

Linux Terminal Tools

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Enhanced version (originally presented at LISA19)

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Part 1: Overview and Logistics

orientation and practical stuff

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Overview: What shall we learn

- Build powerful **command-lines**
 - We will use **Bash shell with default key-bindings**
 - We will **assume GNU/Linux** and call it Linux
- Tools that are available (or easily installable) on most installations
- Goal is to be efficient and effective rather than to be an "expert"
- Benefits: save time, efficient for system, long-term payback
- **We do not cover:** Sysadmin, Networking

Slides and practice data for download

- Slides and two text files available for practice

<https://github.com/ketancmaheshwari/lisa19>

- states.txt

Tabular data with five columns

- prose.txt

Prose with sentences and paragraphs

- c_example.tgz

Code and Makefile example files

About You and Me

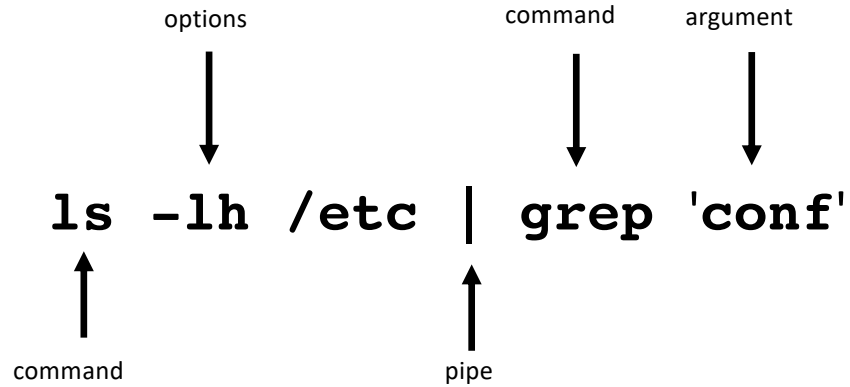
- Basic exposure to Linux is assumed but feel free to interrupt and ask questions
 - common commands, basic understanding of files and directories, editing.
eg. `cd`, `ls`, `pwd`, `cat`
- About Me
 - Linux Engineer at Oak Ridge National Laboratory
 - Command line enthusiast

part 2: Basics

welcome to the school of command line wizardry!

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Anatomy of a Typical Command



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 info about the CPUs
- **lstopo**: display hardware topology (need **hwloc**, **hwloc-gui** packages)
- **free**: free and used memory (try **free -g**)
- **lsb_release -a** : distribution info (sometimes not available)

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

PS1: Some commands may not be available: **which <cmdname>** to verify

Know the Processes

- List the processes by name, pid etc: **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**
- Lower process priority by being **nice** and fly under the radar, eg.:
 - **nice -n 19 tar cvzf archive.tgz large_dir**
- Kill a process: **kill <pid>**
 - to kill zombie processes
 - hung sessions

Many ways to get help

- **man nano**

- Manual pages organized section-wise
- One page for each section (if exists) eg. **man 5 passwd** #5th section

- **wget --help**

- Handy for quick syntax reference

- **info curl**

- Modern

- Browse **/usr/share/doc**

- Usually a README file has info and examples
- Browse with a web-browser

Working with Files

- **cat** for relatively short files
`cat states.txt`
- **less** is more than **more** for long files
`less /etc/ntp.conf`
- **tail -f** to 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
 - **cmp** will compare them byte by byte
- Compare text files with
 - **comm** *sorted* files line by line
 - **diff** differences line by line -- used most frequently, rich options set, see man

Internet on command line

- **curl** is commonly used to download from the web:

```
curl -O http://www.gutenberg.org/files/4300/4300-0.txt
```

```
curl ifconfig.me #quickly find my IP
```

- **wget** is similar:

```
wget http://www.gutenberg.org/files/4300/4300-0.txt
```

```
wget https://kubernetespodcast.com/episodes/KPfGep{001..062}.mp3
```

- **lynx** can be a useful text-based browser:

- avoid pesky ads on the web
- when internet is slow / only care about text eg. **lynx text.npr.org**
- read local html pages, eg. those found in **/usr/share/doc**
- **w3m** and **links** are other text-based browsers: **w3m lite.cnn.com**

Be a command line ninja: Navigation

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

kubectl** set subject rolebinding admin --user=ldf --group=nsed**

ctrl-a / ctrl-xx alt-b alt-f cursor ctrl-e

ctrl-] <char> moves cursor to 1st occurrence of <char> to right

ctrl-alt-] <char> moves cursor to 1st occurrence of <char> to left

Be a command line ninja: Deletion

`kubectl get -o template pod/web-pod-13je7 --template={{.status.phase}}`

ctrl-u ctrl-w alt-d ctrl-k

use ctrl-y to paste back the deleted

wildcards: characters that expand at runtime

- *** any number of characters:**

```
ls -lh /etc/*.conf #all items with .conf extension
```

