)
  INTEGER, PARAMETER :: M = 5, N = 10
  REAL, DIMENSION(1:M,1:N) :: matrix
  REAL, DIMENSION(1000) :: array
      ...

INTEGER, PARAMETER :: M = 5, N = 10
REAL, DIMENSION(1:M,1:N) :: table
REAL, DIMENSION(1000) :: workspace

CALL expl_shape(table, workspace)
```

Explicit Shape Array Args (3)

It is common to pass the bounds as arguments

```
SUBROUTINE expl_shape (matrix, m, n)
  INTEGER, INTENT(IN) :: m, n
  REAL, DIMENSION(1:m,1:n) :: matrix
      ...
```

You can use expressions but it’s not generally recommended

Assumed Size Array Args

The last upper bound can be *

```
SUBROUTINE oldschool (matrix, n)
  INTEGER, INTENT(IN) :: n
  REAL, DIMENSION(n,*) :: matrix
      ...
```

You may come across this but generally avoid it

It makes it very hard to locate bounds errors

WARNING

Argument overlap will NOT be detected
Not even if you turn on array-bounds checking
This is a common cause of obscure errors

In this form all bounds are explicit
They are declared just like automatic arrays
The dummy should match the actual argument
Making an error will usually cause chaos

Example: overlap.f90

Character Arguments

Few scientists do anything fancy with these

People often use a constant length
You can specify this as a digit string
OR define it as a PARAMETER
That is best done in a module

Or define it as an assumed length argument

Explicit Length Character (1)

The dummy should match the actual argument
You are likely to get confused if it doesn't

```
SUBROUTINE sorter (list)
  CHARACTER(LEN=8), DIMENSION(:) :: list
      ...
  CHARACTER(LEN=8) :: data(1000)
      ...
  CALL sorter(data)
```

Explicit Length Character (2)

```
MODULE Constants
  INTEGER, PARAMETER :: charlen=8
END MODULE Constants

SUBROUTINE sorter (list)
  USE Constants
  CHARACTER(LEN=charlen), DIMENSION(:) :: list
=================================
USE Constants
CHARACTER(LEN=charlen) :: data(1000)
CALL sorter(data)
```

Assumed Length Character

A CHARACTER length can be assumed
The length is taken from the actual argument

You use an asterisk (*) for the length
It acts very like an assumed shape array

Note that it is a property of the type
It is independent of any array dimensions

Example

```
FUNCTION is_palindrome(word)
    LOGICAL :: is_palindrome
    CHARACTER(LEN=*), INTENT(IN) :: word
    INTEGER :: n, i
    is _palindrome = .false.
    n = len(word)
    do i = 1,(n-1)/2
       if (word(i:i) /= work(n+1-i:n+1-i) then
         RETURN
       endif
    enddo
    is _palindrome = .true.
END FUNCTION is_palindrome
```

Static Data

Sometimes you need to store values locally
Use a value in the next call of the procedure

You can do this with the SAVE attribute
Initialized variables get this automatically!

The best style avoids this use.

Example: localsave.f90

Warning for C/C++ Users

Initializations in subroutines get performed exactly once.
It does **NOT** reinitialize each time it is called

Modules and Interfaces

Module Summary

- Similar to same term used in other languages. As usual, modules fulfill multiple purposes
- For shared declarations (i.e., "headers")
- Defining global data (old COMMON)
- Defining procedure interfaces
- Semantic extension (described later)

And more...

Use of Modules

- Think of a module as a high-level interface

  It collects <whatevers> into a coherent unit

- Design your modules carefully

  As the ultimate top-level program structure

  Perhaps only a few, perhaps dozens

- Good place for high-level comments

  Please document purpose and interfaces

Module Structure

MODULE module-name

Static data definitions (often exported)

CONTAINS

Procedure definitions and interfaces

END MODULE module-name

Files may contain several modules

Modules may be split across several files

For simplest use, keep them 1 to 1

IMPLICIT NONE

Modules should also use this important specification

```
MODULE double
   IMPLICIT NONE
   INTEGER, PARAMETER :: DP = KIND(0.0D0)
END MODULE double

MODULE parameters
   USE double
   IMPLICIT NONE
   REAL(KIND=DP), PARAMETER :: one = 1.0_DP
END MODULE parameters
```

Module Interactions

Modules can USE other modules
Dependency graph shows visibility/usage

Modules may not depend on themselves
i.e., the standard does not permit the recursive or circular use of modules

