# Make and Software Installation

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# Outline

- Make
  - What is "Make"
  - How to write a makefile
  - How to use the "make" command
- Software installation on HPC clusters

# What is Make

- A tool that
  - Controls the generation of executable and other non-source files (libraries etc.)
  - Simplifies (a lot) the management of a program that has multiple source files
- Have many variants
  - GNU make (we will focus on it today)
  - BSD make
  - …
- Other utilities that do similar things
  - Cmake
  - Zmake
  - …

# What is Make

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# Why having multiple source files

- Different modules of functionalities should be kept in different source files, especially for a large program
  - Easier to edit and understand
  - Easier version control
  - Easier to share with others
  - Allow to write a program with different languages

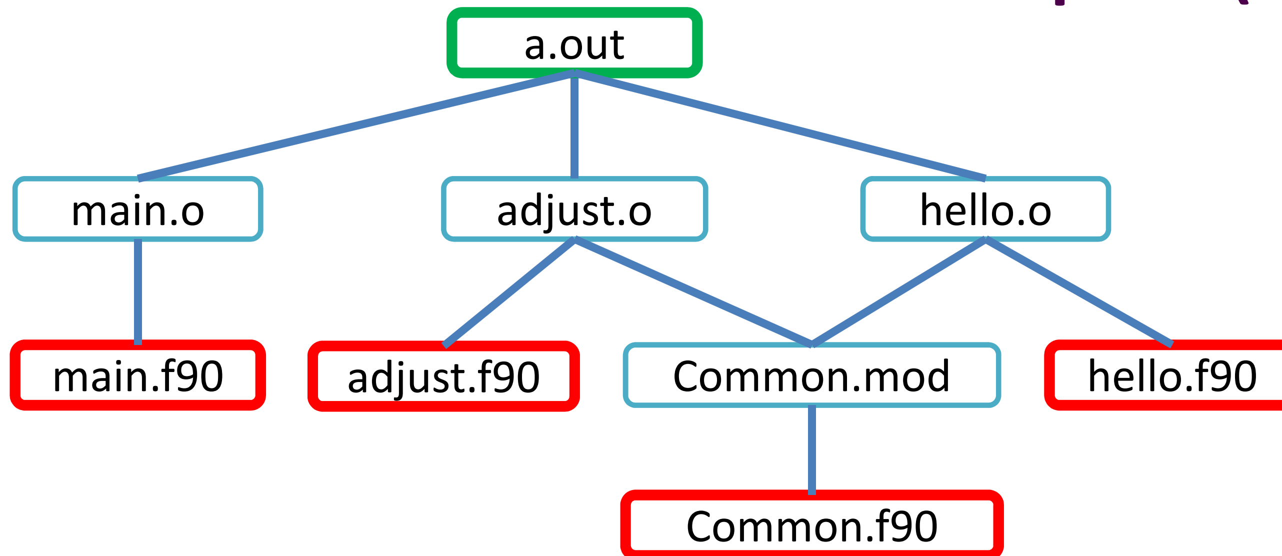
# From source files to executable

- Two-step process
  - The compiler generates the object files from the source files
  - The linker generates the executable from the object files
- Most compilers do both steps by default
  - Use "-c" to suppress linking