- **? expands to one character:**

```
ls -ld ? ?? ??? #list items 1,2 or 3 chars long
```

- **Negation (!)**

```
ls -ld [!0-9]* #items that don't start with a number
```

- Escaping and quoting

- \ for escaping a wildcard
 - ' for quoting a wildcard
- } prevent expansion

Quick and Useful Tricks

- **!!** 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 '^A1'** #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

More Tricks

- **>x.txt** #create an empty file / "zero" a large file
- **lsof -P -i -n #appsusinginternet**
tag & later search hard-to-remember command from history
- **ctrl-l** #clear terminal
- **cd -** #change to previous dir
- **cd** #change to homedir
- **ctrl-r** #recall from history
- **ctrl-d** #**logout** from terminal

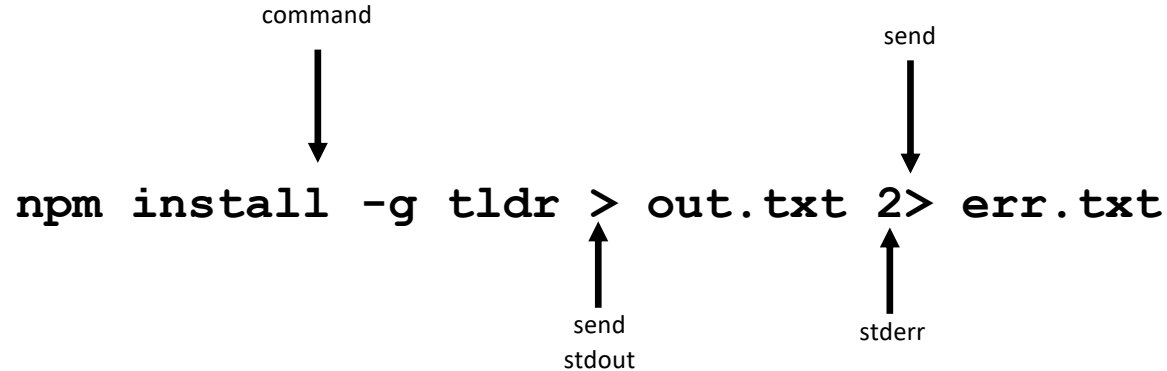
Part 3: Streams, pipe and redirection

I am sure a gardener designed them!

Terminal I/O Streams and Redirection

- Three I/O streams on terminal:
standard input (**stdin**), standard output (**stdout**) and standard error (**stderr**)
- Represented by "**file descriptors**" (think of them as ids):
0 for stdin, 1 for stdout, 2 for stderr
- Angle bracket notation used for redirect to/from commands/files:
 - > to send to a stream
 - < to receive from a stream
 - >> to append to a stream
 - << to in-place append (used in "heredoc")
 - <<< is used in "herestring" (not covering today)
- & is used to "**write into**" a stream, eg. &1 to write into stdout

Anatomy of a redirection using streams



More Redirection Examples

- Send stdout and stderr to same file:

```
pip install rtv > stdouterr.txt 2>&1  
ac -pd &> stdouterr.txt #short form (bash v4+)
```

- Disregard both stdout and stderr:

```
wget imgs.xkcd.com/comics/command_line_fu.png &> /dev/null  
#/dev/null is a "null" file to discard streams
```

- Read from stdin as output of a command

```
diff <(ls dirA) <(ls dirB)
```

- Append stdout to a log file:

```
sudo yum -y update >> yum_update.log
```

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
```

Demystifying and debugging piped commands

```
free -m|grep Mem:|awk '{print $4}'
```

is equivalent to running the following 4 commands:

```
free -m > tmp1.txt
```

```
grep Mem: tmp1.txt > tmp2.txt
```

```
awk '{print $4}' tmp2.txt
```

```
rm tmp1.txt tmp2.txt
```

Reducing the piped stages is often efficient and easier to debug. For instance, the above pipeline may be reduced like so:

```
free -m|awk '/Mem:/{print $4}' #more on awk later
```


More pipe examples

#get pdf of a man page

```
man -t diff | ps2pdf - diffhelp.pdf
```

#get today's files

```
ls -al --time-style=+%D | grep `date +%D`
```

#top 10 most frequently used commands

```
history | awk '{a[$2]++}END{for(i in a){print  
a[i] " " i}}' | sort -rn | head
```

Commands that only accept literal args

- Most commands receive input from stdin (so, pipe) **and** file, eg.

