

Introduction to Unix

- A brief history of UNIX
- Why use UNIX?
- A model of the UNIX environment
- The UNIX file system (directories, commands)
- File attributes (permissions)
- ... and much more.



A brief history of UNIX

- UNIX is a:
 - multi-user, multi-tasking operating system (or “OS”)
 - architecture-independent operating system (“portable”)
- the “UNIX” trademark:
 - owned by AT&T
 - passed to the “Unix System Laboratories” (USL)
 - passed to Novell
 - passed to X/Open Company, Ltd. (1993)
 - X/Open + Open Software Foundation (OSF) → The Open Group
 - The Open Group (1996), <http://www.opengroup.org/>
- So every manufacturer calls it something else!



A brief history of UNIX (2)

- AT&T / Bells Labs (was Lucent Technologies, now Avaya & Alcatel-Lucent)
 - Unix created by two researchers for their own personal use (Thomson & Ritchie, 1970)
 - academic/research operating system
 - Initially, pros: flexibility, extensibility, file sharing
 - Initially, cons: security, robustness, performance
 - easy to use (in comparison with contemporaneous OSes)
 - the first portable OS where "portable" == “recompilable and executable on another instruction set architecture”



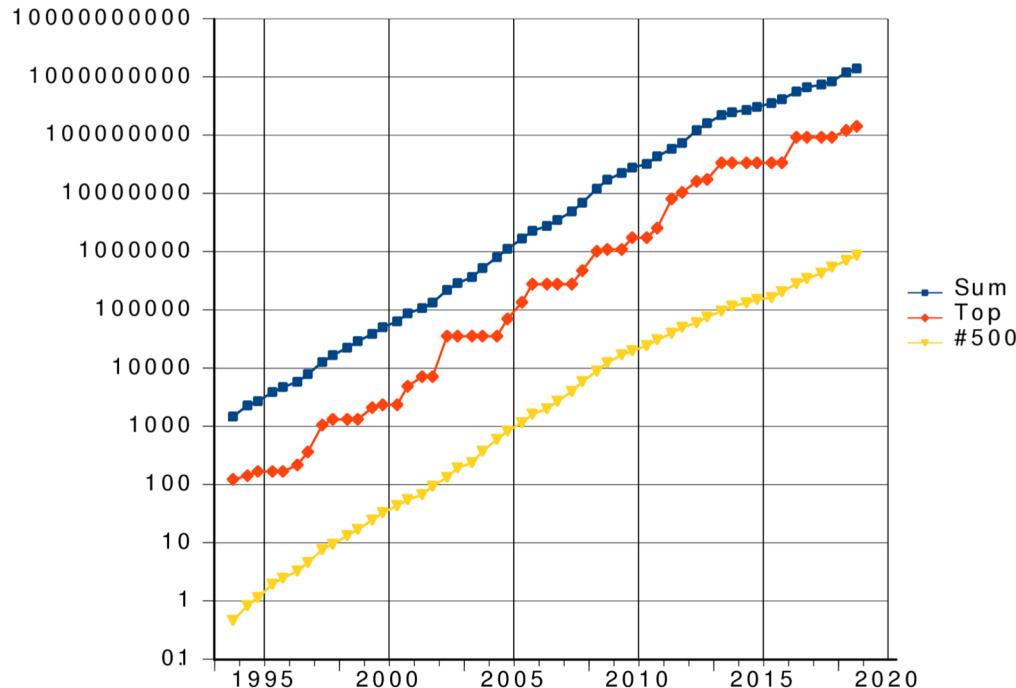
A brief history of UNIX (3)

- Berkeley Standard Distribution (BSD)
 - freeware! (cheap for universities; only paid for distribution cost)
 - first UNIX to include standard network support
 - enhancements to interprocess communication (IPC), job control, security
- many flavours of UNIX in use today:
 - FreeBSD, NetBSD, XENIX, Solaris, SunOS, HP-UX, Linux, A/UX, AIX, macOS
- continues to evolve
 - e.g., Single UNIX Specification (derived from POSIX standard)
- Free Software Foundation and GNU Unix
- Ubuntu – arguably the most popular Linux distribution
- CentOS 7 – used in ELW B238



Aside 1: www.top500.org

Images: <https://bit.ly/2AySpBL>, <https://bit.ly/2QvqGH4>



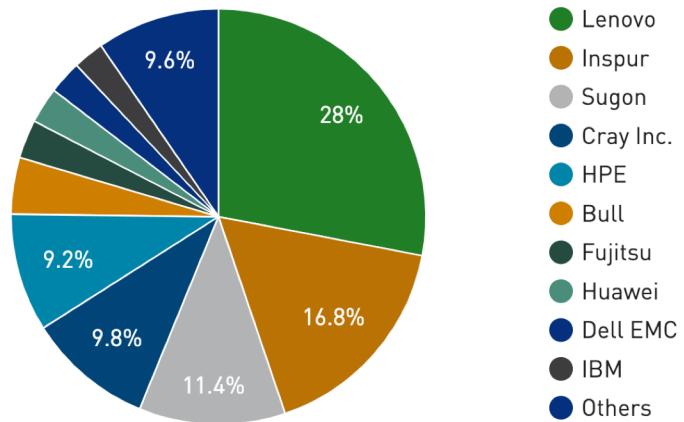
The top-line performance of supercomputers continues its growth (albeit with hiccups here and there).

