This lecture:

- Python debugging demo
- Compiled langauges
- Introduction to Fortran 90 syntax
- Declaring variables, loops, booleans

Compiled vs. interpreted language

Not so much a feature of language syntax as of how language is converted into machine instructions.

Many languages use elements of both.

Interpreter:

- Takes commands one at a time, converts into machine code, and executes.
- Allows interactive programming at a shell prompt, as in Python or Matlab.
- Can’t take advantage of optimising over a entire program — does not know what instructions are coming next.
- Must translate each command while running the code, possibly many times over in a loop.

Compiled language

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These files are input data for the compiler, which is a computer program that analyzes the source code and converts it into object code.

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Often large programs consist of many separate files and/or library routines — don't want to re-compile them all when only one is changed. (Later we'll use Makefiles.)

Fortran history

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> *"I don't know what the language of the year 2000 will look like, but I know it will be called Fortran."*
>
> *– Tony Hoare, 1982*

Fortran history

Major changes again from Fortran 77 to Fortran 90.

Fortran 95: minor changes.

Fortran 2003, 2008: not fully implemented by most compilers.

We will use Fortran 90/95.

gfortran — GNU open source compiler

Several commercial compilers also available.

Fortran syntax

Big differences between Fortran 77 and Fortran 90/95.

Fortran 77 still widely used:

- Legacy codes (written long ago, millions of lines...)
- Faster for some things.

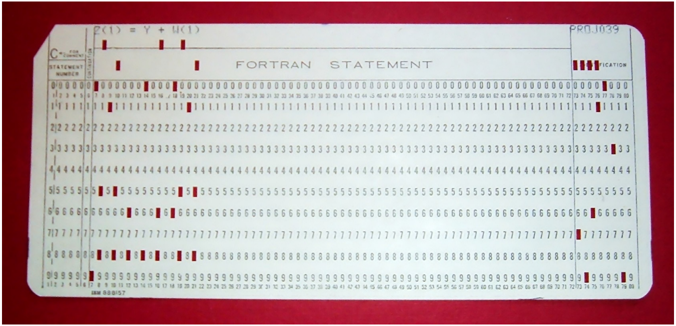
Note: In general adding more high-level programming features to a language makes it harder for compiler to optimize into fast-running code.

Fortran syntax

One big difference: Fortran 77 (and prior versions) required fixed format of lines:

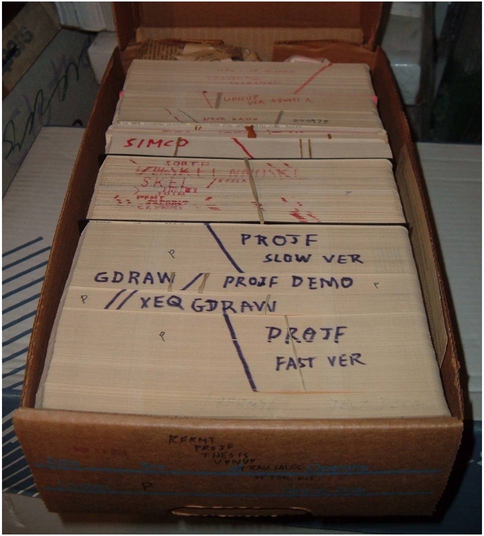
Executable statements must start in column 7 or greater,

Only the first 72 columns are used, the rest ignored!



http://en.wikipedia.org/wiki/File:FortranCardPROJ039.agr.jpg

Punch cards and decks



`http://en.wikipedia.org/wiki/File:PunchCardDecks.agr.jpg`

Paper tape

http://en.wikipedia.org/wiki/Punched_tape

Fortran syntax

Fortran 90: free format.

Indentation is optional (but highly recommended).

gfortran will compile Fortran 77 or 90/95.

Use file extension `.f` for fixed format (column 7 ...)

Use file extension `.f90` for free format.

Simple Fortran program

```
! example1.f90
program example1
    implicit none
    real (kind=8) :: x,y,z

    x = 3.d0
    y = 1.d-1
    z = x + y
    print *, "z = ", z
end program example1
```

Notes:

- Indentation optional (but make it readable!)
- First declaration of variables then executable statements
- implicit none means all variables must be declared

Simple Fortran program

```fortran
! example1.f90
program example1
    implicit none
    real (kind=8) :: x,y,z

    x = 3.d0
    y = 1.d-1
    z = x + y
    print *, "z = ", z
end program example1
```

More notes:

- `(kind = 8)` means 8-bytes used for storage,
- `3.d0` means 3×10^0 in double precision (8 bytes)
- `2.d-1` means $2 \times 10^{-1} = 0.2$

Simple Fortran program

```
! example1.f90
  program example1
    implicit none
    real (kind=8) :: x,y,z

    x = 3.d0
    y = 2.d-1
    z = x + y
    print *, "z = ", z
end program example1
```

More notes:

- `print *, ...`: The `*` means no special format specified As a result all available digits of `z` will be printed.
- Later will see how to specify print format.

