Linux Productivity Tools

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Table of Contents

Part 1: Overview and Logistics *[3 slides]*

orientation and practical stuff

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Slides and practice data for download

- Two text files, a pdf and a pptx file for slides
- states.txt
  - Tabular data
  - Five columns
- prose.txt
  - Prose with sentences and paragraphs
- www.olcf.ornl.gov/calendar/linux-command-line-productivity-tools/
- uncompress: **`unzip lpt.zip`**

About You and Me

- Basic knowledge of Linux is assumed but feel free to interrupt and ask questions
  - common commands, basic understanding of Linux files and directories, editing of simple files etc.
- Access to a basic Linux terminal is assumed
  - A linux laptop, Macbook will do
  - login node to some cluster
- About Me
  - Linux Engineer with CADES
  - Command line enthusiast

Overview

- Build powerful **command-lines and scripts**
  - **We will use Bash with default key-bindings**
  - **We will assume GNU/Linux and call it Linux**
- Linux utilities that are available on most installations
- Goal is to be efficient and effective rather than to be an "expert"
- Benefits: save time, efficient for system, good longterm payback
- **We cover: productive tools and techniques for an HPC Linux user**
- **We do not cover:** System administration, security, networking

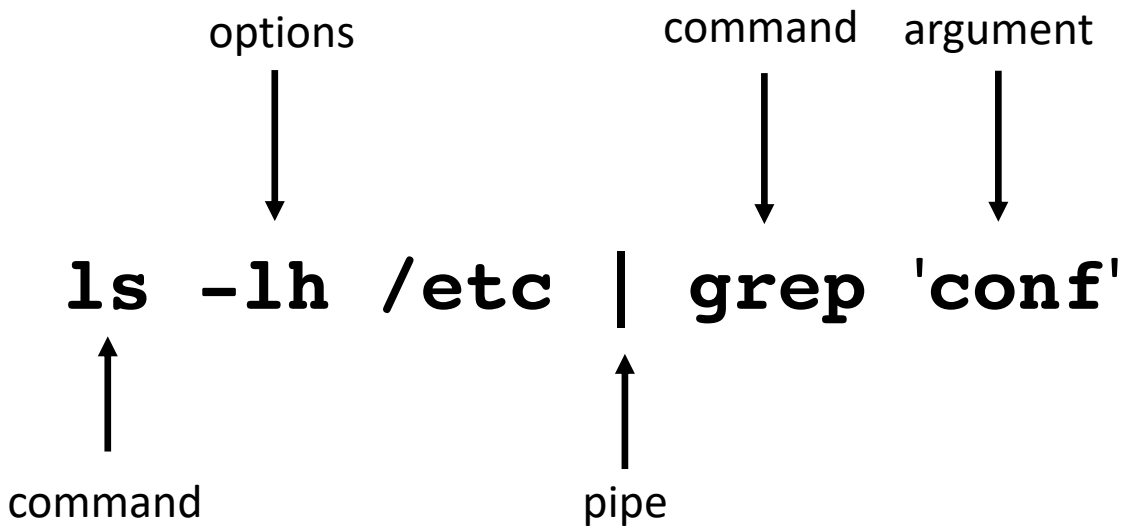
part 2: The Basics *[12 slides]*

welcome to the school of command line wizardry!

back to toc

Try It

Anatomy of a Linux Command



append & at the end to run the command in background

Try It

Know the System

- **`id`**: know yourself
- **`w:`** who is logged in (**`-f`** to find where they are logging in from)
- **`lsblk`**: list block storage devices
- **`lscpu`**: display information about the cpu architecture
- **`free`**: free and used memory (try **`free -g`**)
- **`lsb_release`**: distribution information (try **`lsb_release -a`**)

PS0: Use **`ctrl-c`** to kill stuck commands or long running ones

PS1: Some commands may not be available on some systems: **`which <cmdname>`** to verify

Try It

Wildcards

- **`* any number of characters`**
  - **`ls -lh /etc/*.conf`**
- **`? expands to one character`**
  - **`ls -ld ? ?? ???`**
- Negation (`!`) eg. **`ls -ld [!0-9]*`**
- Escaping and quoting
  - \ for escaping a wildcard
  - ' for quoting a wildcard
  - both will prevent expansion

Try It

Many ways to get help

- **`man nano`**
  - Manual pages
  - Organized sectionwise--one page for each section (if exists)
- **`wget --help`**
  - Handy for quick syntax reference
- **`info curl`**
  - Modern
- Browse **`/usr/share/doc/git-1.*/`**
  - Usually a README file has info

Try It

Work with Files

- **`cat`** for relatively short files
  - **`cat prose.txt`**
- **`less`** is more than **`more`** for long files
  - **`less /etc/ntp.conf`**
- **`tail -f:`** watch a file growing live
- What can you do about binary files? (not much)
  - **`strings`** will print the printable strings of file
  - **`od`** will print file in octal format
- Compare files with **`cmp`** (byte by byte), **`comm`** (line by line), **`diff`** (differences line by line)

Try It

Work with Processes

- List the processes: **`ps`** (commonly used flags: **`aux`**)
- **`ps`** implementations: POSIX, GNU and BSD!
  - implementations differ in behavior
  - determined by style of options: POSIX (-), GNU (--), BSD (no dash) before options
- Display processes: **`top`**, **`htop`**, **`atop`**
- Be **`nice`** and fly under the radar
  - Append "nice -n <niceness_value>" to any command to lower its prio, eg:
  - **`nice -n 19 tar cvzf archive.tgz large_dir`**
- Kill a process: **`kill <pid>`**

Try It

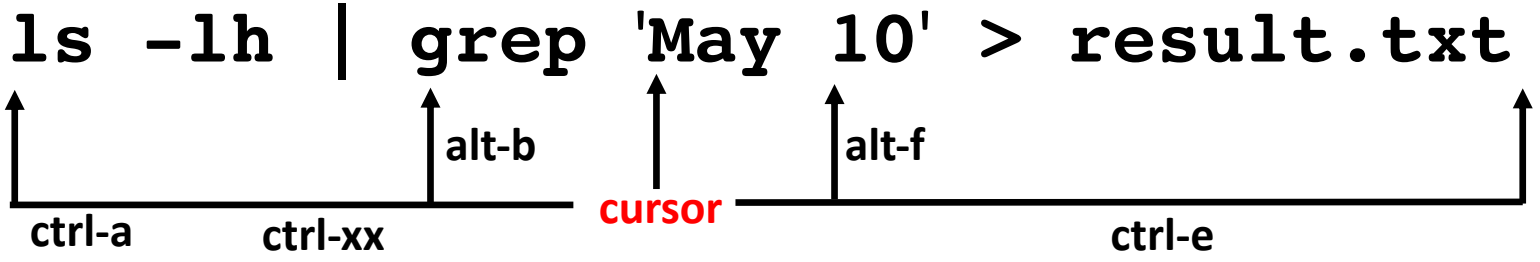
Work with Web: curl, wget, links

- **`curl`**: a tool to transfer data to/from the web
- **`curl`** is commonly used as a quick command to download files from the web
  - **`curl -O http://www.gutenberg.org/files/4300/4300-0.txt`**
- *libcurl* is a curl based library that could be used in program development
- **`wget`** is a similar utility; it has no library though
  - **`wget http://www.gutenberg.org/files/4300/4300-0.txt`**
- **`links`** is a useful text-based browser:
  - over remote connections and when **`curl/wget`** won't work
  - avoid pesky ads on the web
  - when internet is slow and only care about text