Pictured below: IBM/DOE (US) Oak Ridge National Laboratory at head of the top500.org list in June 2018 & November 2018. Cores: 2,397,824; peak performance: 200,794.9 Tflops/sec); Power: 9,783 kW

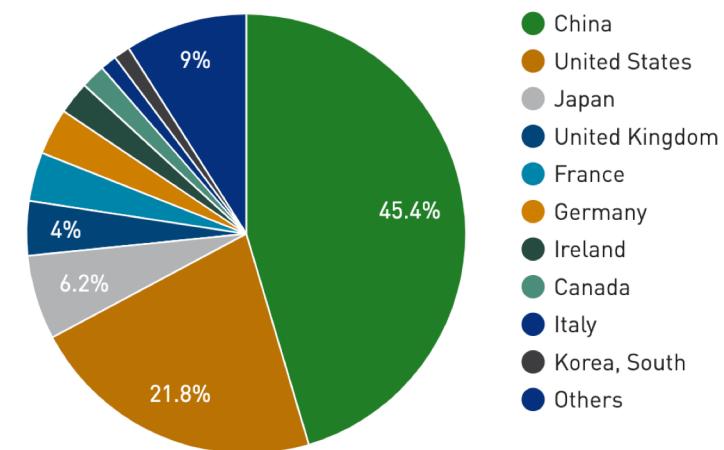


Aside 1: www.top500.org

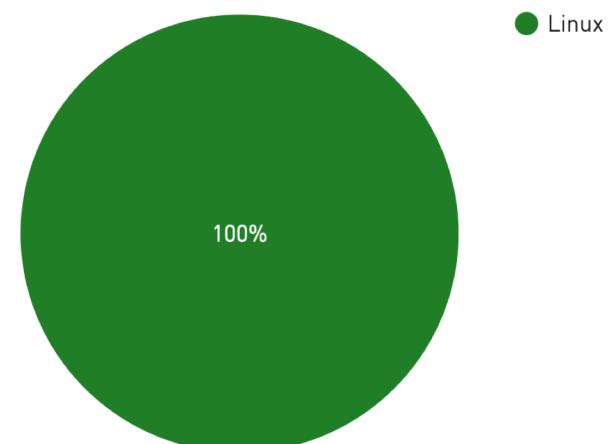
Vendors System Share



Countries System Share



Operating system Family System Share



Graphs generated at: <https://www.top500.org/statistics/list/>



University of Victoria
Department of Computer Science

Aside 2: Android

- First introduced in 2008
 - Android 1.0
 - Running on device codenamed “Dream” (T-Mobile G1)
- Major versions have been released ever since
 - Current active release (August 2018) is Android 8.2 (“Oreo”)
- Other related variants have been released
 - Android TV
 - Wear OS (used to be Android Wear)
 - Android Auto



Wear OS by Google

android auto



University of Victoria
Department of Computer Science

Logos from: <https://bit.ly/2vcPc7t>, <https://arris.ly/2LZKAst>,
<https://bit.ly/2vhfJAf>, <https://bit.ly/2LVHRQG>

Aside 2: AOSP

- **Android Open Source Project**
 - <https://source.android.com>
- **Code for a complete/full software stack**
 - From web browser, media players, etc. ...
 - ... all the way down to USB, wifi, power management, etc.
- **Dependent upon the Linux kernel**
 - And much else besides (including Java)
- Note: The full AOSP distribution is much, much larger than the Android SDK
 - Takes around one hour to download
 - Just the source code is 100 gigabytes...
 - ... and to make one build you'll require another 150 gigabytes.
- Android uses Linux/Unix access controls and process isolation in very interesting & novel ways.

