CISC 372: Parallel Computing

Unix

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How you can play along with today's lecture

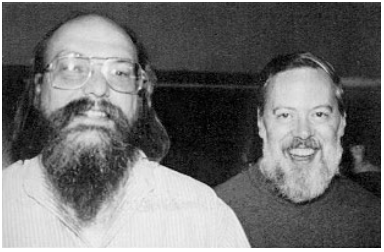
Hopefully one of the following will work for you...

- if you have a Mac, open up a Terminal window
- if you have a Linux VM, start it up, open up a Terminal window
- Windows users: install WSL2
- `ssh cisc372.cis.udel.edu` (you must first be on UD VPN)

UNIX Historical Overview

- AT&T, circa 1970
- started as a reaction to Multics
  - revolutionary OS under development at MIT, AT&T, GE
  - Multics thought to be too complicated but having good ideas
  - Multics = Multiplexed Information and Computing Service
  - Unics = UNiplexed Information and Computing Service
- Ken Thompson, Dennis Ritchie, M. D. McIlroy, J. F. Ossanna, ...
- C language invented in order to develop Unix in a portable way
  - previously used assembly language
- extremely influential and popular, leading to many variants
  - BSD Unix (Berkeley Standard Distribution)
    - Free-BSD, OpenBSD, DragonFly BSD $\cdots \rightarrow$ Darwin (OS X)
    - Solaris (Sun $\rightarrow$ Oracle)
  - GNU/Linux
  - AIX
  - Xenix

Ken Thompson and Dennis Ritchie



Unix: Main ideas

- multitasking, multi-user
- set of relatively independent tools built around a single small kernel
- modularity, re-usable software components
- everything is a file
  - the filesystem is the main means of communication
  - printer, terminal, drives, ... are all files
  - most commands are files: files can be made executable and thus become commands
- shell scripting + command language to combine different tools
- hierarchical file system with no limit on hierarchy
- command interpreter is just another program (shell)
  - makes it very easy to create new commands and thereby extend the language
- all files: newline-delimited ASCII
- use of regular expressions
- self-documenting (man)

UNIX: File system

- the file system is a rooted tree
- the root is `/`
- `a/b/c`
  - `c` is a child of `b` is a child of `a`
  - `a` and `b` are directories (a kind of file)
  - `c` may or may not be a directory (but is a file)
- `.` is the current (working) directory
- `..` is the parent directory of the current directory
- each file has certain metadata associated to it by the OS
  - owner: ID number of the user who "owns" this file
  - group: ID number of the group for this file
  - permissions: who can read/write/execute this file
    - permissions for the owner
    - permissions for the group
    - permissions for everyone else

Using the bash shell

- interactive: prompt, you type a command, get a response, repeat
- an any time, you are "in" a directory (point in the hierarchy)
  - the working directory
- `ls` : list the contents (children) of the working directory
  - `ls -l` : long format: show the user, group, file size, permissions, etc.
  - `ls -a`: show all files including the hidden ones (start with `.`)
- `pwd` : print working directory
- `cd` : change directory to another directory
  - argument to `cd` is a path to a directory
  - argument can be absolute or relative
  - absolute: starts with `/` (root)
  - relative: starts with anything else, is interpreted to be a direction starting from working directory
- `mv a b`: move a file from `a` to `b`
  - this can be used to rename a file
  - or it can be used to move a file into another directory (change the hierarchy)
  - remember: "file" above can be a directory

bash shell commands, cont.

- `cp a b` : copy a file to another directory (or file)
- `rm a` : remove the file named `a`
- `rmdir a` : remove the empty directory named `a`
- `man cmd` : show the manual page for the command cmd
- `chmod` : change the permissions on a file
  - `chmod ugo+rx foo`
    - give everyone read and execute permission on file `foo`
  - `chmod go-w foo`
    - take away write permission from group and others on `foo`
- `chown` : change the owner of the file
- `chgrp` : change the group of the file
- `touch filename` : creates an empty file with that name
- `cat filename` : print the file to the terminal
- `more filename` : page through the file one screen at a time
- `bash` : start (another) bash shell

Exercise 1

1. Create a directory in your home directory called `A`.
2. Create two sub-directories of `A` called `B` and `C`.
3. Adjust the permissions of `C` so that only you can read, write or change into it.
4. Create a file called `foo.txt` in `C`.
5. Copy `foo.txt` to `B`. Check that both copies are really there.
6. Delete both copies of `foo.txt`.
7. Delete `B` and `C` (command: `rmdir`).
8. Delete `A`.

Execution, environment

- many different kinds of executable files can be created
  - shell (e.g., bash) scripts
  - files created by compiling a C program, etc.
- the file then becomes a command
  - just type the full path to the file (and any command line arguments)
  - the user doing this must have execute permission on the file
- to avoid typing the full path, put the file "in your PATH"
- `PATH` is an environment variable
  - a variable used by the shell
- `PATH` is a colon-separated list of directories
- when you type a command in the shell, it looks in the directories in your path for a file with that name (in order)
  - if and when it finds the file, it executes it

Execution, environment, cont.