```
wc < states.txt #ok
```

```
wc states.txt #ok
```

- 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** (assuming want to print file contents)
 - `echo states.txt` **#NOT OK** (assuming 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
 - Converts **standard input** to commands into **literal args**
 - Partitions the args to a permitted number and runs the command over them repeatedly
- For instance, create files with names on the **somelist.txt** file:
xargs touch < somelist.txt

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

GNU Parallel Examples*

- Find all html files and move them to a directory

```
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

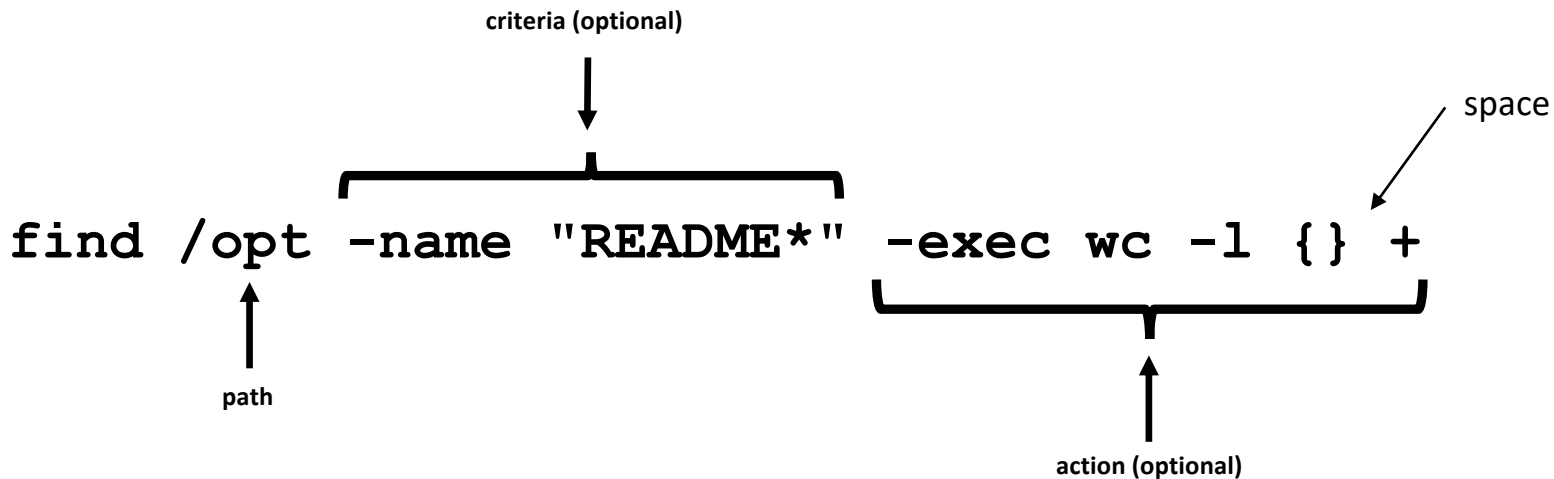
```
cat urlfile | parallel "wget {} 2>errors.txt"
```

Part 4: Classic Tools: find, grep, awk, sed

the evergreens

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find: search files based on criteria



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+/-rwx)`
 - `-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
 - `-ls` : run `ls -lids` command on each resulting file
 - `-exec cmd` : execute command
 - `-ok cmd` like `exec` except that command executed after user confirmation

find Examples

- **find . -type f -iname "*.txt"** #txt files in curdir
- **find . -maxdepth 1** #equivalent to ls
- **find ./somedir -type f -size +512M -print** #all files larger than 512M in ./somedir
- **find /usr/bin ! -type l** #not symlinks in /usr/bin
- **find \$HOME -type f -atime +365 -exec rm {} +**
#delete all files that were not accessed in a year
- **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 "global regular expression print" 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

Anatomy of grep

options

input file

grep **-i -n** 'c.l' states.txt

regular expression

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 lines of matches
- **-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 (regex) is an **expression** that matches a **pattern**.

- Example pattern

```
^Linux is fun.$  
^So is music.$  
^Traffic not so much.$
```

- regex:

b	a	r
---	---	---

 → no match
- regex:

f	u	n
---	---	---

 → **one** match → "Linux is fun."
- regex:

i	s
---	---

 → **two** matches → "Linux is fun." and "So is music."
- regex:

^	s	o
---	---	---

 → one match → "So is music."
- regex:

i	c	.	\$
---	---	---	----

 → one match → "So is music."

Regular Expressions-contd.

- `.` is a Special character; will match **any** character (except newline)
eg. `b.t` will match bat, bbt, b%t, and so on but **not** bt, xbt etc.
- Character class: one of the items in the `[]` will match, sequences allowed:
 - '`[Cc]at`' will match **C**at and **c**at
 - '`[f-h]ate`' will match fate, gate, hate
- `^` within a character class means negation
eg. '`b[^eo]at`' will match brat but **not** boat or beat