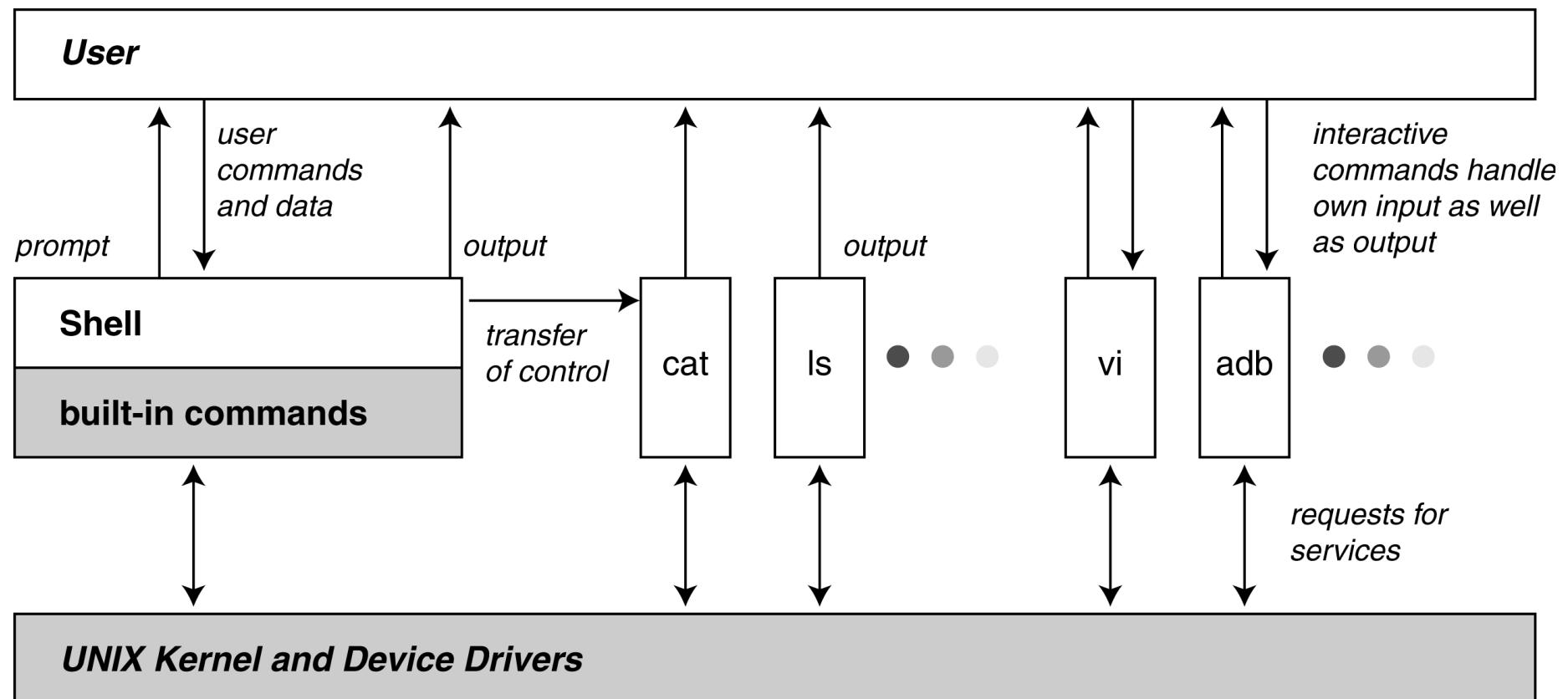


Why use UNIX?

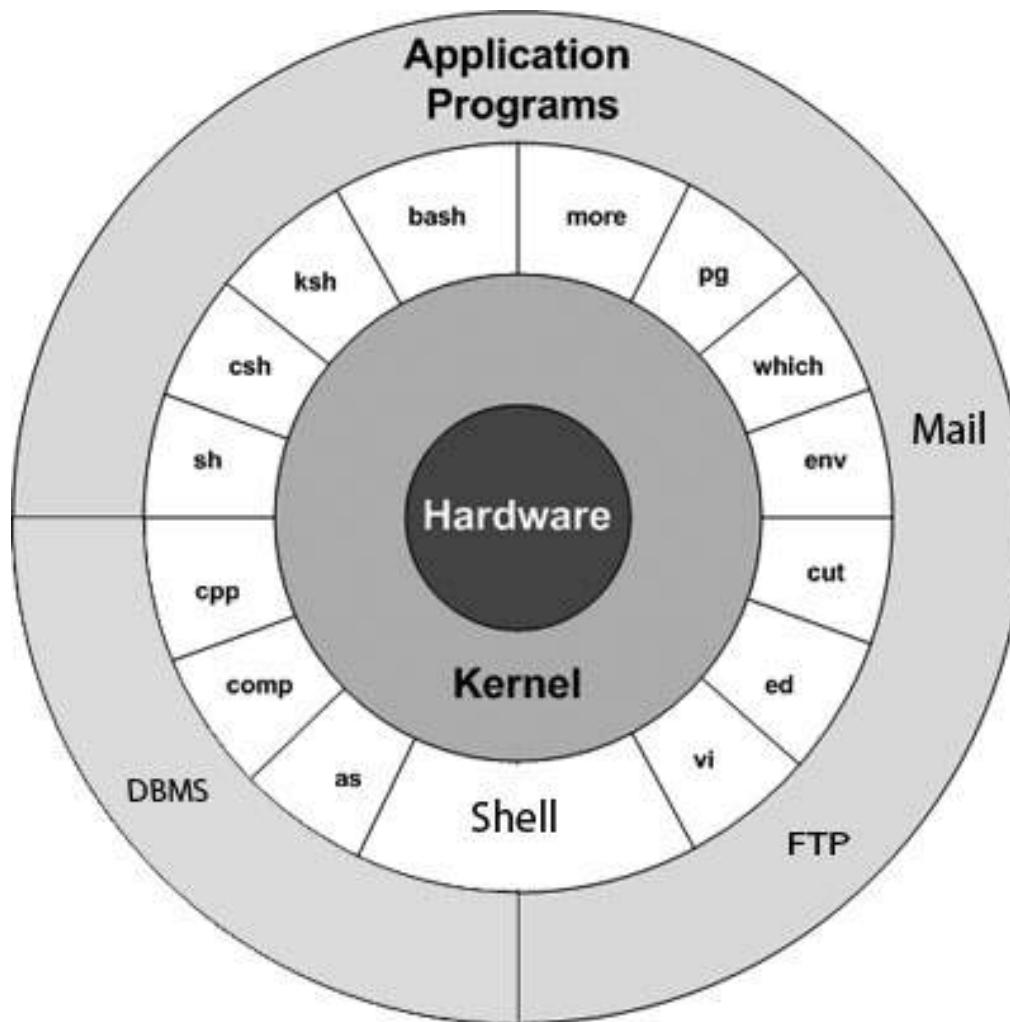
- multiuser
- multitasking
- remote processing
- stable (some might even say "safe")
- highly modular
- some versions are free (open source → freedom to modify)
- large user community, extensive experience
- “tools are mature”



UNIX model of user interaction



UNIX model



shell

- responsible for communication between the user and kernel
- “shell” refers to its position in some diagrams of UNIX structure
 - These diagrams use concentric rings to show layering
- reads and interprets user commands at the console (or from within a “shell script”)
- implements job control
- many shells have been developed:
 - sh, csh, ksh, tcsh, zsh, bash ...
 - in this course we use the bash shell
 - bash extends sh, the Bourne shell



kernel

- the **kernel** is the **protected core** of the OS
- the kernel is itself a large and complex program
- clear demarcation between the “kernel” and a “user”
 - to access a computer’s hardware (via the OS), user's commands must go through kernel
 - that is, “user” must request the kernel to perform work on behalf of “user”
 - user/OS interaction mediated by a command shell (e.g., **bash**), or the system library (compiled application)
- main responsibilities
 - memory allocation
 - **file system**
 - loads and executes programs (assumes a process model)
 - communication with devices (input, output)
 - bootstraps the system