Try It

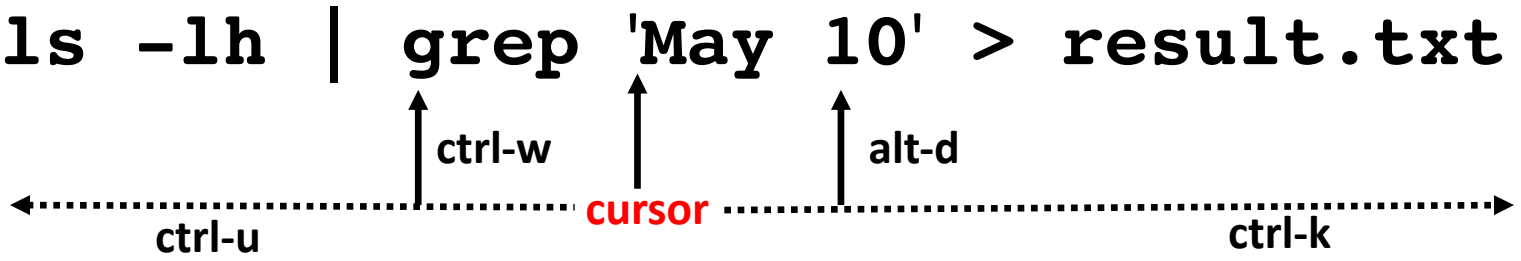
Be a command line ninja: Navigation

MAC users: terminal pref > profile > keyboard settings > Use option as meta key



Try It

Be a command line ninja: Deletion



use ctrl-y to paste back the last deleted item

Useful Shortcuts

- **!!** repeats the last command
- **!$** change command keep last argument:
  - **cat states.txt** # file too long to fit screen
  - **less !$** #reopen it with less
- **!*** change command keep all arguments:
  - **head states.txt | grep** '**^Al**' #should be tail
  - **tail !*** #no need to type the rest of the command

- **alt-.** #paste last argument of previous command
- **alt-<n>-alt-.** #paste **nth** argument of previous command

Try It

More Useful Tricks

- **>x.txt** #quickly create an empty file
- **fc** #(bash builtin)edit to **f**ix last **c**ommand
- **ctrl-l** #clear terminal
- **cd -** #change to previous dir
- **cd** #change to homedir
- **ctrl-r** #recall from history
- **ctrl-d** #logout from terminal

Practice and Exercises [5-7 mins]

- Use your favorite editor to edit .bashrc and .bash_profile --
  - add a line: **`echo 'I am bashrc'`** to .bashrc
  - add a line: **`echo 'I am bash_profile'`** to .bash_profile
- Close and reopen terminal, what do you see? Within terminal type **`/bin/bash`**, what do you see?
- Create a copy of prose.txt using cp prose.txt tmp.txt; make small change to tmp.txt and compare prose.txt and tmp.txt with cmp, comm and diff
- Delete those lines from .bashrc and .bash_profile when done
- The character class **`[[:class:]] may be used as wild card:`** class may be alpha, alnum, ascii, digit, upper, lower, punct, word; try **`ls /etc/[[:upper:]]*`**

Part 3: Streams, pipe and redirection *[11 slides]*

I am sure a gardener designed them!

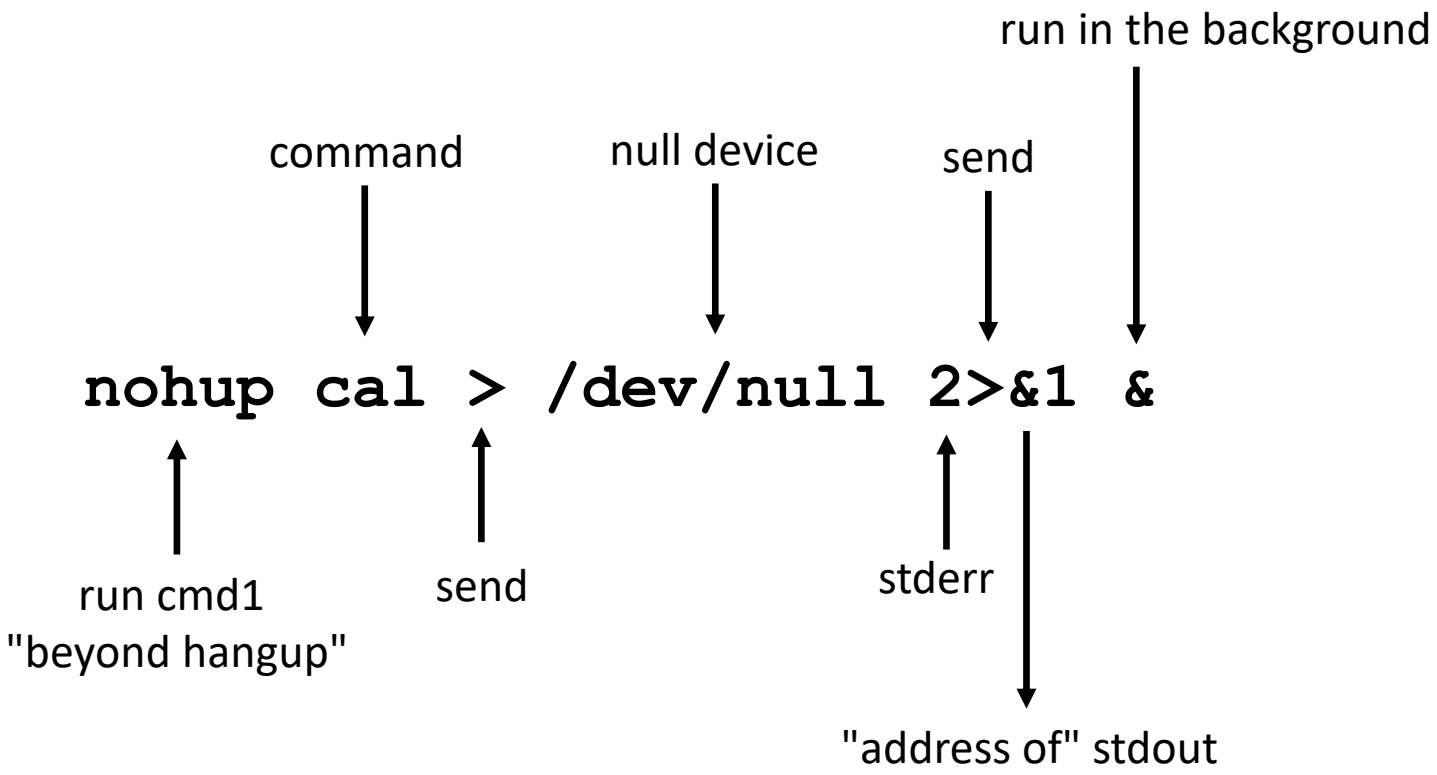
back to toc

Streams and Redirection

- Three streams: standard input (stdin), standard output (stdout) and standard error (stderr)
- Represented by **"file descriptors"**:
  - **0** for stdin
  - **1** for stdout
  - **2** for stderr

  - **&** is used to **"write into"** a stream, eg. **&1** to write into stdout
- Angle brackets are used for redirection:
  - **>** to send
  - **<** to receive
  - **>>** to append
  - **<<** to in-place append (used in "heredoc")
  - **<<<** is used in "herestring" (not covered today)

Anatomy of a redirection using streams



Redirection Quickref

- Send stdout to a file: **`ls > stdout.txt`**
- Send stderr to a file: **`bad_command 2> stderr.txt`**
- Send stdout and stderr to same file:
  `cmd > stdouterr.txt 2>&1`
  `cmd &> stdouterr.txt` `#bash v4 and later`
- Send stdout and stderr to a file and background the command:
  `long_running_cmd > stdouterr.txt 2>&1 &`
- Disregard stdout and stderr: **`cmd > /dev/null 2>&1`**
- Disregard stdout and stderr and let it run after you log out:
  - **`nohup overnight_running_cmd > /dev/null 2>&1 &`**

Try It

The pipe: run second command using output of first!

