

Today:

- Interpreted vs. compiled languages
- Fortran

Wednesday:

- More Fortran
- Computer storage of numbers

Read: Class notes and references.

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 optimizing 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

The program must be written in 1 or more files ([source code](#)).

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

The object code is then passed to a [linker](#) or [loader](#) that turns one or more objects into an [executable](#).

Why two steps?

Object code contains [symbols](#) such as variables that may be defined in other objects. Linker resolves the symbols and converts them into addresses in memory.

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](#).)

Simple Fortran program

```
! $CLASSHG/codes/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
```

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

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  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

```
! $CLASSHG/codes/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:

- 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 = 3.2000000000000000
```

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 = 3.2000000000000000
```

Can separate compile and link steps:

```
$ gfortran -c example1.f90 # creates example1.o
$ gfortran example1.o -o example1.exe
$ ./example1.exe
z = 3.2000000000000000
```

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 = -3.626667641771191E-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

```
! $CLASSHG/codes/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

```
! $CLASSHG/codes/fortran/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:

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

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

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

Fortran if-then-else

```
! $CLASSHG/codes/fortran/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
```

Fortran history

Prior to Fortran, programs were often written in [machine code](#) or [assembly language](#).

FORTRAN = FORmula TRANslator

Fortran I: 1954–57, followed by Fortran II, III, IV, Fortran 66.

Major changes in Fortran 77, which is still widely used.

Major changes again from Fortran 77 to Fortran 90.

Fortran 95: minor changes.

Fortran 2003: not fully implemented by most compilers.

We will use Fortran 90/95.

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.

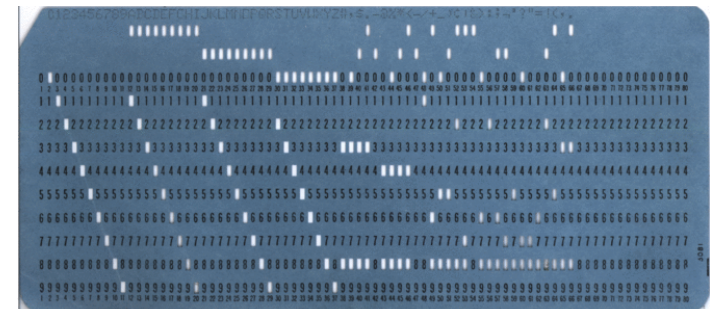
Note: In general adding more high-level programming features to a language makes it harder for compiler to optimize into fast-running code.

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!



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 Fortran 77.