UNIX filesystem

- “file”, “filesystem”: **are key abstractions** of the UNIX computing model
- practically anything can be abstracted as a file (devices, programs, data, memory, IPC, etc.)
- mainly responsible for mapping blocks of data within **physical** storage devices (hard drive, flash memory) onto **logical** blocks that users can manipulate
 - maps filenames to block numbers
 - handles block allocations; chains units together
 - provides methods to access data
- facilitates the “multiuser” view of the OS

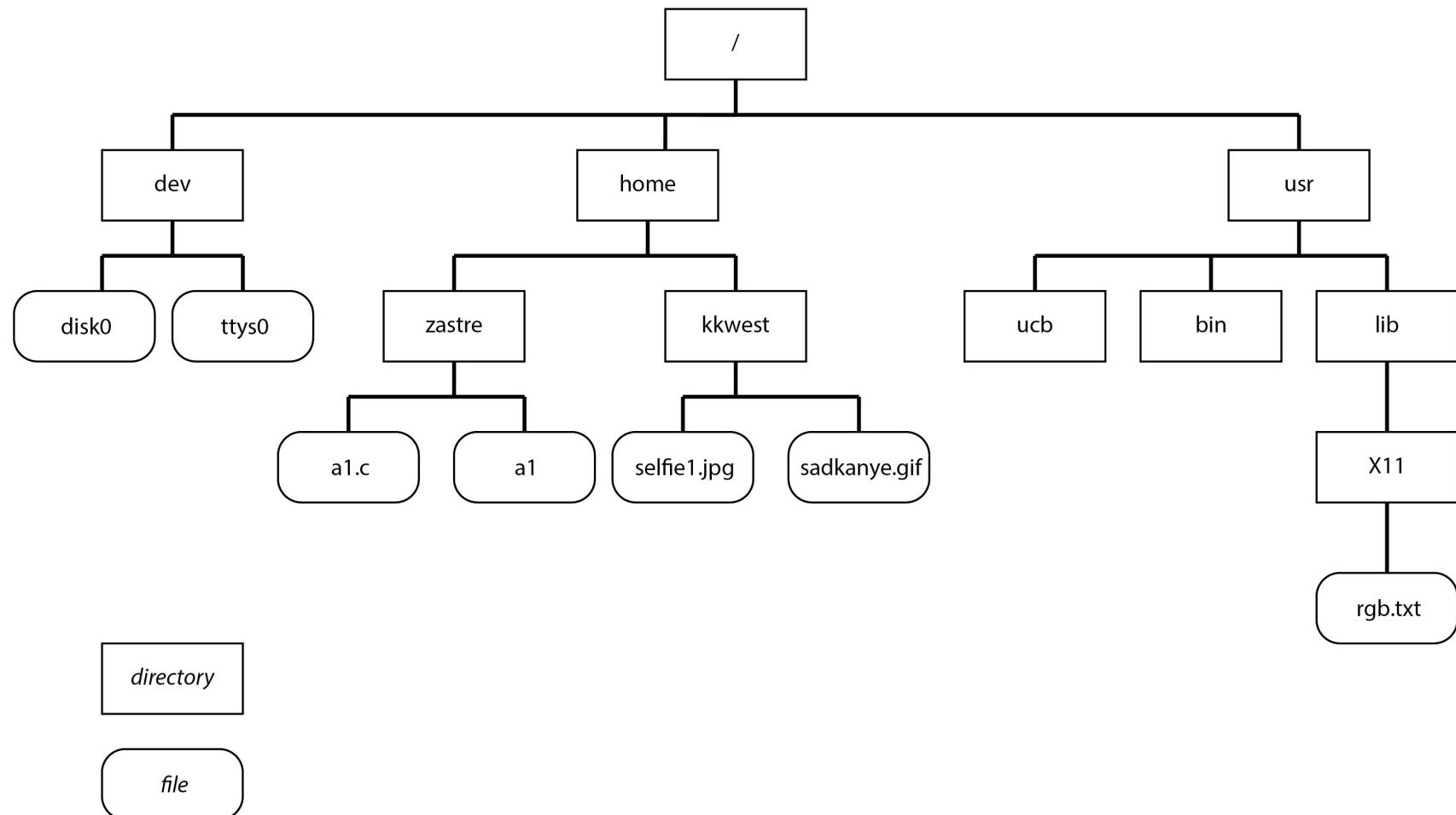


UNIX filesystem

- arranged as a hierarchy (tree-like structure)
 - organized as a collection of directories; think of a directory as a folder
 - forward slash "/" is used to separate directory and file components (cf., Windows uses "\\")
- the root of the filesystem is represented by the **root-directory**, which we denote by a single "/"



Part of a (hypothetical) UNIX filesystem tree



Some properties of directories

- directories are actually “ordinary” files
 - information contained in a directory file simply has a special format
 - every directory contains two special directory entries
 - ".." refers to parent directory in hierarchy
 - ":" refers to the current directory (itself)
 - '~' is used to denote a **home directory**
 - % cd /home/*user* ≈ cd ~*user*
 - % cd ~



Directory commands (ignore %)

- Example:

```
% cd /home
```

- listing directories

```
% ls  
zastre dtrump  
% ls dtrump  
Fence.java right_right_then_left.mov
```

- relative pathnames

```
% cd /home  
% open dtrump/right_right_then_left.mov  
% open ./dtrump/right_right_then_left.mov  
% open ../../dtrump/right_right_then_left.mov
```



“working” vs. “home” directory

- “Working” directory is the directory the shell thinks you are “in” at any given time.
 - Eliminates the need to continuously specify full pathnames for files and directories
 - “Relative pathnames” are locations worked out in relation to (relative to) to the **working directory**.
- “Home” directory is (usually) configured to be your working directory upon logging into the system
 - Sometimes called the “login” directory
 - `/home/zastre` & `/home/seng265` are typical home directories



Directory commands (2)