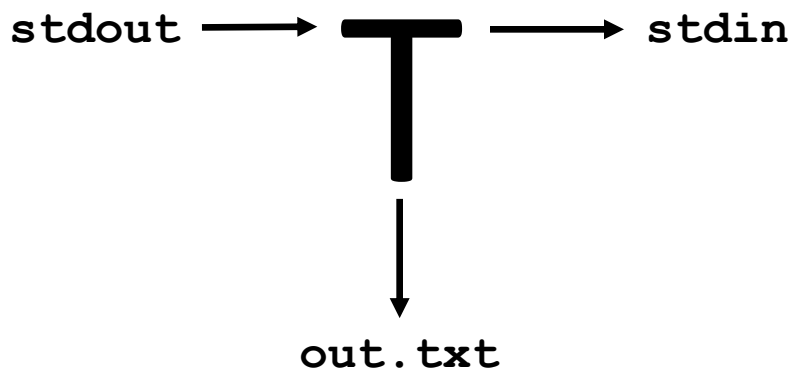
- A pipe is a Linux concept that automates redirecting the output of one command as input to a next command.
- Use of pipe leads to powerful combinations of independent commands. eg.:

```
find .| less #read long list of files page wise
head prose.txt | grep -i 'little'
echo $PATH | tr ':' '\n'#translate : to newline
history | tail #last 10 commands
free -m|grep Mem:|awk '{print $4}' #available memory
du -s *|sort -n|tail #10 biggest files/dirs in pwd
```

Try It

tee: send stdout to file **and** pipe/console

```
find . | tee out.txt | less
```



Try It

Exceptions

- Most commands receive input from stdin (so, pipe) **and** file, eg.
  - **wc states.txt** #ok
  - **wc < states.txt** #ok
- Produce error messages (**if any**) on stderr

- There are some exceptions though
- Some receive input only from stdin and not from file, eg.
  - **tr 'N' 'n' states.txt #(strangely) NOT OK**
  - **tr 'N' 'n' < states.txt** #ok
- Some receive input **neither from stdin nor from file,** eg.
  - **echo < states.txt #NOT OK**
  - **echo states.txt #NOT OK** (assuming you want to print file contents)
  - **echo "Hello miss, howdy?"** #ok, takes literal args
  - **cp**, **touch**, **rm**, **chmod** are other examples

`xargs`: When pipe is not enough!

- Some commands do not read from standard input, pipe or file; they need arguments
- Additionally, some systems limit on number of arguments on command line
  - for example: **`rm tmpdir/*.log`** will fail if there are too many **`.log`** files
- **`xargs`** fixes both problems
  - Appends **standard input** to commands as **arguments**
  - Partitions the list of arguments to a limited number and runs the command over them repeatedly as needed
- For instance create files with names on the somelist.txt file:
  `cat somelist.txt | xargs touch`

GNU Parallel

- Run tasks in parallel from command-line
- Similar to **`xargs`** in syntax
- Treats parameters as independent arguments to command and runs command on them in parallel
- Synchronized output -- as if commands were run sequentially
- Configurable number of parallel jobs
- Well suited to run simple commands or scripts on compute nodes to leverage multicore architectures
- May need to install as not available by default : www.gnu.org/software/parallel

Try It

GNU Parallel Examples

- Find all html files and move them to a dir

```
find . -name '*.html' | parallel mv {} web/
```

- Delete pict0000.jpg to pict9999.jpg files (16 parallel jobs)

```
seq -w 0 9999 | parallel -j 16 rm pict{}.jpg
```

- Create thumbnails for all picture files (imagemagick software needed)

```
ls *.jpg | parallel convert -geometry 120 {} thumb_{}
```

- Download from a list of urls and report failed downloads

```
cat urlfile | parallel "wget {} 2>/dev/null"
```

Practice and Exercises-1 [5 mins]

- Try the commands discussed in this section
- List all conf files in /etc that are permitted to access, redirect stderr to /dev/null
- Build a software and collect errors and output in separate files, replace underlines with right values
  `make all __ std.out __ >std.err`
- Run cmake command and gather all logs in a single file in background
  `cmake .. __ __ cmake.log __` `#bash v4 and above`
- Same as above in long format
  `mpirun -np 8 ./a.out __ outerr.txt 2>__1`

Practice and Exercises-2 [5 mins]

- Create a file titled the words that start with letter 'C' (**fill the __**):
  - **`grep '^c' states.txt | awk '{print $4}' | __ touch`**
- Remove temporary files:
  - **`find . -iname '*.tmp' | __ rm #ok`**
- Create a directory for all running processes
  - **`ps | awk 'NR != 1 {print $4}'| mkdir #NOT OK`**
  - **`ps | awk 'NR != 1 {print $4}'| __ mkdir #ok`**

Part 4: Classic Tools *[21 slides]*

the evergreens

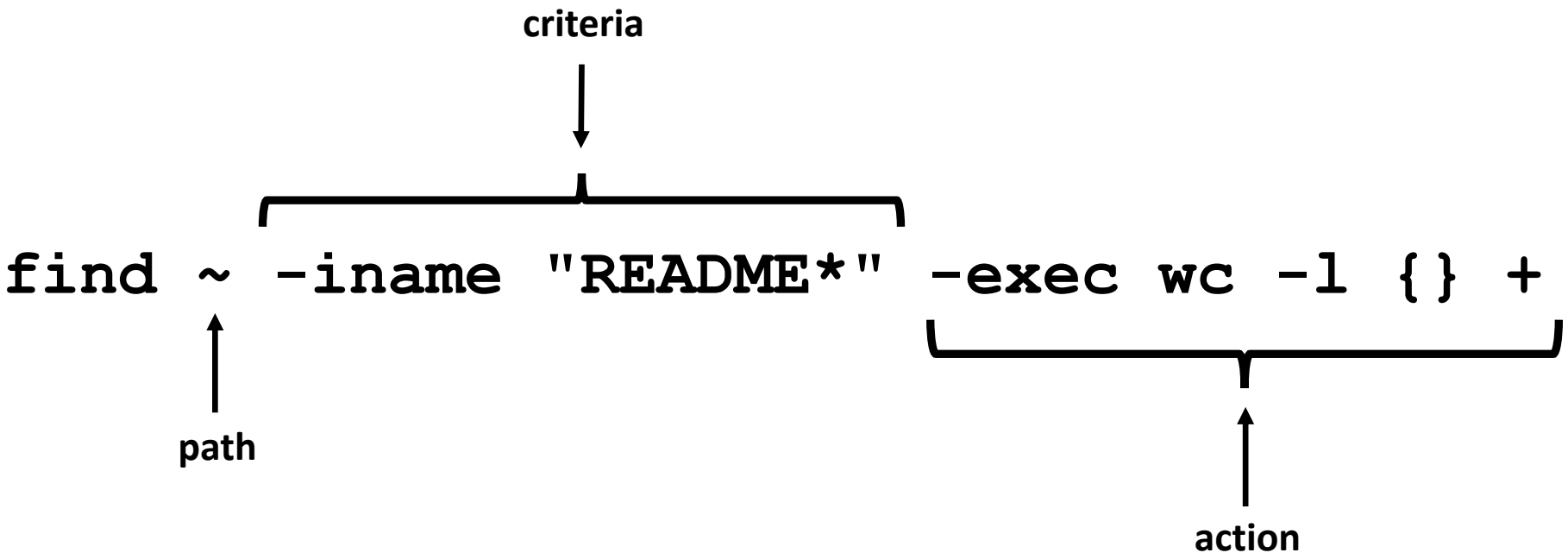
back to toc

Try It

The Versatile find

- *Recursively* examines a directory tree to look for files matching criteria and optionally takes *action* on found files
- Flexible: multiple criteria may be combined to build a very specific description of the file being searched
- Efficient: simple **`find`** is often faster than **`ls`**—very handy on slower filesystems with a large number of files
  - **`find . -maxdepth 1`** `#equivalent to ls`