- `X=foo` : set environment variable `X` to `foo`
- `$X` : expands to current value held by environment variable `X`
- `echo $X` : print the value of the environment variable `X`
- `export X=foo` : set `X` to `foo` and carry this over to all children shells
- `export PATH=/users/joe/bin:$PATH`
  - add `/users/joe/bin` to the front of the list of directories in the PATH
  - `set` : show the current environment

Package managers

- installing, configuring, organizing, and managing software is hard
  - even with `make`
- modern Unix distributions come with package managers
- maintain large databases of software "packages" and dependencies
  - e.g., Subversion 1.9.2 requires gcc 4.6.2 and ...
- these make it very easy to install, update, uninstall software and keep everything consistent
- Mac
  - MacPorts: `https://www.macports.org`
  - Homebrew: `https://brew.sh`
- Ubuntu, Debian
  - Advanced Packaging Tool (APT): `https://help.ubuntu.com/community/AptGet/Howto`

APT

Common commands:

1. `apt-get install` ⟨*package_name*⟩
   - install a package
2. `apt-get update`
   - update your local list of packages
3. `apt-get upgrade`
   - upgrade all your installed packages to the latest versions
4. `apt-cache search` ⟨*search_term*⟩
   - search for packages with names or descriptions matching the string
5. `apt-cache show` ⟨*package_name*⟩
   - show the description of the package and other information

Note: Most commands must be preceded by `sudo`.

See

- `https://help.ubuntu.com/community/AptGet/Howto`

for many more commands and deatils.

MacPorts

Common commands:

1. `port install` ⟨*package_name*⟩
   - install a package
2. `port selfupdate`
   - update your local list of packages
3. `port upgrade outdated`
   - upgrade all your installed packages to the latest versions
4. `port search` ⟨*search_term*⟩
   - search for packages with names or descriptions matching the string
5. `port info` ⟨*package_name*⟩
   - show the description of the package and other information

Note: Most commands must be preceded by `sudo`.

See

- `https://guide.macports.org/#using.port`

for many more commands and deatils.

Text editors

There are many, but some of the most popular are...

1. `pico`, `nano` (simple, easy-to-use, not powerful enough for most programming)
2. `vi` (universal, dating back to mid-late 1970s)
3. `emacs` (powerful, extensible, also mid 1970s)
   - recommended
   - get: use package manager!
   - learn: `https://www.gnu.org/software/emacs/tour/`
   - quick reference card:
     `https://www.gnu.org/software/emacs/refcards/pdf/refcard.pdf`

Choose your editor:

- in your home directory, find file `.bash_profile`
- or create new file with that name, if it is not there
- any bash commands you put here will be executed every time you log on
- add line: `export EDITOR=emacs`
- this will become your default editor for many different tasks

Emacs: thousands of commands with keyboard binding

- C-x C-f: open file
  - C=control, push and hold as you type the next character
- C-x C-s: save file
- C-x C-c: exit
- C-x C-w: write file ("save as...")
- C-a: move to beginning of line
- C-e: move to end of line
- C-n: move to next line
- C-p: move to previous line
- C-f: move forward one character
- C-b: move backward one character
- C-v: move forward one page
- M-v: move backward one page
  - M=meta key, usually ESC, maybe option
- C-spc: set the mark
- C-w: cut everything from the mark to current position (the "region"), copying it into the buffer
- M-w: copy the current region into the buffer without cutting
- C-y: yank from the buffer
- C-g: cancel whatever you're in the middle of
- C-s: search forward incrementally
- C-x u: undo (as many times as you want)

Exercise 2

1. Create a directory called `ex2` and change into it.
2. Create a new file named `hi.c` with these contents:

```
#include <stdio.h>
int main() {
  printf("Hi there\n");
}
```

3. Compile the program: `cc -o hi hi.c`
4. List the directory. You should see a file `hi`.
5. Change the permissions on `hi` so anyone can execute it.
6. Execute `hi`: `./hi`
7. Put the directory containing `hi` in your `PATH`.
8. Change into some other directories and type `hi`.

Congrats: you have extended the language of your OS.

make

make is a utility for automating builds and other tasks that have complex dependency graphs.

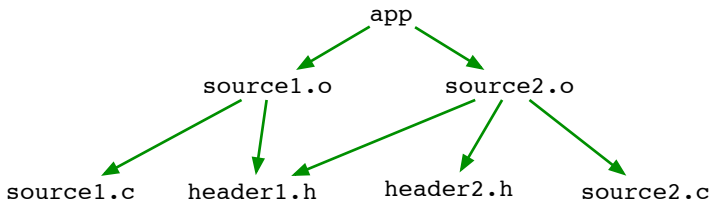
Example. You are developing a C program with source files:

1. `header1.h`
2. `header2.h`
3. `source1.c`, which includes `header1.h`, and
4. `source2.c`, which includes `header1.h` and `header2.h`

To build the binary `app` you issue the following command:

1. `cc -c source1.c` *[produces `source1.o`]*
2. `cc -c source2.c` *[produces `source2.o`]*
3. `cc -o app source1.o source2.o` *[produces `app`]*

make: dependency graph



- there is one build step for each non-leaf node in the graph
- suppose you modify `header1.h`
  - you need to repeat all 3 build steps
- suppose you modify `header2.h`
  - you only need to rebuild `source2.o` and `app`
- now imagine you have hundreds of nodes in a complex directed graph
- goal: when files are modified, figure out the minimal set of build steps to bring the system up-to-date

Makefile

Put the following in a file called "`Makefile`":

```
app: source1.o source2.o
     cc -o app source1.o source2.o

source1.o: source1.c header1.h
     cc -c source1.c

source2.o: source2.c header1.h header2.h
     cc -c source2.c
```

Then just type "`make`".

What `make` does

- `make` will figure out which nodes need rebuilding
- the `Makefile` consists of a set of rules
  - each rule has a target (left of colon)
  - followed by a set of prerequisites
  - then one or more recipes (executable actions to build the target)
- by examining time-stamps, `make` can tell if a target is older than one of its dependencies
  - such a target needs to be re-built
  - anything that depends on that target also needs to be re-built, etc.
- make executes the necessary recipes in the right order