# Compiling multiple source files

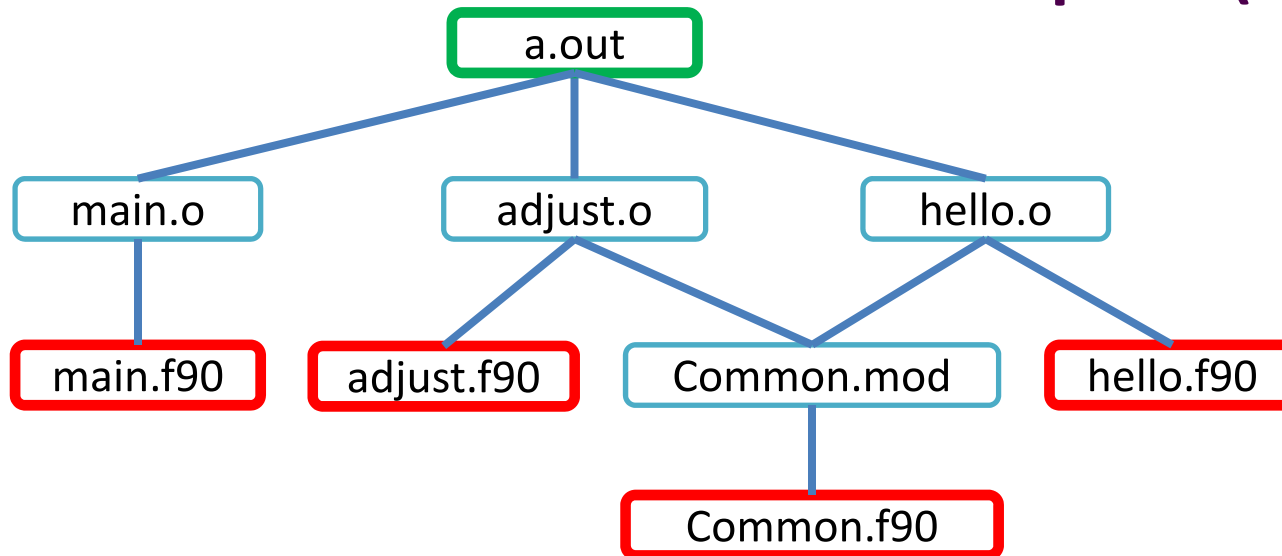
- Compiling single source file is straightforward
  - <compiler> <flags> <source file>
- Compiling multiple source files
  - Need to analyze file dependencies to decide the order of compilation
  - Can be done with one command as well
    - <compiler> <flags> <source file 1> <source file 2>…

# A "Hello world" example (1)




| Source file | Purpose |
|---|---|
| Common.f90 | Declares a character variable to store the message |
| Hello.f90 | Prints the message to screen |
| Adjust.f90 | Modifies the message and prints it to screen |
| Main.f90 | Calls functions in hello.f90 and adjust.f90 |

# A "Hello world" example (2)




```
[lyan1@eric2 make]$ ls
adjust.f90  common.f90  hello.f90  main.f90
[lyan1@eric2 make]$ ifort common.f90 hello.f90
adjust.f90 main.f90
[lyan1@eric2 make]$ ./a.out
 Hello, world!
                 Hello, world!
```

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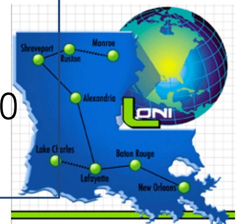
# Command line compilation

- Command line compilation works, but it is
  - Cumbersome
    - Does not work very well when one has a source tree with many source files in many sub-directories
  - Not flexible
    - What if different source files need to be compiled using different flags?
- Use Make instead!

# How Make works

- Two parts
  - The Makefile
    - A text file that describes the dependency and specifies how source files should be compiled
  - The "make" command
    - Compile the program using the Makefile

```
[lyan1@eric2 make]$ ls
adjust.f90  common.f90  hello.f90  main.f90
Makefile
[lyan1@eric2 make]$ make
ifort common.f90 hello.f90 adjust.f90 main.f90
[lyan1@eric2 make]$ ls
adjust.f90  a.out  common.f90  common.mod  hello.f90
main.f90  Makefile
```



# A Makefile with only one rule

Target

Action: shell commands that will be executed

```
[lyan1@eric2 make]$ cat Makefile
all:
	ifort common.f90 hello.f90 adjust.f90 main.f90
```

Explicit rule

A mandatory tab

# Exercise 1

- Copy all files under `/home/lyan1/traininglab/make` to your own user space
- Check the Makefile and use it to build the executable

# Makefile components

- Explicit rules
  - Purpose: create a target or re-create a target when any of prerequisites changes
  - Syntax:

```
target: prerequisites
(tab)  action
```

- Implicit rules
- Variable definition
- Directives

# How Make Processes a Makefile

- Two phases
  - Reads all components of the Makefile (rules, directives, variables) and constructs the dependency graph
  - Determines which targets need to be built and invokes the recipes to do so