Extended Regular Expressions

- Enable by using **egrep** or **grep -E**
- '*' matches zero or more, '+' matches one or more, '?' matches zero or one occurrence of the **previous character**
eg. **[hc]⁺at** will match hat, cat, hhat, chat, cchhat, etc.
- '|' is a delimiter for multiple patterns, '(' and ')' let you group patterns
eg. **([cC]at) | ([dD]og)** will match cat, Cat, dog and Dog
- {} may be used to specify a repetition range
eg. **ba{2,4}t** will match baat, baaat and baaaat but **not** bat

grep Examples

- Lines that end with two vowels:

```
grep '[aeiou][aeiou]$\n' prose.txt
```

- Check 5 lines before and after the line where term 'little' occurs:

```
grep -A5 -B5 'little' prose.txt
```

- Comment commands and search later from history

```
some -hard 'to' \remember --complex=command #success  
history | grep '#success'
```

- Confirm you got an ambiguous spelling right

```
grep -E '^ambig(uou|ou|ouo)s$\n' /usr/share/dict/linux.words
```

- find+grep is one very useful combination

```
find . -iname "*.py" -exec grep 'add[_-]item' {} +
```


awk: Extract and Manipulate Data

- A **programmable** filter that reads and processes input **line by line**
- Rich built-in features:
 - explicit fields (\$1 ... \$NF) & records management
 - functions (math, string manipulation, etc.)
 - regular expressions parsing and filtering
- Features like variables, loops, conditionals, associative arrays, user-defined functions

Highly recommended book: The awk programming language by Aho, Kernighan and Weinberger, ia802309.us.archive.org/25/items/pdfy-MgN0H1joloDVoIC7/The_AWK_Programming_Language.pdf

Anatomy of an awk program

Often used as one-line **idiom** of the form:

```
awk 'awk_prog' file.txt
```

OR

```
command | awk 'awk_prog'
```

where **awk_prog** is:

```
BEGIN {actions} #run one time before input data is read
```

```
/pattern/ or condition {actions} #run actions for each line of  
input files and/or stdin that satisfy /pattern or condition/
```

```
END {actions} #run one time after input processing section
```

At least one of the **BEGIN**, **/pattern/ or condition**, **{}**, **END** section needed

patterns, conditions and actions

- A **pattern** is a regex that matches (or not) to an input line, eg.

```
/New/           # any line that contains 'New'  
/^[0-9]+ /      # beginning with numbers  
/(POST|PUT|DELETE)/ # has specific words
```

- A **condition** is a boolean expression that selects input lines, eg.

```
$3>1 # lines for which third field is greater than 1
```

- An **action** is a sequence of ops, eg.

```
{print $1, $NF}      #print first and last field/col  
{print log($2)}     #get log of second field/col  
{for (i=1;i<x;i++){sum += $3}} #get cumulative sum
```

- User defined functions may be defined in any action block

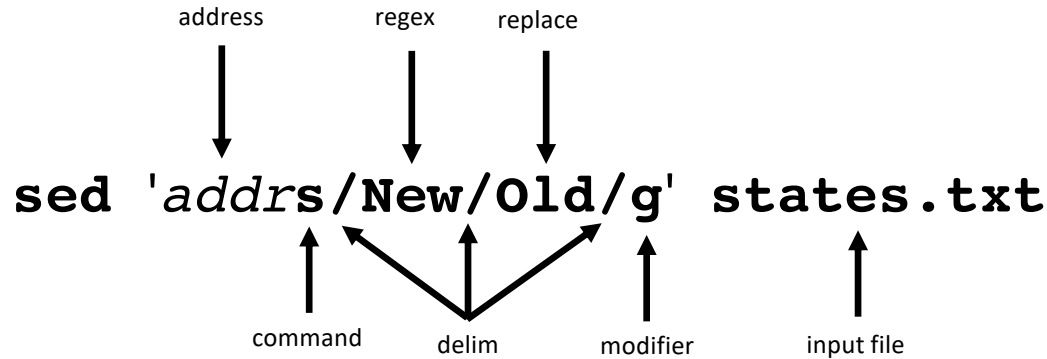
useful awk one-liners

- `awk '{print $1}' states.txt`
- `awk '/New/{print $1}' states.txt`
- `awk NF > 0 prose.txt # print lines that has at least one field (skip blank lines)`
- `awk '{print NF, $0}' states.txt #fields in each line and the line`
- `awk '{print length($0)}' states.txt #chars in each line`
- `awk 'BEGIN{print substr("New York",5)}' #York`

sed: parse and transform text

- **sed** is a **s**tream **e**ditor
- Looks for a pattern in text and applies changes (edits) to them
- A batch or non-interactive editor
- Reads from file or stdin (so, pipes are good) **one line at a time**
- The original input file is unchanged (sed is also a filter), results are sent to standard output
- Most frequently used idiom is for text substitution

Anatomy of a typical sed command



Options

- address: may be a line number, range, or a match; default: 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 in the line
- Common **sed** flags: **-n** (no print), **-e** (multiple ops), **-f** (read sed from file), **-i** (in place edit **[careful]**)