Anatomy of find



Features of find

- **path**: may have multiple paths, eg. **`find /usr /opt -iname "*.so"`**
- **criteria**
  - -name, -iname, -type (f,d,l), -inum <n>
  - -user <uname>, -group <gname>, -perm (ugo)
  - -size +x[c], -empty, -newer <fname>
  - -atime +x, -amin +x, -mmin -x, -mtime -x
  - criteria may be combined with logical **and** (**`-a`**) and **or** (**`-o`**)
- **action**
  - -print -- default action, display
  - -exec *`cmd`* -- execute command *`cmd`*
  - -ls -- run **`ls -lids`** command on each resulting file
  - -ok *`cmd`* like exec except that command executed after user confirmation

Try It

find Examples

- **find . -type f -name "*.txt"** #all text files in current dir

- **find ./somedir -type f -size +512M -print** #all files larger than 512M in ./somedir

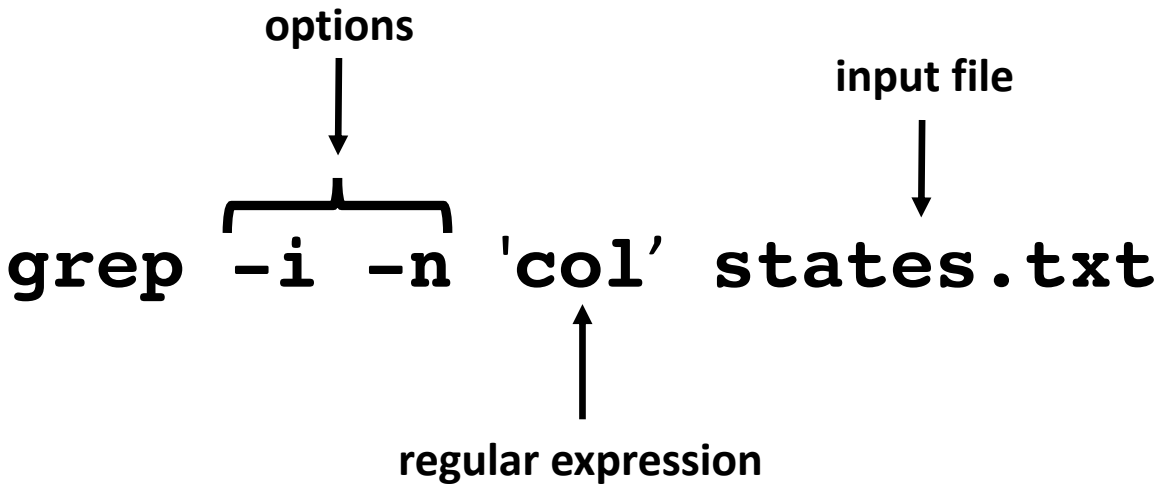
- **find . \(-name “*.c” -o -name “*.h” \)** #all files that have either .c **OR** .h extension

grep: Search for patterns in text

- **`grep`** originally was a command "**g**lobal **r**egular **e**xpression **p**rint" or '**`g/re/p`**' in the **`ed`** text editor
- It was so useful that a separate utility called **`grep`** was developed
- **`grep`** will fetch **lines** from a text that has a match for a specific pattern
- Useful to find lines with a specific pattern in a large body of text, eg.:
  - look for a process in a list of processes
  - spot check a large number of files for occurrence of a pattern
  - exclude some text from a large body of text

Try It

Anatomy of grep



Useful grep Options

- **`-i`**: ignore case
- **`-n`**: display line numbers along with lines
- **`-v`**: print inverse ie. lines that do not match the regular expression
- **`-c`**: print a count of number of occurrences
- **`-A<n>`**: include n lines after the match
- **`-B<n>`**: include n lines before the match
- **`-o`**: print only the matched expression (not the whole line)
- **`-E`**: allows "extended" regular expressions that includes (more later)

Regular Expressions

- a regular expression is an **expression** that matches a **pattern**.
- example pattern:

^why waste time learning, when ignorance is instantaneous?$

- regular expression: `b` `a` `r` ➔ no match
- regular expression: `e` `a` `r` ➔ **one** match ➔ "**learning**"
- regular expression: `w` `h` ➔ **two** matches ➔ "**why**" and "**when**"
- regular expression: `^` `w` `h` ➔ one match ➔ "**why**"
- regular expression: `u` `s` `?` `$` ➔ one match ➔ "**instantaneous?**"

Regular Expressions-contd.

- Special characters:
  - `^<anything>` will match from beginning of a line
  - `<anything>$` will match up to end of line
  - `.` will match any character
- Character class: one of the items in the [] will match, sequences allowed
  - `'[Cc]at'` will match Cat and cat
  - `'[f-h]ate'` will match fate, gate, hate
  - `'b[^eo]at'` will match "brat" but **not** "boat" or "beat"
- **Extended** regular expressions (use with egrep or grep **-E**)
  - `'*'` matches zero or more, `'+'` matches one or more, `'?'` matches zero or one occurrence of the **previous character**
  - `'|'` is a delimiter for multiple patterns, `'('` and `')'` let you group patterns
  - `{}` may be used to specify a repetition range in numbers

Who is this?

Try It

grep Examples

- Lines that end with two vowels: **`grep '[aeiou][aeiou]$' prose.txt`**
- Count occurrence of term 'max': **`grep -c 'max' prose.txt`**
- Check 5 lines before and after the term 'little':
  - **`grep -A5 -B5 'little' prose.txt`**
  - **`history | grep 'successful outputs' #comment commands and search with grep`**

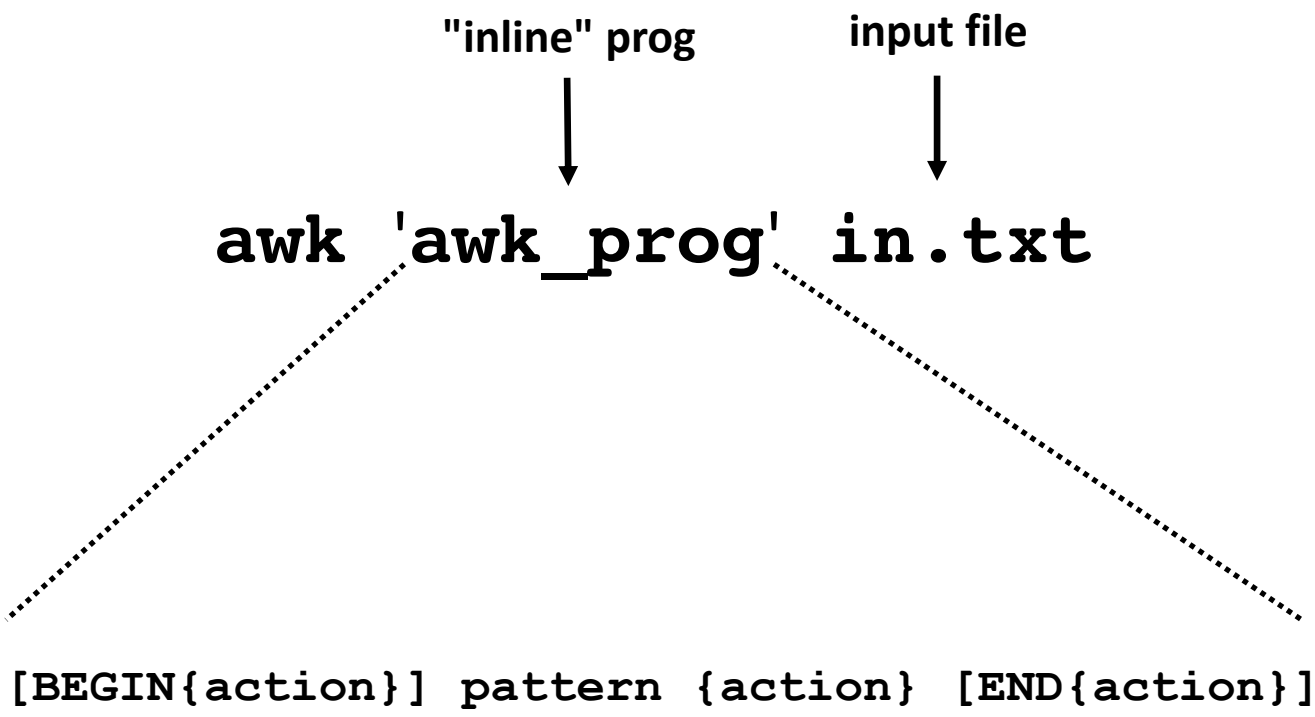
- A classic demo of the power of regular expressions
  - **`M[ou]'?am+[ae]r ([AEae]l[-])?[GKQ]h?[aeu]+([dtz][dhz]?){1,2}af[iy]`**
- This regular expression matches the dictator's name used by various news agencies:
  - **`Muammar al-Kaddafi`** (BBC)
  - **`Moammar Gadhafi`** (Associated Press)
  - **`Muammar al-Qadhafi`** (Al-Jazeera)
  - **`Mu'ammar Al-Qadhafi`** (US Department of State)