```
MODULE A
   USE B
END MODULE A

MODULE B
   USE A
END MODULE B
```

```
MODULE double
    INTEGER, PARAMETER :: DP = KIND(0.0D0)
END MODULE double

MODULE parameters
    USE double
    REAL(KIND=DP), PARAMETER :: one = 1.0_DP
    INTEGER, PARAMETER :: nx = 10, ny = 25
END MODULE parameters

MODULE workspace
    USE double
    USE parameters
    REAL(KIND=DP), DIMENSION(nx,ny) :: now, then
END MODULE workspace
```

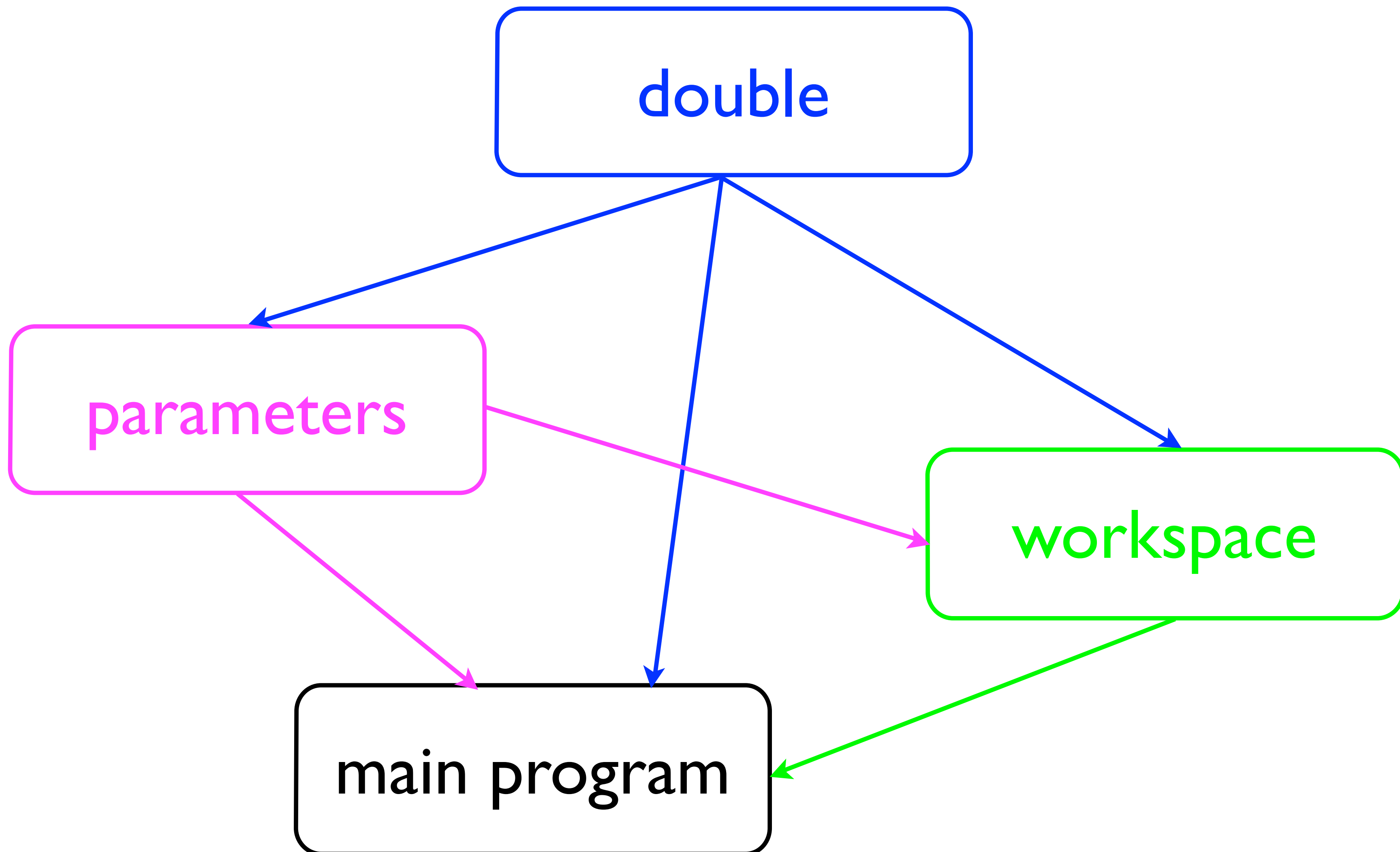
Example (cont.)

The main program might look like this

```
PROGRAM main
    USE double
    USE parameters
    USE workspace
    ...
END PROGRAM main
```

Could omit the USE double and USE parameters as they would be inherited through USE workspace

Module Dependencies



Shared Constants

We have already seen and used this:

```
MODULE double
    INTEGER, PARAMETER :: DP = KIND(0.0D0)
END MODULE double
```

You can do a great deal of this sort of thing

Greatly improves clarity and maintainability
The larger the program, the more it helps

Example: shr_const_mod.F90

Derived Type Definitions

We shall cover these later:

```
MODULE Bicycle
    REAL, PARAMETER :: pi = 3.141592
    TYPE Wheel
        INTEGER :: spokes
        REAL :: diameter, width
        CHARACTER(LEN=15) :: material
    END TYPE Wheel
END MODULE Bicycle

USE Bicycle
TYPE(Wheel) :: w1
```

Global Data

Variables in modules define global data
These can be fixed-size or allocatable arrays

- You need to specify the SAVE attribute

Set automatically for initialized variables
But it is good practice to do it explicitly

A simple SAVE statement saves everything

- This isn't always the best thing to do

Example (1)

```
MODULE state_variables
   INTEGER, PARAMETER :: nx=100, ny=100
   REAL, DIMENSION(NX,NY), SAVE :: &
        current, increment, values
   REAL, SAVE :: time = 0.0
END MODULE state_variables

USE state_variables
IMPLICIT NONE
DO
   current = current + increment
   CALL next_step(current, values)
END DO
```

Example (2)

This is equivalent to the previous example:

```
MODULE state_variables
    IMPLICIT NONE
    SAVE
    INTEGER, PARAMETER :: nx=100, ny=100
    REAL, DIMENSION(NX,NY) :: &
        current, increment, values
    REAL :: time = 0.0
END MODULE state_variables
```

Example (3)

The arrays sizes do not have to be fixed:

```
MODULE state_variables
    REAL, DIMENSION(:,:), ALLOCATABLE, SAVE :: &
          current, increment, values
END MODULE state_variables

USE state_variables
IMPLICIT NONE
INTEGER :: NX, NY
READ *, NX, NY
ALLOCATE(current(NX,NY), increment(NX,NY), &
     values(NX,NY))
```

Explicit Interfaces

Procedures now need explicit interfaces
e.g., for assumed shape arrays, keywords

- Modules are the primary way of doing this

We will come to the secondary way later

Simplest to include the procedures in modules
The procedure code goes after CONTAINS
This is what we discussed earlier

Example

```
MODULE mymod
CONTAINS
    FUNCTION Variance (Array)
      REAL :: Variance, X
      REAL, INTENT(IN), DIMENSION(:) :: Array
      X = SUM(Array)/SIZE(Array)
     Variance = SUM((Array-X)**2)/SIZE(Array)
    END FUNCTION Variance
END MODULE mymod

PROGRAM main
    USE mymod
    PRINT *, 'Variance = ', Variance(array)
```

Procedures in Modules (1)

Including all procedures within modules works very well in almost all programs

- There really isn't much more to it

It doesn't handle very large modules well
Try to avoid designing these if possible

Procedures in Modules (2)

These are very much like internal procedures
Works very well in almost all programs

Everything accessible in the module can
also be used in the procedure

Again, a local name takes precedence
But reusing the same name is very confusing

Procedures in Modules (3)

```
MODULE thing
    INTEGER, PARAMETER :: temp = 123
    CONTAINS
    SUBROUTINE pete ()
        INTEGER, PARAMETER :: temp = 456
        PRINT *, temp
    END SUBROUTINE pete
END MODULE thing
```

This will print 456, not 123

Avoid doing this as it's very confusing

Interfaces in Modules

The module can define just the interface
The procedure code is supplied elsewhere
The interface block comes before CONTAINS

- Be absolutely sure they are consistent!

The interface and code are not checked

Example: Cholesky decomposition

What Are Interfaces?

The FUNCTION or SUBROUTINE statement
And everything directly connected to that

Strictly, the argument names are not part of it
You are strongly advised to keep them the same

Local variables can be left out

Example

SUBROUTINE cholesky(A)	YES
USE DOUBLE	YES
INTEGER :: j, n	NO
REAL(KIND=dp) :: A(:,:), X	YES for A
	NO for X
. . .	
END SUBROUTINE cholesky	YES

Interfaces in Procedures

Can use an interface block as a declaration
Provides an explicit interface for a procedure

Can be used for ordinary procedure calls
But using modules is almost always better

- Essential for using certain specific features

e.g., keyword arguments within a module

Example: proc_as_arg

Generic procedure example:
genericswap.f90