Useful sed Examples

- `sed -n '5,9p' states.txt` #print lines 5 through 9
- `sed '20,30s|New|Old|1' states.txt` #affects 1st occurrence in ln20-30
- `sed -n '$p' states.txt` #print last line
- `sed '1,3d' states.txt` #delete first 3 lines
- `sed '/^$/d' states.txt` #delete all blank lines
- `sed '/York/!s/New/Old/' states.txt` #substitute except York
- `kubectl -n kube-system get configmap/kube-dns -o yaml | sed 's/8.8.8.8/1.1.1.1/' | kubectl replace -f -`

Part 5:

Session Management: tmux

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

Workspace Management with tmux

- **tmux (v1.8)** 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 other operation will take a long time
 - for interactive multitasking
 - for exotic stuff such as pair programming
 - to preserve environment for multiple operations

A Short tmux Tutorial

- Typical tmux workflow

```
tmux new -s s1 #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 s1 #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 s1 #kill a session
```

Live collaboration with tmux

```
#user1#
```

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

```
#user2#
```

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

Create Panes and Synchronize with tmux

tmux new -s s2 #start a tmux session

ctrl-b " #split horizontally

ctrl-b % #split vertically

ctrl-b :setw synchronize-panes on

#synchronized#

ctrl-b :setw synchronize-panes off

ctrl-b o #move through the panes

ctrl-b x #kill the active pane

Part 6: ssh config and tunneling

build secure tunnels

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ssh config (~/.ssh/config)

Host **login1**

hostname login1.ornl.gov

User km0

Host cades

Port 22

hostname or-slurm-login.ornl.gov

ProxyJump **login1**

User km0

ServerAliveCountMax=3 #max num of alive messages sent without ack

ServerAliveInterval=15 #send a null message every 15 sec

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
- And much 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
```


Port forward over SSH Tunnel*

lclhost\$ ssh -L lport:host:hport remotehost -N

The diagram illustrates the components of the SSH port forwarding command. Arrows point from descriptive labels to specific parts of the command:

- ssh**: ssh command (arrow from below)
- L**: local (arrow from above)
- lport**: localport (arrow from below)
- :**: "hostname" on remote host (arrow from above)
- hport**: port on remote host (arrow from below)
- remotehost**: remote host (arrow from above)
- N**: no command (arrow from below)

SSH Tunneling Example

- Run an HTTP server on remote node and browse through local web browser:

```
step 1. remote$ python2 -m SimpleHTTPServer 25000  
OR
```

```
step1. remote$ python3 -m http.server 25000
```

```
step2. local$ ssh -L 8000:localhost:25000 id@remote -N
```

```
step3. Open browser on local and navigate to http://localhost:8000
```

Incremental Remote Copy with **rsync**

- Synchronize data between local and remote storage
- Rich set of options (see man):
 - a and -v most commonly used
 - rsync -av localdir/ remotehost:~/remotedir**
trailing **/** imp in localdir, else, the dir will be synced not contents
- A useful rsync hack: **fast deletion of a large directory**
mkdir empty && rsync -a --delete empty/ large_dir/

part 7: Secure Communication with GnuPG

Share top secrets securely over web

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GNU Privacy Guard Basics

- A tool for secure communication
- We cover
 - keypair creation
 - key exchange and verification
 - encrypting and decrypting documents
 - authenticating documents with digital signatures
- We do not cover
 - public-key cryptography concepts
 - sophisticated and advanced use-cases

Create a new keypair

gpg --gen-key #answer the prompted questions

- Provide name and email as ID, choose hard-to-guess passphrase
- Keypair artefacts in **\$HOME/.gnupg** dir

- Create a **revocation certificate**

gpg --output revoke.asc --gen-revoke <ID>

- use the email as ID
- Useful to notify others the keypair may no longer be used -- eg. if you forgot your passphrase, lost keypair etc.

Key Exchange and Verification

- Export a public key

```
gpg --output pub.gpg --export <ID>          #binary  
gpg --armor --export <ID> > pubtxt.gpg #ascii
```

- Import a public key

```
gpg --import billpub.gpg #import Bill's pubkey
```

- Verify and sign an imported key

```
gpg --edit-key b@ms.us #out key info & prompt  
...
```

```
command> fpr #fingerprint, verify over phone
```

```
command> sign #verify at prompt and done!
```

Encrypting and Decrypting Documents

- Encrypt a document for Bill using Bill's public key

```
gpg --output doc_pdf.gpg --encrypt --recipient  
b@ms.us doc.pdf #must have Bill's public key
```

- Bill Decrypts the document (must have his private key & passphrase)

```
gpg --output doc.pdf --decrypt doc_pdf.gpg
```

- Documents may be encrypted without key, just with passphrase

```
gpg --output doc_pdf.gpg --symmetric doc.pdf  
Enter passphrase:
```


Authenticate Docs with Digital Signatures

- Digitally signed document ensure they are authentic & untempered