awk: Extract and Manipulate Data

- A **programmable** filter that reads and processes input **line by line**
- Has variables, loops, conditionals, arrays and built-in functions
- Reads input from file as well as standard input (so, pipes are good)
- May be run as **command** as well as an independent **program**
- **We will only discuss the command form of awk**

- **Highly recommended book**: The awk programming language by Aho, Kernighan and Weinberger, PDF available to download here: https://ia802309.us.archive.org/25/items/pdfy-MgN0H1joIoDVoIC7/The_AWK_Programming_Language.pdf

Anatomy of awk



awk patterns and actions

- A **pattern** is a regex that matches (or not) to an input line, eg.
  - **`/New/ {action}`** `#any line that contains 'New'`
  - **`/^[0-9]+ / {action}`** `#beginning with numbers`
  - **`/(POST|PUT|DELETE)/ {action}`** `#specific words`
- An **action** is a sequence of ops performed on matching lines, eg.
  - **`{print $1;}`** `#print first field`
  - **`{next;}`** `#skip to the next line of input`
  - **`{for (i=1;i<x;i++) {sum += $3;}}`** `#run a loop`
- User defined functions may be defined in any action block

awk Feature Highlights

- Fields in text are addressed by: **`$1, $2,…,$NF`**
  - **`$0`** means the whole line
- Pattern specified as **`/regex/`** or **`$n~/regex/`**
- Special variables
  - may be modified by user: **`FS(Field Sep), RS(Record Sep), OFS(Output FS), ORS(Output RS)`**
  - may **not** be modified by user: **`NF(num fields), NR(num records)`**
- Built-in functions, eg.: **`sin, cos, log, rand, substr`**

Try It

Some Useful awk Examples

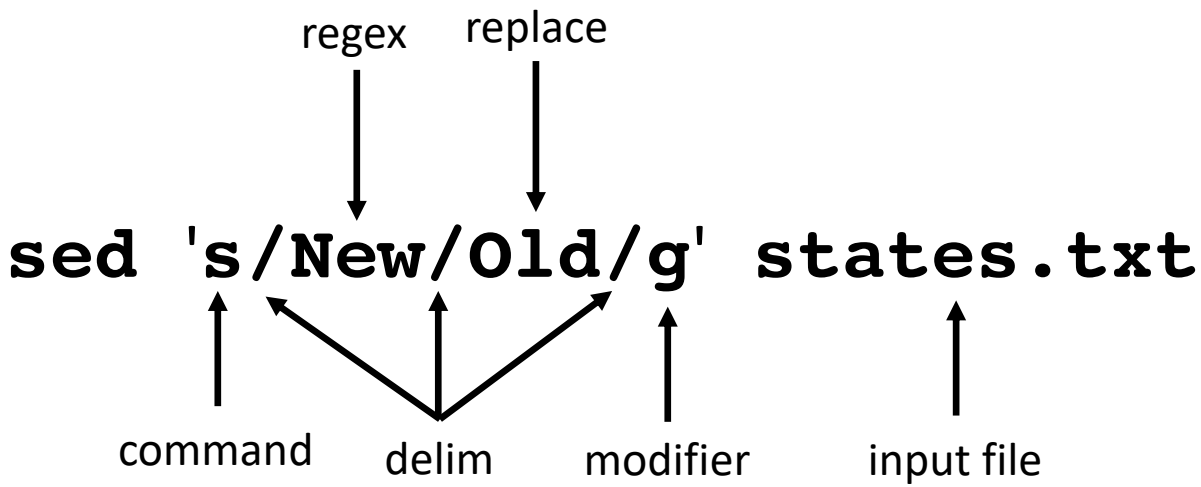
- awk **'{print $1}'** states.txt
- awk **'/New/{print $1}'** states.txt
- awk **NF>0** prose.txt #skip blank lines
- awk **'{print NF, $0}'** states.txt #num fields
- awk **'{print length($0)}'** states.txt #num chars
- awk **1** states.txt #just print the contents of file
- awk **'BEGIN**{print **substr("New York",5)**}' #York

sed: parse and transform text

- **`sed`** is a **s**tream **ed**itor
- Looks for a pattern **one line at a time** and applies changes (edits) to them
- A batch (non-interactive) editor
- Reads from file or stdin (so, pipes are good) **one line at a time**
- Lines are changed **one line at a time**
- The original input file is unchanged (sed is also a filter), results are sent to standard output

Try It

Anatomy of sed



sed Options

- address: may be a line number or a range, defaults to whole file
- command: **`s`**:substitute, **`p`**:print, **`d`**:delete, **`a`**:append, **`i`**:insert, **`q`**:quit
- regex: A regular expression
- delimiter: Does not have to be **`/`**, can be **`|`** or **`:`** or any other character
- modifier: may be a number **`n`** which means apply the command to n^{th} occurrence. **`g`** means apply globally
- Common **`sed`** flags: **`-n`** (no print), **`-e`** (multiple ops), **`-f`** (read sed commands from file), **`-i`** (in place)

Try It

Some Useful sed Examples

- **sed -n '5,9p' states.txt** #print lines 5 through 9
- **sed -n '$p' states.txt** #print last line
- **sed 's/[Aa]/B/g' states.txt**
- **sed '1,3d' states.txt** #delete first 3 lines
- **sed '/^$/d' states.txt** #delete all blank lines
- **sed '/^$/,$d' states.txt** #delete from the first blank line through last line
- **[negation]sed '/York/!s/New/Old/' states.txt** #change New to Old except when York appears in the line

Practice and Exercises [7-10 mins]

- Use **`sed`** to print lines 11-15 of states.txt
- Fill up the __ in the following find commands
  - **`__ . -type d -perm 777 -exec chmod 755 {} +`**
  - **`find . -type __ -name "*.tmp" -exec rm -f {} +`**
  - **`find __ -atime +50`** `#files <50 days in /usr/local/lib`
  - **`find . -mtime __ –mtime -100`** `#<50 & <100 days`
- Use **`awk`** to print only the state names and capitals columns from states.txt
- use **`grep`** to search for all lines of file states.txt containing a word of length four or more starting with the same two characters it is ending with. You may use extended regular expressions (**`-E`**)

Part 5:
Session Management *[4 slides]*

for when the network goes down on my world-saving project

back to toc

Workspace Management with tmux

- **`tmux`** is a terminal multiplexer that lets you create multiple, persistent terminals within one login
- In other words tmux is **a program which allows you to have persistent multiple "tabs" in a single terminal window**.
- Useful
  - when eg. a compilation or a remote copy operation will take a long time
  - for interactive multitasking
  - for exotic stuff such as pair programming

Try It

A Short tmux Tutorial

- Typical tmux workflow

```
tmux new -s mysession #start a new session
# run any commands as normal
ctrl-b :detach #detach the session, logout, go home
#later, log in again
tmux a -t mysession #get the same session back
```