Compiling and running Fortran

Suppose example1.f90 contains this program.

Then:

```
$ gfortran example1.f90
```

compiles and links and creates an executable named `a.out`

To run the code after compiling it:

```
$ ./a.out
 z =    3.2000000000000
```

The command `./a.out` executes this file (in the current directory).

Compiling and running Fortran

Can give executable a different name with -o flag:

```
$ gfortran example1.f90 -o example1.exe
$ ./example1.exe
  z =    3.20000000000000
```

Can separate compile and link steps:

```
$ gfortran -c example1.f90 # creates example1.o

$ gfortran example1.o -o example1.exe
$ ./example1.exe
  z =    3.20000000000000
```

This creates and then uses the object code example1.o.

Compile-time errors

Introduce an error in the code: (zz instead of z)

```
program example1
    implicit none
    real (kind=8) :: x,y,z
    x = 3.d0
    y = 2.d-1
    zz = x + y
    print *, "z = ", z
end program example1
```

This gives an error when compiling:

```
 $ gfortran example1.f90
   example1.f90:11.6:
   zz = x + y
     1
Error: Symbol 'zz' at (1) has no IMPLICIT type
```

Without the "implicit none"

Introduce an error in the code: (`zz` instead of `z`)

```
program example1
    real (kind=8) :: x,y,z
    x = 3.d0
    y = 2.d-1
    zz = x + y
    print *, "z = ", z
end program example1
```

This compiles fine and gives the result:

```
 $ gfortran example1.f90
 $ ./a.out
    z =  -3.62666764177119E-038
```

Or some other random nonsense since `z` was never set.

Fortran types

Variables refer to particular storage location(s), must declare variable to be of a particular type and this won't change.

The statement

```
implicit none
```

means all variables must be explicitly declared.

Otherwise you can use a variable without prior declaration and the type will depend on what letter the name starts with.
Default:

- integer if starts with i, j, k, l, m, n
- real (kind=4) otherwise (single precision)

Many older Fortran codes use this convention!

Much safer to use `implicit none` for clarity,
and to help avoid typos.

Fortran arrays and loops

```fortran
! loop1.f90
program loop1
   implicit none
   integer, parameter :: n = 10000
   real (kind=8), dimension(n) :: x, y
   integer :: i

   do i=1,n
      x(i) = 3.d0 * i
      enddo

   do i=1,n
      y(i) = 2.d0 * x(i)
      enddo

   print *, "Last y computed: ", y(n)
end program loop1
```

Fortran arrays and loops

```
program loop1
   implicit none
   integer, parameter :: n = 10000
   real (kind=8), dimension(n) :: x, y
   integer :: i
```

Comments:

- `integer, parameter` means this value will not be changed.
- `dimension(n) :: x, y` means these are arrays of length `n`.

Fortran arrays and loops

```
do i=1,n
   x(i) = 3.d0 * i
   enddo
```

Comments:

- `x(i)` means i'th element of array.
- Instead of `enddo`, can also use labels...

```
     do 100 i=1,n
        x(i) = 3.d0 * i
100     continue
```

The number 100 is arbitrary. Useful for long loops.
Often seen in older codes.

Fortran if-then-else

```
! ifelse1.f90

program ifelse1
    implicit none
    real(kind=8) :: x
    integer :: i

    i = 3

    if (i<=2) then
        print *, "i is less or equal to 2"
    else if (i/=5) then
        print *, "i is greater than 2, not equal to 5"
    else
        print *, "i is equal to 5"
    endif
end program ifelse1
```

Fortran if-then-else

Booleans: `.true.` `.false.`

Comparisons:

`<`	or `.lt.`	`<=`	or `.le.`
`>`	or `.gt.`	`>=`	or `.ge.`
`==`	or `.eq.`	`/=`	or `.ne.`

Examples:

```
if ((i >= 5) .and.  (i < 12)) then

if (((i .lt.  5) .or.  (i .ge.  12)) .and.  &
 (i .ne.  20)) then
```

Note: `&` is the Fortran continuation character.
Statement continues on next line.

Fortran if-then-else

```
! boolean1.f90
program boolean1
    implicit none
    integer :: i,k
    logical :: ever_zero

    ever_zero = .false.
    do i=1,10
        k = 3*i - 1
        ever_zero = (ever_zero .or. (k == 0))
        enddo

    if (ever_zero) then
        print *, "3*i - 1 takes the value 0 for some i"
    else
        print *, "3*i - 1 is never 0 for i tested"
    endif
end program boolean1
```