```
gpg --output doc.signed --sign doc.pdf
```

Enter Passphrase:

Must have the private key to sign

- A signed document can be verified and decrypted like so:

```
gpg --ouput doc.pdf --decrypt doc.signed
```

Must have owner's public key

part 8: Bash Tools

For when that 'hello world' becomes a project

[back to toc](#)

Bash Shell Basics

- Commands and utilities such as **grep**, **sed**, **awk** may be invoked
- Variables, constants, conditionals, loops and functions may be defined
- Arithmetic operations available
- Logical operations **&&** (AND) and **||** (OR) available:
 - **wget ... || curl ...** : run curl *iff* wget **fails**
 - **make install && make test** : test *iff* install **succeeds**
- Shell "Startup" files set environment as you start your shell
 - **.bashrc** : a file that runs in each new shell that is spawned
 - **.bash_profile** : a file that runs only in a "login shell" (and not all shells eg. it won't run if you invoke a shell script that creates a subshell)

Aliases and Functions

- Aliases are short and convenient names for long commands
- They are usually defined in `.bashrc` or a separate `.aliases` file
- To temporarily bypass an alias (say we aliased `ls` to `ls -a`), use `\:`
`\ls`
- Bash functions are usually defined in `.bashrc/.bash_profile`
- Functions are more expressive and preferred over aliases

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 cleanup='rm -f *.tmp *.aux *.log'`

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 }`
- `rtfm() { help $@ || man $@ || $BROWSER
"http://www.google.com/search?q=$@"; }`
- See `/usr/share/doc/bash-*/examples/functions` for more function examples

Variables and Command Substitution

- 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 -l | wc -l) items in the current dir"**

Conditionals

- if-then-else construct to branch similar to programming languages
- Two forms of conditional evaluation mechanisms:
 - `test` and `[...]`

```
$ if test $USER = 'km0'; then echo 'I know you';  
else echo 'Who are you'; fi
```

```
$ if [ -f /etc/yum.conf ]; then echo 'yum.conf  
exists'; else echo 'file do not exist'; fi
```


Conditionals summary

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

Loops

- Basic structure (three forms):

```
for i in {0..9}; do echo $i; done
```

```
for ((i=0;i<10;i++)){ echo $i;} #C-like
```

```
for var in list; do command; done #'python-like'
```

- often used with command substitution:

```
for i in $(\ls -l *.txt); do echo "$i"; done
```

```
for i in $(get_files.sh); do upload.sh "$i"; done
```

The heredoc

- Create "inplace" files
- example:
- **sh << END**
echo "Hello World"
END <press enter>
- Uses of heredoc
 - Multiline message using cat
 - Use variables to plug into created files, eg test multiple configurations for a program

```
cat << EOF | kubectl create -f -
apiVersion: v1
kind: Pod
metadata:
  name: nginx
spec:
  containers:
    - name: nginx
      image: nginx
EOF
```