- Other useful tmux commands

```
ctrl-b ( #switch to previous session
ctrl-b ) #switch to next session
tmux ls #list all sessions
tmux kill-session -t mysession #kill a session
```

Live collaboration with tmux

```
#user1#
tmux -S /tmp/collab
chmod 777 /tmp/collab

#user2#
tmux -S /tmp/collab attach
```

Practice and Exercises [5 mins]

- Try the commands discussed in this section
- Create three tmux sessions: s1, s2 and s3; detach them
- List the active sessions with **`tmux ls`**
- Kill the active sessions with **`tmux kill-session -t <name>`**
- Can you kill them all with one command? hint: use xargs in a pipe

Part 6: Safe and secure use of facilities *[9 slides]*

build secure tunnels

back to toc

ssh

- ssh (secure shell) used most commonly when connecting remotely
- Offers commands and options to efficiently and securely work with remote systems
- Uses the versatile and universal key-based exchange
- A rich set of practical and useful configuration features:
  - keep connection alive during inactivity
  - graphical content forwarding from remote to local
  - allows compressed data motion
  - lets you mount remote dirs using sftp

Basic usage of ssh

- Connect to a remote host
ssh [id@]remotehost

- Run a command on remote host and return
ssh id@remotehost uptime

- Connect with X11 forwarding
ssh -X id@remotehost `#-Y for secure X11 fwd`

- Copy your identity to remote host for keybased auth
ssh-copy-id -i id_file id@remotehost

- Connect with verbose output for troubleshooting
ssh -v id@remotehost

ssh config (~/.ssh/config)

```
Host summit
  Port 22
  hostname summit.olcf.ornl.gov
  User ketan2
  ServerAliveCountMax=3 #max num of alive messages sent without ack
  ServerAliveInterval=15 #send a null message every 15 sec

Host cades
 Port 22
 hostname or-condo-login.ornl.gov
 User km0
 ServerAliveCountMax=3
 ServerAliveInterval=15

# now to ssh/scp to cades, just need "ssh/scp cades"
```

Benefits of ssh config

- Makes ssh commands easier to remember in case of multiple hosts
- Customizes connection to individual hosts
- For more, see **`man 5 ssh_config`**
- For example: **`ssh summit`** is sufficient to connect to **`summit.olcf.ornl.gov`** with all the properties mentioned in the section:

```
Host summit
  Port 22
  hostname summit.olcf.ornl.gov
  User ketan2
  ServerAliveCountMax=3
  ServerAliveInterval=15
```

Secure Copy using scp

```
scp -r srcdir id@remotehost:$HOME #recursively copy dir

scp -C largefile id@remotehost:~/ #compress and copy

scp srcfile id@remotehost:$HOME #local to remote

scp id@remotehost:/etc/host.conf . #remote to local
```

SSH Tunneling

Why:
To access firewall'd ports on a host which is otherwise accessible by ssh

Terminology:

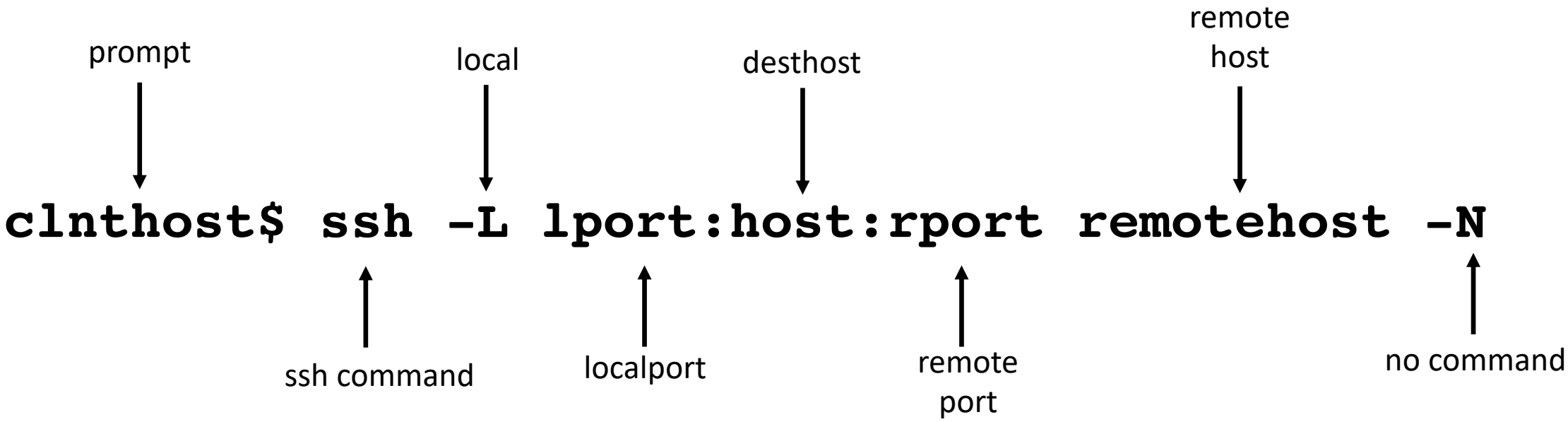
Local host: From where a connection goes out, usually runs ssh client

Remote host: One that gets connected to, runs ssh service

Port forwarding: When contents of a port are forwarded to another port on another host

Application: The application that is serving contents on given ports

Anatomy of SSH Tunneling Operation*



* simplest form

SSH Tunneling Example

- Run an HTTP server on remote node and browse through local web browser:
  - step 1. **`remote$ python -m SimpleHTTPServer 25000`**
  - step2. **`local$ ssh -L 8000:localhost:25000 id@remote -N`**
  - Open browser on **`local`** and navigate to **`localhost:8000`**

Practice and Exercises [5-7 mins]

- Try the commands discussed in this section
- Compare the time it takes with and without the -C switch of scp to send data remotely (hint: use the time command)
- Create a config file in your ~/.ssh directory, add the contents presented in previous slides to it. How will you test if it works?

Part 7: Debugging *[4 slides]*

Am I (or my guests) firewalled?

back to toc

Try It

strace

- Strace will print every system call your program uses:
  `strace <options> <program>`
  `strace -o lstrace.txt ls`

- Useful options
  - -f : trace child processes created by current program
  - -p <pid> : trace a running process by its pid
  - -s <len> : limit the string length of the output to len characters
  - -o <outfile> : save output in a file for later analysis
  - -e <syscall> : trace only a selected system call

netcat : 'cat' over network

- Send data over network
  `cat somefile | nc <remote_ip> <rport>`
  will send contents of somefile to remote_ip on port rport

- Useful to test if a remote socket (ip + port) is accepting data or even connected!
- Can be used to test client server connections:

server (ip: **`172.23.213.81`**)
`nc -l 21000 > incoming.txt`

client
`cat outgoing.txt|nc 172.23.213.81 21000`

netstat

- Every network program either sends data to a socket (host+port) or listens for data on a socket (host+port)
- netstat will give you information about what programs are running currently and listening on what ports:

`sudo netstat -tunapl #tuna please!`

- **`-t: tcp`**
- **`-u: udp`**
- **`-n: do not resolve names`**
- **`-a: display all sockets`**
- **`-p: display PID/Program name for sockets`**
- **`-l: display listening server sockets`**

Practice and Exercises [5 mins]

- Try the commands discussed in this section
- Create a **`netcat`** client and server on the localhost and transfer a file over port 45000
- strace the **`date`** command, what can you say about the command from trace?
- List only the tcp connections using **`netstat`**
- How will you find port statistics using **`netstat`** (hint: man netstat)

part 8: Scripting and Programming Tools *[13 slides]*

For when that 'hello world' becomes an NFS/DOE project

back to toc

Try It

Shell Scripting Basics

- Set of shell commands in a file that constitute an executable
- Arithmetic operations may be performed
- Variables and constants may be defined
- Conditionals, loops and functions may be defined
- Commands and utilities such as **`grep`**, **`sed`**, **`awk`** may be invoked
- A simple shell script:

```
#!/bin/bash
#prints hello
echo "Hello World"
```

