Numerical Modelling in **FORTRAN**

day 1

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Today’s Goals

• Review class structure (see http://www.gfd.geophys.ethz.ch/%7Epjt/FORTRAN/FortranClass.html)
• Review background/history of Fortran
• Example programs to introduce the basics
• Edit, compile and test simple programs
Project
(optional, 1 KP)

1. Chosen topic, agreed upon with me
   (suggestions given, also ask the advisor of
   your MSc or PhD project).
   - Due end of Semesterprüfung (15 Feb 2019)
   - Start planning soon!
Project: general guidelines

• Choose something either
  – related to your research project and/or
  – that you are interested in

• Effort: 1 KP => 30 hours. About 4 days’ work.

• I can supply information about needed equations and numerical methods that we have not covered
Some ideas for a project

• Involving solving partial differential equations on a grid (like the convection program)
  – Wave propagation
  – Porous flow (groundwater or partial melt)
  – Variable-viscosity Stokes flow
  – Shallow-water equations
  – 3-D version of convection code

• Involving other techniques
  – Spectral analysis and/or filtering
  – Principle component analysis (multivariate data)
  – Inversion of data for model parameters
  – N-body gravitational interaction (orbits, formation of solar system, ...)
  – Interpolation of irregularly-sampled data onto a regular grid
History of Fortran

FORmulaTRANslation
(see http://en.wikipedia.org/wiki/Fortran)

• Invented by John Backus at IBM in 1953
  – “Much of my work has come from being lazy. I didn't like writing programs, and so, when I was working on the IBM 701, writing programs for computing missile trajectories, I started work on a programming system to make it easier to write programs.”

• First compiler 1957
  – First widely-used high-level language

• Standardised (by ANSI) in 1966: FORTRAN 66

• New ANSI standard in 1978: FORTRAN 77.
  – Became out of date: many features lacking compared to Pascal, C, Ada etc.

• New standard in 1992: FORTRAN 90.
History (2)

• FORTRAN 90: A big leap forwards!
  – free source format, modern control structures, precision specification, whole array processing (like MATLAB), dynamic arrays, user defined types, modules. But backward-compatible with F77

• FORTRAN 95 (1996): A few small fixes & improvements.

• FORTRAN 2003: Major additions mainly related to object-oriented programming

• FORTRAN 2008: Minor improvements

• FORTRAN 2018: Minor upgrades
Recommendation

• Use Fortran95 not 77 for new codes
  – f2003 is not yet fully implemented by all compilers
• f95 even has some advantages to C++
  – easier to understand, learn and write (typically)
  – easier to debug (e.g., no worry about pointers)
  – codes run faster (usually)
  – built-in complex numbers, array operations, multidimensional arrays, etc.
  – built-in parallel computing constructs & versions
  – doesn’t have such advanced object oriented programming but this is addressed with f2003&2008
Example program 1

program Temp_conversion

implicit none
real :: Deg_F, Deg_C, K

print*, "Please type in the temperature in F"
read*, Deg_F

Deg_C = 5.*(Deg_F-32.)/9.
print*, "This is equal to", Deg_C, "C"

K = Deg_C + 273.15
print*, "and", K, "K"

end program Temp_conversion
Analysis

• program....end program delineates the code
• Specification of variables comes first
  – implicit none means that all variables must be
    explicitly declared. Optional, but helps to avoid bugs
    (problems)
  – real is one of 5 variable types (also integer, logical,
    character, complex)
• Execution part comes next
  – print* and read* are the simplest I/O operations to
    stdout and stdin (often the screen and keyboard)
Notes

• Case doesn’t matter: e.g., PROGRAM, program, PrOgRaM all mean the same, deg_c and Deg_C refer to the same variable

• Doesn’t matter what column statements start (indent for legibility)

• Extra lines, and spaces within lines, can be added to improve legibility
f77 version

```fortran
program Temp_conversion

implicit none
real   Deg_F, Deg_C, K

print*,"Please type in the temperature in F"
read*, Deg_F

Deg_C = 5.*(Deg_F-32.)/9.
print*,"This is equal to",Deg_C,"C"

K = Deg_C + 273.15
print*, "and", K , "K"

end
```

- Not much difference because simple
- statements have to begin in >=7th column
- No “::” in variable declarations
EXERCISE 1

• write, compile and run a simple program that writes a message to the screen (e.g., “Hello World”)
  – edit a file ending in “.f90” (or “.f95”), using a text editor like emacs, vi, etc.
  – on linux or macOS, compile using “ifort program.f90” or “gfortran program.f90”. This will make an executable “a.out”
    • To specify a different name use -o, e.g., “gfortran -o myname program.f90”
  – Type “a.out” to execute it
    • If the computer doesn’t find it type “./a.out”
Beware of integer constants!