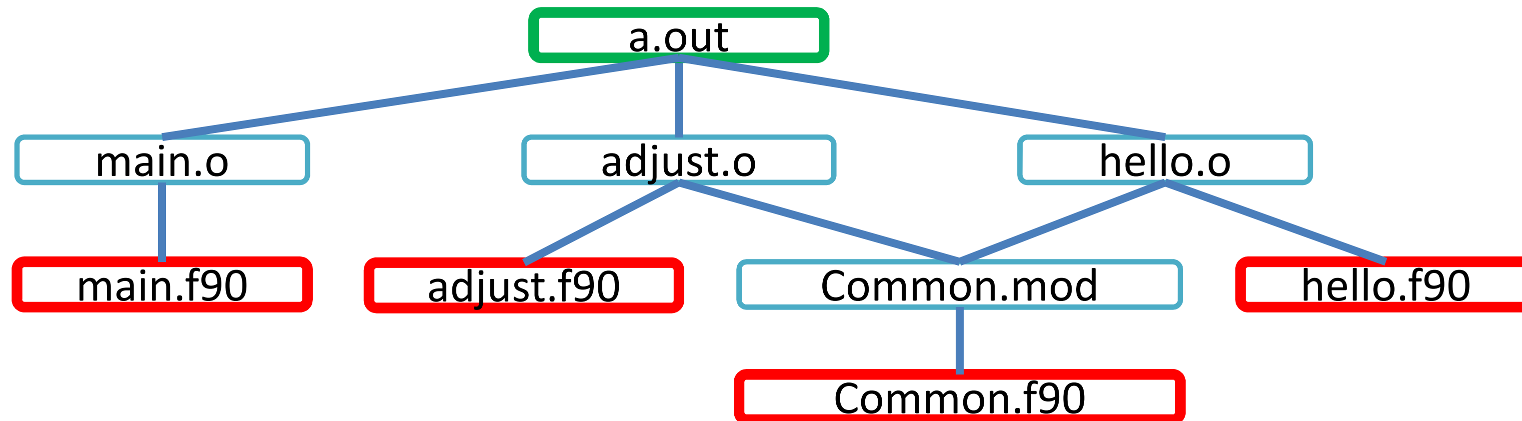
# Explicit rules (1)

- Multiple rules can exist in the same Makefile
  - The "`make`" command builds the first target by default
  - To build other targets, one needs to specify the target name
    - `make <target name>`
- A single rule can have multiple targets separated by space
- An action (or recipe) can consist of multiple commands
  - They can be on multiple lines, or on the same line separated by semicolons
  - Wildcards can be used
  - By default all executed commands will be echoed on the screen
    - Can be suppressed by adding "@" before the commands

# Explicit rules (2)

- How file dependencies are handled
  - Targets and prerequisites are often file names
  - A target is considered out-of-date if
    - It does not exist, or
    - It is older than any of the prerequisites

# Describing Dependency in A Makefile




```
all: main.o adjust.o hello.o
        ifort main.o adjust.o hello.o
main.o: main.f90
        ifort -c main.f90
adjust.o: adjust.f90 common.mod
        ifort -c adjust.f90
hello.o: hello.f90 common.mod
        ifort -c hello.f90
common.mod: common.f90
        ifort -c common.f90
```

# Exercise 2

- Write a Makefile using the template provided on the previous slide and “make”
- Run “make” again and see what happens
- Modify the message (`common.f90`) and “make” again
- Add a new rule “clean” which deletes all but the source and makefiles (the executable, object files and common.mod), and try “make clean”

# Variables in Makefile (1)

- These kinds of duplication are error-prone
- One can solve this problem by using variables

```
all: main.o adjust.o hello.o
        ifort main.o adjust.o hello.o
main.o: main.f90
        ifort -c main.f90
adjust.o: adjust.f90 common.mod
        ifort -c adjust.f90
hello.o: hello.f90 common.mod
        ifort -c hello.f90
common.mod: common.f90
        ifort -c common.f90
```

# Variables in Makefile (2)

- Similar to shell variables
  - Define once as a string and reuse later

Without variables

```
all: main.o adjust.o hello.o
        ifort main.o adjust.o hello.o
main.o: main.f90
        ifort -c main.f90
```

With variables

```
FC=ifort
OBJ=main.o adjust.o hello.o

all: $(OBJ)
        $(FC) $(OBJ)
main.o: main.f90
        $(FC) -c main.f90
```

# Automatic variables

- The values of automatic variables change every time a rule is executed
- Automatic variables only have values within a rule
- Most frequently used ones
  - `$@`: The name of the current target
  - `$^`: The names of all the prerequisites
  - `$?`: The names of all the prerequisites that are newer than the target
  - `$<`: The name of the first prerequisite