- Save in a file **`my.sh`** and run as
  `bash -x my.sh` `# -x is a handy debugging tool`

Try It

Digression: heredoc

- Handy when you need to create "inplace" files from within a script
- example:
- **sh << END**
  echo "Hello World"
  END *<press enter>*
- Uses of heredoc
  - Multiline message using cat
  - Use variables to plug into created files

```
cat << feed >afile.txt
message line1
message line2
feed
```

```
#!/bin/sh
now=$(date)
cat <<END>timestamped.txt
The script $0 was last executed at $now.
other stuff
END
```

Try It

Shell Variable and Assignment

- Variables are implicitly typed
- May be a literal value or ***command substitute***
- **`vname=value`** `#assign value to variable vname`
- **`$vname`** `#read value of variable vname`

```
#!/bin/sh
msg="Hello World"
echo $msg
```

- Command substitution:
  - **`curdir=$(PWD)`**
  - **`curdate=$(date +%F)`**
  - **`echo "There are $(ls -1 | wc -l) items in the current dir"`**

Try It

Command line Parameters

- Parameters may be provided to a script at command line
- Accessible as **$1**, **$2**, …
- Special parameters:
  - **$0**: program name
  - **$#**: number of parameters
  - **$***: all parameters concatenated
  - **"$@"**: each quoted string treated as a separate argument

```
#!/bin/sh
echo "Program: $0" #$0 contains the program name
echo "number of parameters specified is $#"
echo "they are $*" #all parameters stored in $*
grep "$1" $2
```

Try It

Conditionals

- if-then-else construct to branch into a script similar to programming languages
- Two forms of conditional evaluation mechanisms:
  - **`test`** and **`[ … ]`**

```
#!/bin/sh
if test $USER = 'km0'
then
   echo "I know you"
else
   echo "who are you"
fi
```

```
#!/bin/sh
if [ -f /etc/yum.conf ]
then
   echo "yum conf exists"
   if [ $(wc -l < /etc/yum.conf) -gt 10 ]
   then
       echo "and is more than 10 lines"
   else
      echo "and is less than 10 lines"
   fi
else
     echo "file does not exist"
fi
```

Conditional test summary

- string based tests
  - -z string: length of string 0
  - -n string: length of string not 0
  - string1 = string2: strings are identical
- numeric tests
  - int1 -eq int2: first int equal to second
  - -ne, -gt, -ge, -lt, -le: not-equal, greater-than, -greater-or-equal, -less-than
- file tests
  - -r file: file exists and is readable
  - -w file: file exists and is writable
  - -f, -d, -s: regular file, directory, exists and not empty
- logic
  - !, -a, -o: negate, logical and, logical or

Try It

Loops

- Basic structure:

```
#!/bin/sh
for var in list
do
  command
done
```

```
#!/bin/sh
for i in $(seq 0 9)
do
  echo $i
done
```

- Typically used with positional params or a list of files:

```
#!/bin/sh
sum=0
for var in "$@"
do
  sum=$(expr $sum + $var)
done
echo The sum is $sum
```

```
#often used as one-liners on command-line
for file in $(\ls -1 *.txt) ; do echo we have "$file"; done
```

Should I write a script or a program

script

- (often) Quick and dirty
- Limited functionality
- Slow
- Interpreted
- Poor fit for algorithms
- example: bash, R

program

- (often) Structured and "systemic"
- Broader functionality
- Fast
- Compiled
- Good fit for algorithms
- example: C, C++

Elements of program development

- Four phases:
  1. development (aka program writing)
  2. compile
  3. execution (aka runtime)
  4. debug (optional but almost inevitable)

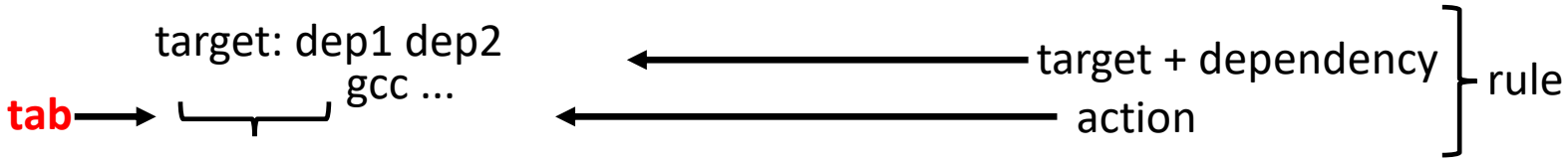
- Tangible elements:
  - Source code file(s)
  - Object code file(s)
  - Config file(s)
  - Shared and static lib file(s)
  - Executable file(s)

Program development tools

- Most systems have all you need to develop simple programs
  - Editors: **`nano, vim, emacs`**
  - Compilers: **`gcc, g++, gfortran, etc.`**
  - Program library tool: **`ar`**
  - Build system: **`make`**
- C code
  - Compile: **`gcc -c example.c -o example.o`**
  - Link: **`gcc main.o example.o -o example`**
  - Build a shared library: **`gcc example.o -shared -o example.so`**
  - Build a static library: **`ar -rv example.a main.o example.o`**
  - To Build using Makefile: **`make -f <makefile>`** **`#reads Makefile by default`**

Anatomy of a Makefile

action is taken to achieve **target; dependencies** are **targets** that are resolved first



To run:

```
$ make target #optionally -f for a non-default makefile
# example (use comments to interpret lines):
sum: main.o sum.o                    # main.o and sum.o are needed to produce sum
        gcc -o sum main.o sum.o      # run this when main.o and sum.o are available
main.o: main.c                       # main.c is needed to produce main.o
        gcc -c main.c                # run this to produce main.o
sum.o: sum.c                         # sum.c is needed to produce sum.o
        gcc -c sum.c                 # run this to produce sum.o
```

An Example Makefile

```
all: exec
exec: main.o example.o
	gcc main.o example.o -o exec
main.o: main.c
	gcc -c main.c -o main.o
example.o: example.c
	gcc -c example.c -o example.o
clean:
	rm *.o exec
install: exec
	cp exec ${HOME}
```

Practice and Exercises [homework]

- Try the commands discussed in this section
- Add a new target **`static`** to the Makefile to build the archive **`example.a`**
- Develop a program in C that prints multiplication table of a number given as argument
- Develop a program in C that lists all prime numbers up to a given number
- Write a Makefile to compile the above programs using gcc

part 9: Miscellaneous Utilities *[12 slides]*

handy like a midnight snack

back to toc

Try It

Get things done at specific times with **at**

- **at** will execute the desired command on a specific date and time
  - schedule a job for one-time execution
  - **at 17:00**
    at> log_days_activities.sh #sometimes no at> prompt
    [ctrl-d]
  - ***at*** offers keywords such as **now**, **noon**, **today**, **tomorrow**
  - also offers terms such as hours, days, weeks to be used with the + symbol

```
at noon
at now + 1 year
at 3:08pm + 1 day
at 15:01 December 19, 2018
```

Try It

Get things done periodically with **cron**

- **cron** will execute the desired command periodically
- A **crontab** file controls and specifies what to execute when
- An entry may be created in any file and added to system with the **crontab** command like so:

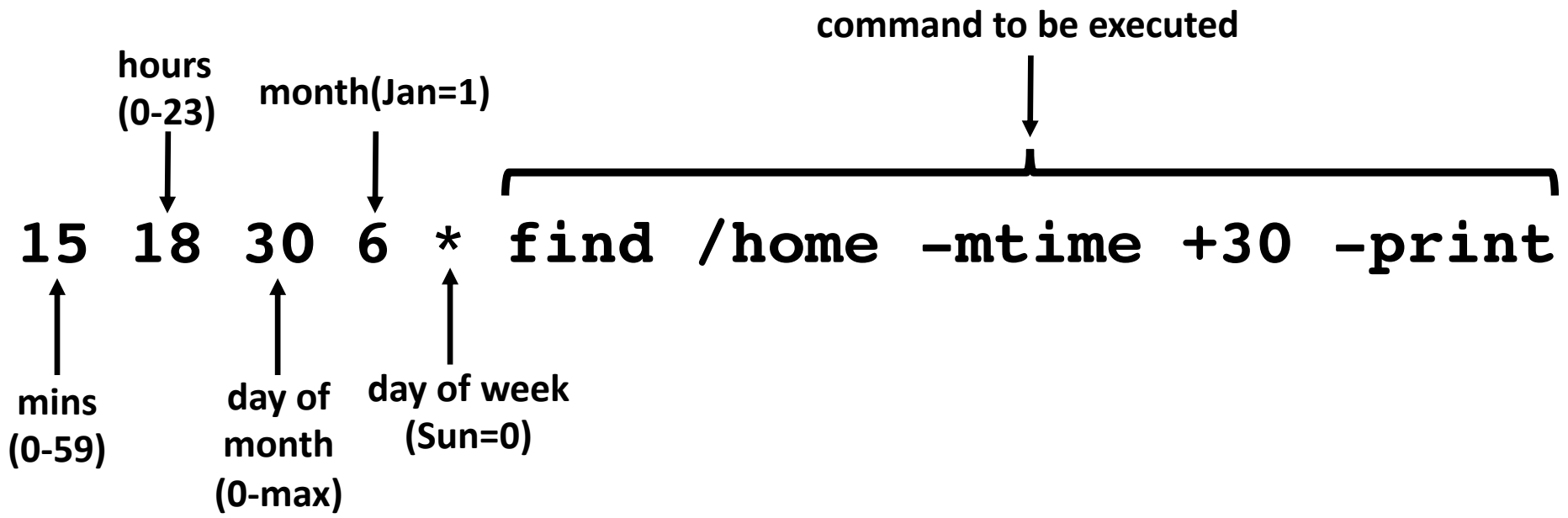
```
echo '15 18 30 6 * find /home -mtime +30 -print' > f00
crontab f00 #add above to system crontab
```

-

```
crontab -l #list crontab entries
crontab -r #remove crontab entries
```

- Output of the cron'd command will be in **mail** (alternatively it may be redirected to a file with '>')
- What does the entries in a crontab mean though? (see next slide)

Anatomy of a crontab entry



Try It

Math

- Factorize numbers using **`factor`** (may need to install)
  - **`factor 300`**
- **`bc`** is a versatile calculator
  - **`bc <<< 48+36`** `#no space on either side of +`
  - **`echo 'obase=16; ibase=10; 56'|bc`** `#decimal to hex`
  - **`echo 'scale=6; 60/7.02' |bc`** `#arbitrary precision`
- Bash for non-precise calculations
  - **`echo $(( 10/3 ))`**
  - **`echo $(( 3**4 ))`**

Try It

Python utilities

- Stand up a simple web server in under a minute with Python
  - **`python -m SimpleHTTPServer`**
  - **`python3 -m http.server`**
- Run small programs
  - **`python -c "import math; print(str(math.pi)[:7])"`**
- Do arithmetic
  - **`python -c "print(6*6+20)"`**
  - **`python -c "fctrl=lambda x:0**x or x*fctrl(x-1); print(fctrl(6))"`** `#compute factorial`

The powerful dd

- **dd**, the low-level data dumping utility is a dangerous but also one of the most useful commands when used lucidly.

  For instance, burning an ISO image to USB stick is just one command away:

```
sudo dd if=ubuntu-18.04.1-desktop-amd64.iso of=/dev/sdb bs=1M
```

- **"hard-wipe"** your disk completely

```
sudo dd if=/dev/zero of=/dev/sda #dangerous
```

Aliases and Functions

- Aliases are useful to quickly type long command forms
- Aliases are usually defined in .bashrc/.bash_profile files or a separate .aliases file
- To temporarily bypass an alias (say we aliased **`ls`** to **`ls -a`**), use \: **`\ls`**
- Functions are usually defined in **`.bashrc/.bash_profile`**
- Functions are useful to accomplish multiple steps in one command

Try It

Examples of useful aliases

- `alias s=ssh`
- `alias c=clear`
- `alias cx='chmod +x'`
- `alias ls='ls -thor'`
- `alias more=less`
- `alias ps='ps auxf'`
- `alias psg='ps aux | grep -v grep | grep -i -e USER -e'`
- `alias ..='cd ..'`
- `alias myp='ps -fjH -u $USER'`
- `alias texclean='rm -f *.toc *.aux *.log'`

Try It

Examples of useful Functions

- `mcd () { mkdir -p $1; cd $1 }`
- `cdl() { cd $1; ls}`
- `backup() { cp "$1"{,.bak};}` `#test first`
- `gfind() { find / -iname $@ 2>/dev/null }`
- `lfind() { find . -iname $@ 2>/dev/null }`

- See **`/usr/share/doc/bash-*/examples/functions`** for more function examples

Random stuff - 1

- Run a command for specified time using **`timeout`**:
  `timeout 2 ping google.com`
- **`watch`** a changing variable
  - **`watch -n 5 free -m`**
- Say **`yes`** and save time
  - **`yes | rm -r largedir #dangerous`**
  - **`yes '' | pdflatex report.tex`**
- Create pdf from text using **`vim`**:
  `vim states.txt -c "hardcopy > states.ps | q" && ps2pdf states.ps #convert ps to pdf`

Random stuff - 2

- Run a command as a different group
  - **sg <grp-name> -c 'qsub myjob.pbs'**
- Format numbers with **numfmt**
  - **numfmt --to=si 1000**
    1.0K
  - **numfmt --from=iec 1K**
    1024
- Generate password
  head /dev/urandom|tr -dc a-z0-9|head -c8;echo
  -dc(delete complement) deletes all characters except a-z and 0-9

pwgen # may not be available by default

Practice and Exercises [5-7 mins]

- Practice the commands discussed in this section
- Run the command **`yes`** for 5 seconds using **`timeout`**
- Create an alias **`d`** to print current **`date`**
- Run **`style`** and **`diction`** (if available) on prose.txt
- Interpret the following crontab entry:
  `30 21 * * * find /tmp /usr/tmp -atime +30 -exec rm -f {} +`
- Frame an **`at`** command to run the date command tomorrow at 8 p.m.
- write a shell script to find all the prime numbers between 1000 and 10000
  - hints: use **`for`**, **`if`**, **`factor`**, **`wc`**

Summary

- Linux command-line environment powerful if exploited well
- Rewarding in the short-term as well as long-term
- Classical and modern tools well suited for HPC-style usage
- Practice!

- Send comments, feedback, questions: **km0@ornl.gov**

Credits, references and resources

- The man, info and doc pages
- bash: www.gnu.org/software/bash/manual/bashref.html
- grep: www.gnu.org/software/grep/manual/grep.html
- sed: www.catonmat.net/blog/worlds-best-introduction-to-sed
- awk: ferd.ca/awk-in-20-minutes.html
- tmux: gist.github.com/MohamedAlaa/2961058
- wikipedia articles: unix, linux, Bash_(Unix_shell)

Where to go from here

- github.com/jlevy/the-art-of-command-line
- jeroenjanssens.com/2013/08/16/quickly-navigate-your-filesystem-from-the-command-line.html
- linux.byexamples.com/archives/42/command-line-calculator-bc
- catonmat.net/blog/bash-one-liners-explained-part-three
- wiki.bash-hackers.org
- https://gist.github.com/MohamedAlaa/2961058#file-tmux-cheatsheet-markdown
- wizardzines.com
- unix.stackexchange.com
- danyspin97.org/blog/makefiles-best-practices

Thank you for your attention