• If you write numbers without a “.” you may get unexpected results:
  • 1/3 = 0
  • 1./3.=0.33333
  • 1.0/3.0=0.33333
EXERCISE 2

• Write a program that asks the user to input three real numbers, then calculates the arithmetic mean, harmonic mean and geometric mean and prints them to the screen.
Example Program 2

program loopdemo

implicit none
integer :: i
integer, parameter :: low=3, high=5

! This program does nothing useful

do i = 1, 10 ! repeats loop with i=1,2,3...10

    if (i>high) then
        print*, i, " is greater than 5"
    else if (i<=low) then
        print*, i, " is less than or equal to 3"
    else
        print*, i, " is nothing special"
    end if

end do

end program loopdemo
Notes

• the “parameter” label indicates that these things have a fixed value that cannot be altered later
• “!” indicates a comment: everything after it is ignored
• The do...end do loop construct
• The if...else if...else...end if construct
• Comparison operators are <, >, ==, /=, >=, <=
  – in f77 these are .lt. .gt. .eq. .ne. .ge. .le.
• Indentation helps see the structure
• So do editors that auto-colour (xemacs in this case)
f77 version

program loopdemo

implicit none
integer i, low, high
parameter (low=3, high=5)

! This program does nothing useful

do i = 1,10 ! repeats loop with i=1,2,3...10
    if (i.gt.high) then
        print*,i," is greater than 5"
    else if (i.le.low) then
        print*,i," is less than 3"
    else
        print*,i," is nothing special"
    end if

end do

end

• ‘c’ in column 1 indicates a comment line
• ‘!’ comments and do...end do are not strict f77 but are supported by all modern compilers
Notes

• So far, 2 types of variable:
  – **Real**: floating-point number
  – **Integer**: whole number

• Soon we will come across 2 more types:
  – **Logical**: either .true. or .false.
  – **Character**: one or more characters

• And there is also
  – **Complex**: has real and imaginary parts
Exercise 3

• Write and test a program that
  – asks the user for a positive integer number
  – checks whether it is positive and prints an error message if not
  – calculates the factorial of the number
  – prints the result to the screen
Homework (due next class)

• Finish the 3 exercises
• Study the section “Introduction and Basic Fortran” at http://pages.mtu.edu/%7eshene/COURSES/cs201/NOTES/fortran.html
• Write a 4th program as specified on the next page, and hand in all programs by email. Deadline: next class
• Send f90 files to ETHfortran@gmail.com
Exercise 4

• Write a program that calculates the mean and standard deviation of an series of (real) numbers that the user inputs
  – Ask the the user to input how many numbers (this will be an integer)
  – check the user has input a positive number
  – input each number in turn (these will be real, and could be +ve or –ve) and add to the sum and (sum of squared) immediately so you don’t have to store them
  – after all numbers are input, calculate the mean and standard deviation from the sum, sum_of_squared and number
Policy on collaborating

• It is fine to consult with fellow students about things that are unclear, about solving problems when you get stuck, etc.
• Everyone must separately write their own programs.
• No copying of programs from other students, or two or more students developing a single code and each turning it in.
Appendix: Do while...construct

- N=0
- Do while (n<1)
  - read*,n
  - if (n<1) print*, ”number not positive”
- End do
Appendix: Mathematical formulae

Arithmetic, geometric and harmonic means:

\[
\bar{a}_{\text{arithmetic}} = \frac{1}{N} \sum_{i=1}^{N} a_i \quad \bar{a}_{\text{geometric}} = \left( a_1 \times a_2 \times \ldots \times a_N \right)^{\frac{1}{N}} \quad \bar{a}_{\text{harmonic}} = \frac{N}{1/a_1 + 1/a_2 + \ldots + 1/a_N}
\]

In fortran, ’to the power of’ is written **, e.g., a**b

Factorial: \( N! = 1 \times 2 \times 3 \times \ldots \times N \)

Standard deviation: \( \sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} a_i^2 - \left( \frac{1}{N} \sum_{i=1}^{N} a_i \right)^2} \)

In fortran, the square root function is sqrt()

Note: This is the population standard deviation; the sample standard deviation has a slightly different form