- traversing directories

```
% cd /usr  
% ls  
ucb bin lib
```

- display the **current working directory**

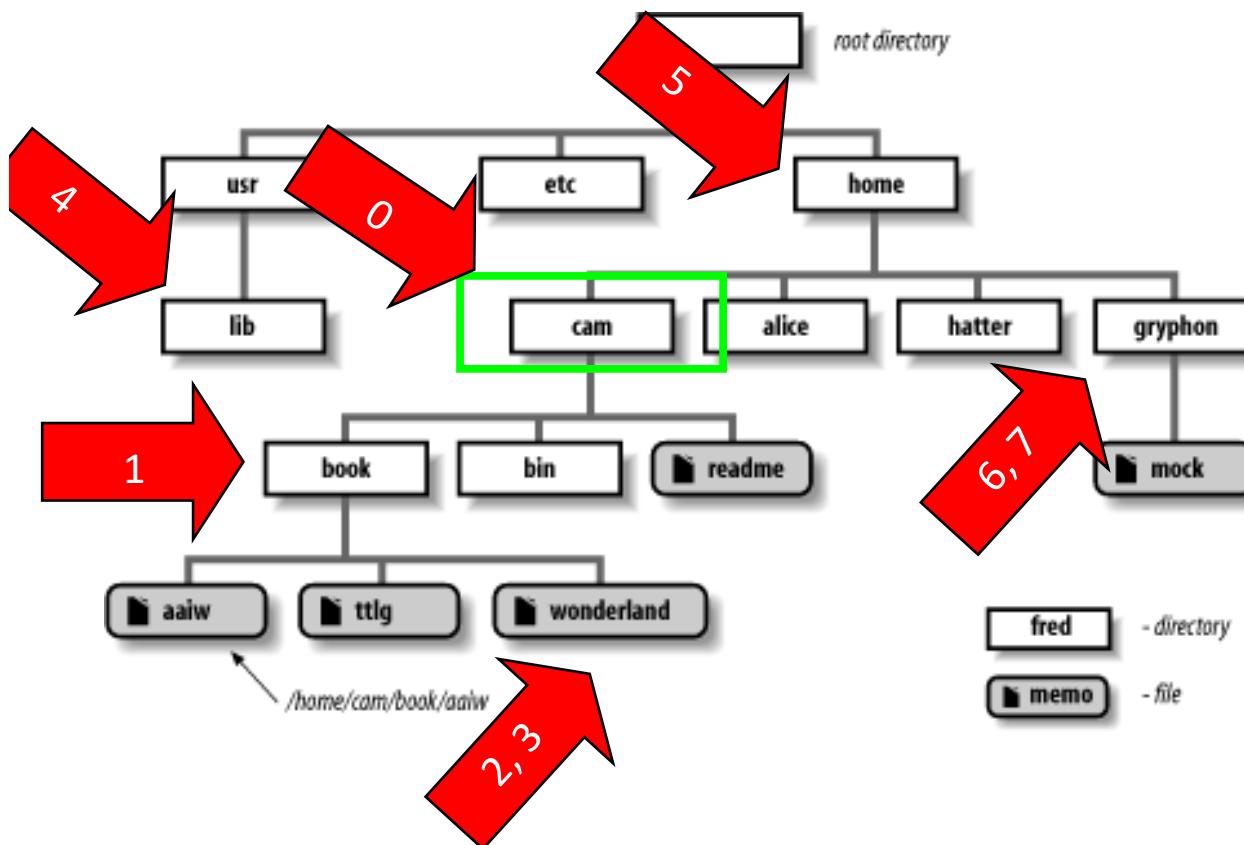
```
% pwd  
/usr
```

- creating a **symbolic reference** to a file (i.e., like an alias)

```
% cd ~zastre  
% # ln -s <target> <name of alias>  
% ln -s a1 sample_solution  
% ls  
a1 sample_solution
```



working directories



```
# "cam" is the logged-in user  
#  
# Each of the following commands  
# starts in Cam's current directory  
# /home/cam (i.e., every item  
# below assumes we reference  
# from at red-arrow 0).  
% cd book #1  
% vi book/wonderland #2  
% vi ~/book/wonderland #3  
% cd /usr/lib #4  
% cd .. #5  
% cd ../gryphon #6  
% cd ~gryphon #7  
% cd alice # ??
```



File attributes

- every plain file and directory has a set of **attributes**, including:
 - user name (owner of file)
 - group name (for sharing)
 - file size (bytes)
 - creation time, modification time
 - file type (file, directory, device, link)
 - permissions

```
% ls -l unix.tex test
-rwxr-xr-x 1 joe users      200 Dec 29 14:39 test
-rw-r--r-- 1 dmg users    21009 Dec 29 14:39 unix.tex
```



Who has permission?

- permissions can be set for
 - user ("u") [-rwx-----]: the file owner
 - group ("g") [-----rwx---]: group for sharing
 - other ("o") [-----rwx]: any other
 - all ("a"): user + group + other
- **user**: the owner of the file or directory; owner has full control over permissions
- **group**: a group of users can be given shared access to a file
- **other**: any user who is not the owner and does not belong to the group sharing a file



What kind of permissions?