# Implicit rules (1)

- Tells Make system how to build a certain type of targets
  - GNU make has a few built-in implicit rules
- Syntax is similar to an explicit rule, except that “%” is used in the target
  - “%” stands for the same thing in the prerequisites as it does in the target

```
%.o: %.c
(tab)  action
```

  - There can also be unvarying prerequisites
  - Automatic variables can be used here as well

# Implicit rules (2)

```
CC=icc
CFLAGS=-O3

%.o : %.c
	@$(CC) $(CFLAGS) -c -o $@ $<

data.o: data.h
```

- In this example, any .o target has a corresponding .c file as an implied prerequisite
- If a target needs additional prerequisites, write a action-less rule with those prerequisites

# Exercise 3

- Rewrite the Makefile from Exercise 2
  - Define an implicit rule so that no more than 3 explicit rules are necessary (excluding “clean”)
    - Should be able to do with only 2 explicit rules
  - Use variables so that no file name appears in the action section of any rule

# Directives

- Make directives are similar to the C preprocessor directives
  - E.g. include, define, conditionals
- `Include` directive
  - Read the contents of other Makefiles before proceeding within the current one
  - Often used to read
    - Top level and common definitions when there are multiple makefiles

# Command line options of make (1)

- `-f <file name>`
  - Specify the name of the file to be used as the makefile
  - Default is GNUmakefile, makefile and Makefile (in that order)
  - Multiple makefiles may be useful for compilation on multiple platforms
- `-s`
  - Turn on silent mode (as if all commands start with an “@”)

# Command line options of make (2)

- `-j <number of jobs>`
  - Build multiple targets in parallel
- `-i`
  - Ignore all errors
  - A warning message will be printed out for each error
- `-k`
  - Continue as much as possible after an error.

# Software installation

- Install from binary distribution
  - Pre-compiled files, usually with the form of
    - RPMs – need root privilege (in most cases)
    - Tarballs with interactive installation scripts
  - Easy to install, but the target platform must be similar to the one where it is compiled
- Install from source distribution
  - Users need to compile the source files with their own choice of compilers, options and libraries
  - Most flexible, but choosing the best/right compilers and options can be a demanding task
  - Many packages use GNU build system (autoconf etc.) to produce shell scripts that handle the configuration and build

# Installation from source

- Configure the package - Choose compilers and options
  - With `autoconf`
    - Pass options to the "`configure`" script, which will generate Makefiles accordingly
    - The "`configure`" script comes with a "`--help`" option which displays all options acceptable to "configure"
  - Without `autoconf`: need to edit the Makefile (or files that it includes)
- Make - Compile the source files
- Make install - Copy compiled files to desired location

# Case Study (1): Modflow 2005

- Modflow is a USGS finite-difference flow model
  - No `autoconf`
  - The makefile is located in the `src` directory
  - There is no "`clean`" or "`install`" target in the makefile
- Installation steps
  - Edit Makefile
  - Make
  - Optional: copy the executable to the desired location

# Case Study (2): SPRNG

- SPRNG stands for Scalable Parallel Random Number Generator Library
  - No `autoconf`
  - The files `make.CHOICES` and `SRC/make.$PLATFORM` are included in the Makefile
- Installation steps:
  - Edit `make.CHOICES` and `SRC/make.$PLATFORM`
    - Need to choose the MPI compilers to build the MPI version
  - Make
  - Optional: run "`make test`" to test the build
  - Optional: copy the files to the desired location

# Autoconf

- Provides a "configure" script which can automatically generate Makefiles according to the options provided by users
- Usage: ./configure [<option>[=<value>]] <var>=<value>
- Environment variables
  - CC, CFLAGS: C compiler command and flags
  - FC, FFLAGS: Fortran compiler command and flags
  - CXX, CXXFLAGS: C++ compiler command and flags
  - LDFLAGS: linker flags
- Most frequently used options
  - --help: display comprehensive help information
  - --prefix=PREFIX: install files in PREFIX

# Case Study (3): FFTW

- FFTW stands for Fast Fourier Transform West
  - With `autoconf`
- Installation steps
  - Run the "`configure`" script
    - Ex: `./configure --prefix=/home/lyan1/packages/fftw-3.3.2-intel-11.1 CC=icc F77=ifort CXX=icpc`
  - Make
  - Make install

# Exercise 4

- Install gnuplot 4.6.0 from source
  - Get the source tar ball from gnuplot website
  - Extract the contents
  - Configure, make and make install

# Questions?