Introduction to Modern Fortran

Derived Types

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Summary

There is one important new feature to cover.

It is not complicated, as we shall do it.
• But we won’t cover it in great depth.

Doing it fully would be a course in itself.
The same applies in other languages, too.
What Are Derived Types?

As usual, a hybrid of two, unrelated concepts C++, Python etc. are very similar

- One is structures – i.e. composite objects
  Arbitrary types, statically indexed by name

- The other is user-defined types
  Often called semantic extension
  This is where object orientation comes in

- This course will describe only the former
Why Am I Wimping Out?

Fortran 2003 has really changed this
full object orientation
semantic extension
polymorphism (abstract types)
and lots more

The course was already getting too big
And, yes, I was getting sick of writing it!

This area justifies a separate course
About one day or two afternoons, not three days
Please ask if you would like it written
Simple Derived Types

TYPE :: Wheel
   INTEGER :: spokes
   REAL :: diameter, width
   CHARACTER(LEN=15) :: material
END TYPE Wheel

That defines a derived type Wheel
Using derived types needs a special syntax

TYPE(Wheel) :: w1
More Complicated Ones

You can include almost anything in there

```
TYPE :: Bicycle
    CHARACTER(LEN=80) :: description(100)
    TYPE(Wheel) :: front, back
    REAL, ALLOCATABLE, DIMENSION(:) :: times
    INTEGER, DIMENSION(100) :: codes
END TYPE Bicycle
```

And so on ...
**Fortran 95 Restriction**

**Fortran 95** was much more restrictive
You couldn’t have **ALLOCATABLE** arrays
You had to use **POINTER** instead

**Fortran 2003** removed that restriction
You may come across **POINTER** in old code
It can usually be replace by **ALLOCATABLE**

Ask if you hit problems and want to check
Component Selection

The selector ‘%’ is used for this
Followed by a component of the derived type

It delivers whatever type that field is
You can then subscript or select it

```
TYPE(Bicycle) :: mine

mine%times(52:53) = (/ 123.4, 98.7 /)
PRINT *, mine%front%spokes
```
Selecting from Arrays

You can select from arrays and array sections. It produces an array of that component alone.

```fortran
TYPE :: Rabbit
    CHARACTER(LEN=16) :: variety
    REAL :: weight, length
    INTEGER :: age
END TYPE Rabbit

TYPE(Rabbit), DIMENSION(100) :: exhibits
REAL, DIMENSION(50) :: fattest

fattest = exhibits(51:) % weight
```
Assignment (1)

You can assign complete derived types
That copies the value element-by-element

\[
\text{TYPE(Bicycle) :: mine, yours}
\]
\[
yours = \text{mine}
\]
\[
\text{mine\%front = yours\%back}
\]

Assignment is the only intrinsic operation

You can redefine that or define other operations
But they are some of the topics I am omitting
Assignment (2)

Each derived type is a separate type
You cannot assign between different ones

```
TYPE :: Fred
   REAL :: x
END TYPE Fred
TYPE :: Joe
   REAL :: x
END TYPE Joe
TYPE(Fred) :: a
TYPE(Joe) :: b
a = b    ! This is erroneous
```
Constructors

A constructor creates a derived type value

```
TYPE Circle
  REAL :: X, Y, radius
  LOGICAL :: filled
END TYPE Circle

TYPE(Circle) :: a
a = Circle(1.23, 4.56, 2.0, .False.)
```

Or use keywords for components *(Fortran 2003)*

```
a = Circle(X = 1.23, Y = 4.56, radius = 2.0, filled = .False.)
```
You can specify default initial values

TYPE :: Circle  
   REAL :: X = 0.0, Y = 0.0, radius = 1.0  
   LOGICAL :: filled = .False.  
END TYPE Circle

TYPE(Circle) :: a, b, c  
 a = Circle(1.23, 4.56, 2.0, .True.)

This becomes much more useful with keywords

a = Circle(X = 1.23, Y = 4.56)
I/O on Derived Types

Can do normal I/O with the ultimate components
A derived type is flattened much like an array
[ recursively, if it includes derived types ]

TYPE(Circle) :: a, b, c
a = Circle(1.23, 4.56, 2.0, .True.)
PRINT *, a; PRINT *, b; PRINT *, c

1.23000000  4.55999999  2.00000000 T
0.00000000E+00  0.00000000E+00  1.00000000 F
0.00000000E+00  0.00000000E+00  1.00000000 F
Private Derived Types

When you define them in modules

A derived type can be wholly private
I.e. accessible only to module procedures

Or its components can be hidden
I.e. it’s visible as an opaque type

Both useful, even without semantic extension
Wholly Private Types

MODULE Marsupial
  TYPE, PRIVATE :: Wombat
    REAL :: weight, length
  END TYPE Wombat
  REAL, PRIVATE :: Koala
CONTAINS
  
  END MODULE Marsupial

Wombat is not exported from Marsupial
No more than the variable Koala is
Hidden Components (1)

MODULE Marsupial
  TYPE :: Wombat
  PRIVATE
  REAL :: weight, length
END TYPE Wombat
CONTAINS
  . . .
END MODULE Marsupial

Wombat **IS exported** from Marsupial
But its **components** *(weight, length)* are not
Hidden Components (2)

Hidden components allow opaque types
The module procedures use them normally

- Users of the module can’t look inside them
  They can assign them like variables
  They can pass them as arguments
  Or call the module procedures to work on them

An important software engineering technique
Usually called data encapsulation
Trees

E.g. type A contains an array of type B
Objects of type B contain arrays of type C

```
TYPE :: Leaf
   CHARACTER(LEN=20) :: name
   REAL(KIND=dp), DIMENSION(3) :: data
END TYPE Leaf

TYPE :: Branch
   TYPE(Leaf), ALLOCATABLE :: leaves(:)
END TYPE Branch

TYPE :: Trunk
   TYPE(Branch), ALLOCATABLE :: branches(:)
END TYPE Trunk
```
Recursive Types

Pointers allow that to be done a little more flexibly.
You don’t need a separate type for each level.

People often use more complicated structures.
You build those using derived types.
E.g. linked lists (also called chains).

Both very commonly used for sparse matrices.
And algorithms like Dirichlet tessellation.

We shall return to this when we cover pointers.
Opaque Types etc.

This is another using aspect that has been omitted. It’s there in the notes, if you are interested.

- Skip the practical that needs that facility