- files:
 - **read (r)** : allows file to be read
 - **write (w)**: allows file to be modified (edit,delete)
 - **execute (x)**: tells UNIX the file is executable
 - **dash (-)** : owner/group/other have no permissions
- directories:
 - **read (r)**: allows directory contents to be read (listed)
 - **write (w)**: allows directory contents to be modified (create, delete)
 - **execute (x)**: allows users to navigate into that directory (e.g, with the `cd` command)
 - **dash (-)** : owner/group/other have no permissions



chmod: set file permissions

- there are several ways to use "chmod"
 - use letter symbols to represent "who" and "what"

```
% chmod o+rx ~/.www/ppt    # other can read and cd "ppt"
% chmod u+x run.pl          # script "run.pl" executable
% chmod go-rwx ~/private    # removing access group & other
% chmod u=rwx,g=rx,o=x foobar.txt # all permissions
```
 - can also use "octal" (base 8) notation, representing each three-bit field with an octal digit; $r \in \{0,4\}$, $w \in \{0,2\}$, $x \in \{0,1\}$

```
% chmod 751 foobar.txt      # specify all permissions
```
 - the following are different ways of setting "read-only" permission for a file

```
% chmod =r file
% chmod 444 file
% chmod a-wx,a+r file
```



Various & Sundry

- UNIX file names are case-sensitive
 - assumption here: underlying file system is UNIX
 - e.g., `myFile` and `myfile` are two different names, and the `Logout` command cannot be typed as `Logout`
- commands are available to change the **owner** and/or **group** of a file; e.g. `chown`, `chgrp`
- **pager** is a command (`less`, `more`) used to display a text file one page at a time

```
% less unix.txt
```
- quickly create a file (or update the timestamp of an existing file)

```
% touch unix.txt
% ls -l unix.txt
-rw-r--r-- 1 zastre users 0 Aug 29 14:39 unix.tex
```



Introduction to UNIX (contd)

- The shell
- Basic command syntax
- Command types
- Getting help on commands
- I/O streams
- Redirection and pipelining
- Command sequences
- Console



the shell (again)

- The shell is **the** intermediary between you and the UNIX OS kernel
- It interprets your typed commands in order to do what you want
 - the shell reads the next input line
 - it interprets the line (expands arguments, substitutes aliases, etc.)
 - performs action
- There are two families of shells:
 - “sh” based shells, and “csh” based shells
 - they vary slightly in their syntax and functionality
 - we’ll use “bash”, the Bourne Again SHell (derivative of “sh”, known as the “Bourne shell”)
 - tip: you can find out what shell you are using by typing:
`echo $SHELL`



basic command syntax

% cmd [options] [arguments]

- cmd represents here some builtin-shell or UNIX command
- [options] = zero or many options
- [arguments] = zero or many arguments

<i>option</i>	<i>example</i>
opt	a
-opt	-v
--optname	--verbose
-opt arg	-s 5
--optname arg	--size 5



basic command syntax (2)

- **opt** is a character in {a..zA..Z0..9}
- **optname** is an option name; e.g., **--size**, **--keep**
- **argument**, **arg** is one of the following:
 - file name
 - directory name
 - device name, e.g., `/dev/hdb2`
 - number, e.g., `10`, `010`, `0x1af`, ...
 - string, e.g., `"*.c"`, `"Initial release"`, ...
 - ...



command types

- commands can be:
 - built into the shell (e.g., `cd`, `alias`, `bg`, `set`,...)
 - aliases created by the user or on behalf of the user (e.g., `rm='rm -i'`, `cp='cp -i'`, `vi='vim'`)
 - an executable file
 - binary (compiled from source code)
 - script (system-parsed text file)
- Use the `type` command to determine if a command is builtin, an alias, or an executable.

```
% type rm  
rm is aliased to ‘rm -I’
```



some simple commands

% **cat** [file1 file2 ...]

- (catenate) copy the files to stdout, in order listed

% **less** [filename]

- browse through a file, one screenful at a time

% **date**

- displays current date and time

% **wc** [filename]

- (word count) counts the number of lines, words and characters in the input

% **clear**



getting help on commands

- You can ask for help in several ways.
- Display a description of a shell command (builtin)

```
% help times
```

- Display a long description of a command (from section *n* of manual)

```
% man [n] chmod
```

- Display a one line description of a command

```
% whatis gcc
```

```
gcc      gcc (1) - GNU project C and C++ compiler
```

- Use "info"

```
% info gcc
```

```
% info ls
```

- Many commands provide their own help

```
% somecmd -h
```

```
% somecmd --help
```



input & output streams

- each UNIX program has access to three I/O “streams” when it runs:
 - **standard input** or **stdin**; defaults to the console keyboard
 - **standard output** or **stdout**; defaults to the console screen
 - **standard error** or **stderr**; defaults to the console screen
- the shell provides a mechanism for overriding this default behaviour (**stream redirection**)



stream redirection

- redirection allows you to:
 - take input from a file
 - save command output to a file
- redirecting from/to files using **bash** shell:
 - stdin:

```
% cmd < file
```

```
% less < ls.1
```
 - stdout:

```
% cmd > file          # write
```

```
% ls -la >dir.listing
```

```
% cmd >> file        # append
```

```
% ls -la /home >>dir.listing
```
 - stderr:

```
% cmd 2> file          # write
```

```
% cmd 2>> file        # append
```



stream redirection (2)

- redirecting stdin and stdout simultaneously
 - % cmd < infile > outfile
 - % sort < unsorted.data > sorted.data
- redirecting stdout and stderr simultaneously
 - % cmd >& file
 - % grep 'hello' program.c >& hello.txt
 - % cmd 1>out.log 2>err.log
- UNIX gotchas:
 - symbols used for redirection depend on shell you are using
 - our work will be with the Bash shell (bash, sh)
 - slight differences from C-shell's (csh, tcsh)



pipes

- Pipes are considered by many to be one of the major Unix-shell innovations
 - excellent tool for creating powerful commands from simpler components,
 - does so in an effective, efficient way.
- Pipes route standard output of one command into the standard input of another command
- Allows us to build complex commands using a set of simple commands
- Motivation:
 - without pipes, lots of temporary files result



without pipes

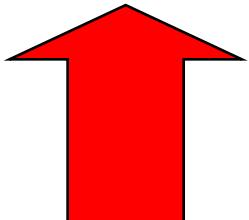
- Example: How many different users are currently running processes on the server?



without pipes

- Example: How many different users are currently running processes on the server?

```
% ps aux > temp1.txt  
% awk '{ print $1 }' temp1.txt > temp2.txt  
% sort temp2.txt > temp3.txt  
% uniq temp3.txt > temp4.txt  
% wc -l < temp4.txt > temp5.txt  
% cat temp5.txt
```



Off by one – need to
mentally subtract one
from the resulting number



with pipes

- Example: How many different users are currently running processes on the server?

```
% ps aux | awk '{ print $1 }' | sort | uniq | wc -l
```

```
% ps aux | awk '{ print $1 }' | sort | uniq | wc -l | xargs expr -1 +
```

- Note the structure of the command:
 - “generator” command is at the head
 - successive “filter” commands transform the results
 - this is a very popular style of Unix usage



A bit more about pipes

- Pipes can save time by eliminating the need for intermediate files
- Pipes can be arbitrarily long and complex
- All commands are executed **concurrently**
- If any processing error occurs in a pipeline, the whole pipeline fails



command sequencing

- multiple commands can be executed sequentially, that is: cmd1;cmd2;cmd3;...;cmdn
% date; who; pwd
- may group sequenced commands together and redirect output
% (date; who; pwd) > logfile
- note that the last line does not have the same effect as:
% date; who; pwd > logfile



Introduction to UNIX (contd)

- Filename expansion
- Command aliases
- Quoting and backslash escapes
- **bash** command history
- Job control
- Shell/environment variables
- Customizing your shell



filename expansion

- "shorthand" for referencing multiple **existing** files on a command line
 - * any number of characters
 - ? exactly one of any character
 - [abc] any character in the set [abc]
 - [!abc] any character **not** in the set [abc]
- these can be combined together as seen on the next slide



filename expansion (2)

- examples:
 - count lines in all files having the suffix ".c"
% wc -l *.c
 - list detailed information about all files with a single character file extension
% ls -l *.?
 - send to the printer all files with names beginning in Chap* and chap* files
% lpr [Cc]hap*



filename expansion (3)

- * matches any sequence of characters (except those with an initial period)

```
% rm *.o          # remove all files ending in '.o'  
% rm *            # remove all files in directory  
% rm ../*-old*.c
```

- ? matches any single character (except an initial period)

```
% rm test.?      # remove test.c and test.o (etc.)
```

- So to delete a file of the form ".filename" you can't use wildcards

```
% rm .viminfo
```

How do we delete a file named *?



quoting

- controls bash's interpretation of certain characters
- what if you wanted to pass '>' as an argument to a command?
- **strong quotes** – All characters inside a pair of single quotes (') are preserved.
- **weak quotes** – Some characters (\$,) inside a pair of double quotes ("") are expanded (interpreted) by the shell.
- **backquotes** – substitute result of evaluation as a command



quoting

```
% echo $SHELL *  
/bin/bash file1 file2 file3
```

```
% echo '$SHELL' '*'  
$SHELL *
```

```
% echo "$SHELL" "*"  
/bin/bash *
```

```
%echo `date`  
Fri May 12 11:54:27 PDT 2017
```



backslash escaping

- Characters used by **bash** which may need to be escaped:
~, ` , #, \$, &, *, (,), \, [,], {, }, ;, ', ", <, >, /, ?, !
- single characters can be "protected" from expansion by prefixing with a backslash ("\\")
cmd * is the same as typing cmd '*'
- protecting special characters in such a manner is an example of **backslash escaping**

```
% cp ~bob/junk \\* # make copy of junk named '*'  
% rm '*' # remove '*' (not "delete all files")
```
- Single quotes around a string turn off the special meanings of most characters

```
% rm 'dead letter'  
% cp ~bob/junk '*' # same as up above
```

command substitution

- backquotes (`) are used to substitute the result of evaluating a command into a quoted string or shell variable:

```
% echo "Current date is: `date`"  
Current date is: Fri May 12 11:54:27 PDT 2017  
% BOOTTIME=`date`  
% echo $BOOTTIME  
Fri May 12 11:54:27 PDT 2017
```

- standards-compliant (i.e. POSIX) style avoids backticks:

```
% echo "Current date is: $(date)"  
Current date is: Thu 15 Sep 2011 14:58:13 PDT
```



bash command history

- bash (and other shells like sh, tcsh, ksh, csh) maintain a history of executed commands
- uses the readline editing interface
- history will show list of recent commands

```
% history    # print your entire history  
% history n # print most recent n commands  
% history -c      # delete your history
```
- a common default size of the history is 500 commands
 - and the history is usually remembered across login sessions



Using history

- simple way: use up and down arrows
- using the “!” history expansion

% ! ! repeat last command

% !n repeat command number n

% !-n repeat the command typed
n commands ago

% ! foo last command that started with foo



shell variables

- a running shell carries with it a **dictionary** of variables with values
- some are **built in** and some are **user defined**
- used to customize the shell
- use **env** to display the values of your **environment variables**
- use **set** to display the values of your **environment + shell variables**

```
% env  
PWD=/home/bgates  
GS_FONTPATH=/usr/local/fonts/type1  
XAUTHORITY=/home/dtrump/.Xauthority  
TERM=ansi  
HOSTNAME=c70  
...
```



shell variables (2)

- many variables are automatically assigned values at login time
- variables may be re-assigned values at the shell prompt
- new variables may be added, and variables can be discarded
- assigning or creating a variable – and notice absence of spaces around the "=" symbol:
`% somevar="value"`
- to delete a variable:
`% unset somevar`
- To use the value of a shell variable use the \$ prefix:
`% echo $somevar`



PATH shell variable

- helps the shell find the commands you want to execute
- its value is a list of directories separated by ':' symbol
- when we intend to run a program, the directory of its executable should be in the PATH in order to be found quickly
- Example: assume that program `cmd` is located in directory `"/usr2/bin"`

```
% echo $PATH  
PATH=/usr/bin:/usr/sbin:/etc  
% cmd  
bash: cmd: command not found  
% PATH="$PATH:/usr2/bin"  
% echo $PATH  
PATH=/usr/bin:/usr/sbin:/etc:/usr2/bin  
% cmd  
(... now runs ...)
```

- the shell searches sequentially in the order directories are listed



environment variables

- some shell variables are exported to every subshell
 - when executing a command, the shell often launches another instance of the shell; this is called a **subshell**
`% (date ; who ; pwd) > logfile`
 - the subshell executes as an entirely different process
 - the subshell “inherits” the environment variables of its “parent” (main shell)
- “exporting” shell variables (*var*) to the environment
 - `% export var`
 - `% export var=value`
- example:
`% export EDITOR=vim`



customizing the shell

- In your accounts there will be two files you can modify to customize the **bash** shell
- “`~/.bash_profile`” is evaluated by the shell each time you login to your account.
- by default, “`~/.bash_profile`” **sources** (reads and evaluates) a second file “`~/.bashrc`”
- **conventional wisdom** suggests that permanent shell/environment variables should be placed in “`~/.bash_profile`”, and aliases should be placed in “`~/.bashrc`”
- system administrators, for very sound reasons, often prefer that we don’t modify “`~/.bash_profile`”, but instead customize the shell by modifying “`~/.bashrc`” (adding shell variables, aliasing, etc.)
- In both cases, the changes you make to these files will not take effect until you source the modified file
`% source .bashrc`

Use with caution!

shell scripting

- Why write a shell script?
 - Sometimes it makes sense to wrap a repeated task into a command.
 - Sequences of operations can be placed in a script and executed like a command.
- Not everything is sensible for a script, though
 - For some problems it would make more sense for a full program
 - Instances: resource-intensive tasks, complex applications, mission critical apps, etc.



Some simple scripts

- For what appears below, ensure the file containing the script is executable

```
#!/bin/bash  
echo 'Hello, world!'
```

hello.sh

```
#!/bin/bash  
uptime  
users
```

status.sh

- The very first line is called a "shebang" path
 - What follows the "#!" ("shebang") is the command that interprets everything else that follows.



Selection

- The numeric representation of true and false are inverted
 - True == 0
 - False == anything else
- Common tests involve file operators
- Note the spacing in the test expression!

```
#!/bin/bash

if [ -e /home/zastre/seng265/assign1 ] ; then
    echo 'Hooray! The file exists!'
else
    echo 'Boo! The file ain't yet there...'
fi

# Other tests:
# -f True if file is a regular file
# -d True if file is a directory
# -w True if file exists and is writable
# -O True if the account running script owns the file
```



String and arithmetic relationals

- String operators compare lexical order (i.e., dictionary order)
- Arithmetic operators only work on integers
- Note spacing variants...

```
#!/bin/bash

if [ "abc" != "ABC" ] ; then
    echo 'Case does matter here' ; fi

if [ 12 < 2 ] ; then
    echo 'Why is 12 less than 2??!' ; fi

a=12
b=2
if [ "$a" -lt "$b" ]
then
    echo 'Something is wrong with numbers here...'
else
    echo "Ah ha! $a can be either a string or integer"
fi
```

More generate tests

- Sometimes we could use a good old logical OR or logical AND
- Some C-like expressive power is possible
- (Note slight syntax variation with the "if" statement)

```
#!/bin/bash

if [[ -e ~/.bashrc && ! -d ~/.bashrc ]]
then
    echo 'Definitely a config file to process'
fi
```



Arithmetic? Not so good...

- Bash usually treats variables as strings
- We can force bash to treat a variable's value as an integer

```
#!/bin/bash

x=1
x=$x+1
echo $x    # Still a string

y=1
(( y=y+1 ))
echo $y    # This gets it...
```



Iteration

- List-like values are common in the shell
 - Arguments passed to command
 - Files expanded by wildcards
- A list literal is simply spelled out

```
#!/bin/bash

for x in 1 2 a
do
    echo $x
done

for x in *
do
    echo $x
done
```



Iteration

- The output from commands may be used to create a list
 - Note that the text from the command will be tokenized into a sequence of individual words...
- We can also write old-style for loops
- Use "set -x" to have the shell print out commands as they are executed
 - Handy for debugging

```
#!/bin/bash

set -x

for i in $(date) ; do
    echo item: $i
done

for (( i=0; i<5; i++ )) ; do
    echo item: $i
    echo in$i.txt
done
```



Iteration

- Also: while loops
 - Recall: quantity in the square brackets is tested
 - Top-tested

```
#!/bin/bash

COUNTER=0
while [ $COUNTER -lt 5 ] ; do
    echo The counter is $COUNTER
    let COUNTER=COUNTER+1
done

COUNTER=8
until [ $COUNTER -lt 2 ] ; do
    echo COUNTER $COUNTER
    let COUNTER-=1
done
```



Lots more to shell scripting...

- ... parameter expansion ...
- ... regular expressions ...
- ... but we have enough for now.
- Recall: selection and loops control by a test
 - If a program runs to completion without errors, it returns 0;
 - otherwise it should return something other than zero
 - This can be used to phrase a conditional (i.e., for driving a test plan involving sets of inputs and outputs)



endnotes

- This was a brief introduction to UNIX with a heavy emphasis on the use of the "bash" shell
- you should try out the concepts presented in these slides
- you should read man pages and/or other sources of information
 - books
 - online resources
- you can learn from others
 - rarely is there a single way to do the same thing
 - especially true when constructing large commands using pipes
- Slides on bash shell scripting based on lectures by Kurt Schmidt (Drexel University)