```
#!/bin/bash
for i in local remote cluster all
do
  cat <<END>install.yml
  ---
  - hosts: $i
    <other stuff>
  END
  ansible-playbook install.yml --check > out"$i".txt
done
```

part 9: Program Development Tools

get-serious stuff

[back to toc](#)

Programming Language Platforms

- Interpreted programming platforms available on most systems
 - Python, Perl, awk, bash
 - We cover awk, some bash and a bit of python
- Compiled programming platforms available on most systems
 - C, Fortran
 - We cover C in this section
- Additionally, a build system called **Make** is available

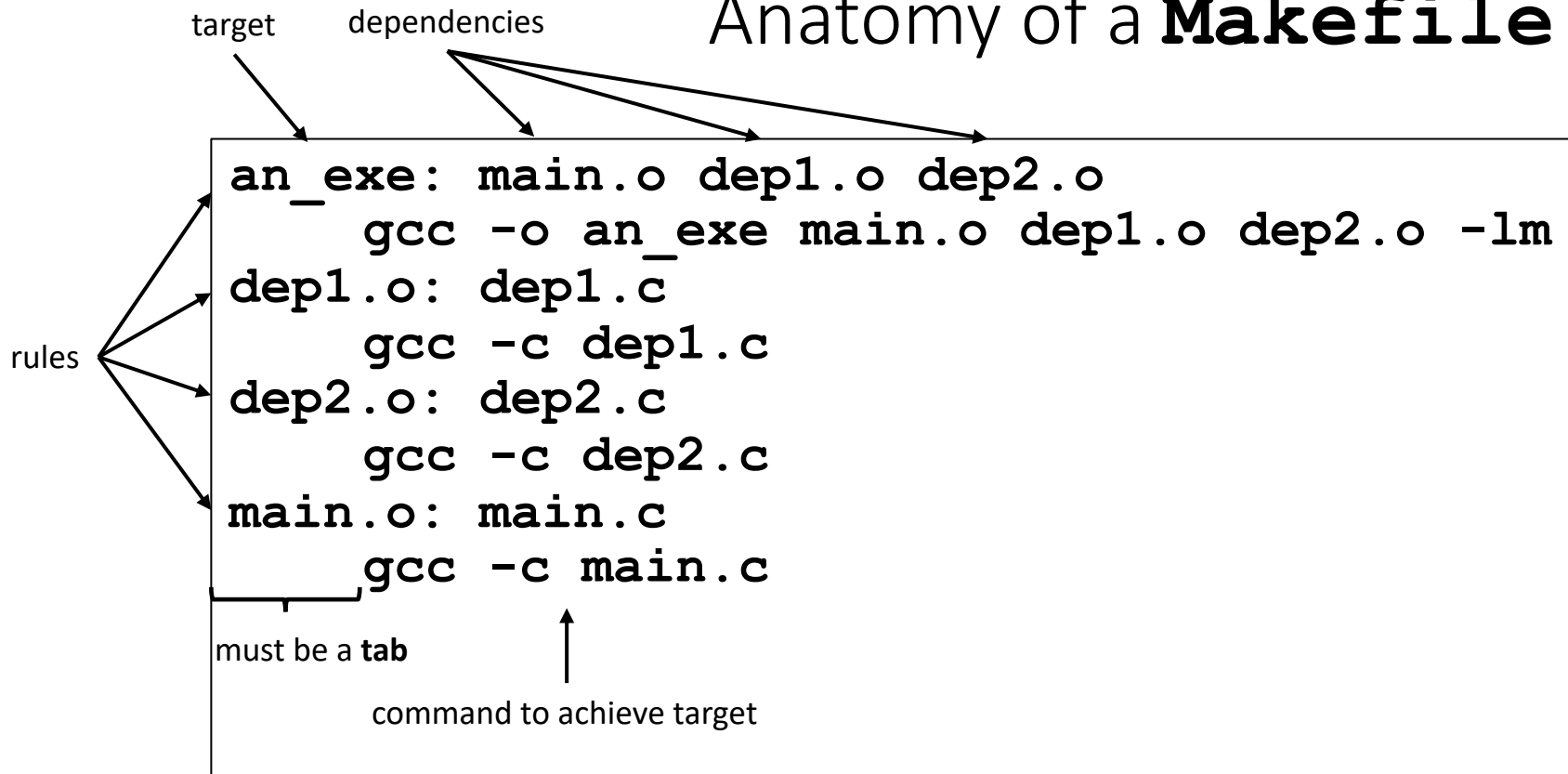
Elements of **C** Program Development

- The **source code** that is written/edited by a programmer
 - Often split into header files (**.h**) and source code files (**.c**)
- The compiler **gcc** does the following
 - compile (**-S**) convert the source code (**.c**) to **assembly code** (**.s**)
 - assemble (**-c**) -- translate the assembly code to **object code** (**.o**)
 - link (**-l**) -- link to the standard libraries to produce **executable**
- By default gcc combines the above stages producing the executable
gcc hello.c #creates a.out; no .o or .s files

The **make** build system

- Automates compilation of multiple source files in a complex project
- Streamlines dependent actions and performs them in order
- Reads configuration from a "build" file usually named as Makefile
- Makefile acts as an artefact of project build process

Anatomy of a **Makefile**



How the **make** command works

- The **make** command will read from the Makefile and run commands in order to build the ultimate target
- For instance, in the Makefile shown in previous slide, **make** will run commands for rule 2-4 followed by rule 1:

```
gcc -c dep1.c #create dep1.o
```

```
gcc -c dep2.c #create dep2.o
```

```
gcc -c main.c #create main.o
```

```
gcc -o an_exe main.o dep1.o dep2.o -lm
```

part 10: Miscellaneous Utilities

handy like midnight snack

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

- **at** will execute the desired command on a specific day and time
 - **at 17:00 #press enter**
at> log_days_activities.sh #smtimes no at> prompt
[ctrl-d]
 - **at** offers keywords such as **now, noon, today, tomorrow**
 - offers terms such as **hours, days** to be used with the **+** symbol

at noon

at now + 1 year

at 3:08pm + 1 day

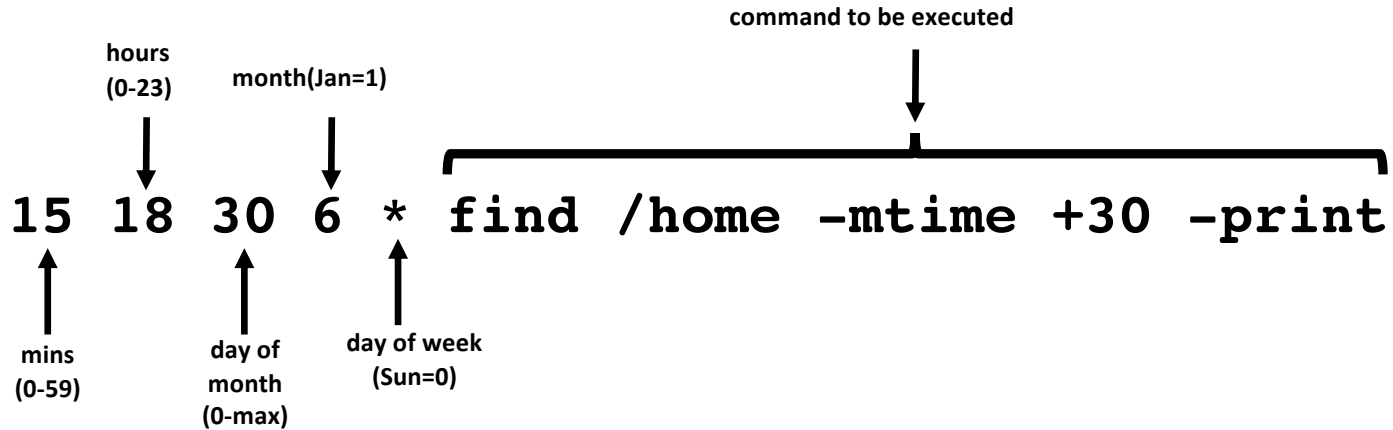
at 15:01 December 19, 2018

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



Run the find command on June 30 of every year at 6:15 PM no matter what day of week it is.

Math

- Generate random number using **shuf** (may need to install)
 - **shuf -i 1-100 -n 1**
- Format numbers with **numfmt**
 - **numfmt --to=si 1000**
1.0K
 - **numfmt --from=iec 1K**
1024
- **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=8; 60/7.02' | bc** #arbitrary precision

Python utilities

- Stand up a simple web server in under a minute with Python
 - `python3 -m http.server 35000`
- Pretty print a json file
 - `python3 -m json.tool afile.json`
- Run small python 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`

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 | pip install pkg --upgrade`
 - `yes "this is a test" | head -50 > testfile.txt` # create file with arbitrary no. of lines
- 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 Linux group
 - `sg grpgit -c 'git push'`
- Display a csv in columnar/tabular format
 - `column -t -s , filename.csv`
- Have difficulty sending binary executables over emails?
 - `xxd f.exe f.hex` #hexdump the exe, send over email
 - `xxd -r f.hex f.exe` #receiver convert back to exe
- Generate password
 - `head /dev/urandom | tr -dc A-Za-z0-9 | head -c 8`
 - `openssl rand 8 -base64 | cut -c1-8` #-base64 8 for some version

Random stuff - 3

- pandoc to convert between md, tex, txt, html, docx, pdf, odt

```
pandoc manual.md -o manual.pdf
pandoc example.txt -o example.html
pandoc -s example.txt -o example.docx
```
- Parse and read **xml** files with **xmlint**
- Split a large file into small chunks (eg. to send as attachment in mail)
 - **split -b 20M large.tgz parts_** #20MB chunks
#send parts_* over mail
 - **cat parts_a* > large.tgz** #at receiving end

Summary

- Linux command-line environment powerful if exploited well
 - Pipes and redirection key Linux contributions
 - Rewarding in the short-term as well as long-term
 - Classical and modern tools well suited for modern-style usage
 - Practice!
-
- Send comments, feedback, questions: **km0@ornl.gov**

Credits, references and resources

- The man, info and doc pages
- bash: gnu.org/software/bash/manual/bashref.html
- grep: gnu.org/software/grep/manual/grep.html
- sed: 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)
- commandlinefu.com

Where to go from here

- github.com/jlevy/the-art-of-command-line
- jeroenijanssens.com/2013/08/16/quickly-navigate-your-filesystem-from-the-command-line.html
- linux.byexamples.com
- catonmat.net/blog/bash-one-liners-explained-part-three
- wiki.bash-hackers.org
- gist.github.com/MohamedAlaa/2961058#file-tmux-cheatsheet-markdown
- wizardzines.com
- crontab.guru
- leimao.github.io/blog/Tmux-Tutorial
- unix.stackexchange.com
- danyspin97.org/blog/makefiles-best-practices

Thank you for your time and attention
Questions?

Practice and Exercises

- 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
- Create a tmux session and split the screen into 4 panes vertically and horizontally
- Set it so that all panes are synchronized. Test with any command.

Practice and Exercises

- 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:]]*`

Practice and Exercises

- List all conf files in **/etc** you have access to, redirect stderr to **/dev/null**
- Build a software and collect errors and output in separate files, fill in the ____
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

Simplify the following command line:

```
TOKEN=$(kubectl describe secret -n kube-system  
$(kubectl get secrets -n kube-system | grep  
default | cut -f1 -d ' ') | grep -E '^token' |  
cut -f2 -d ':' | tr -d '\t' | tr -d " ")
```

Hints:

- Replace the **cut** commands with **awk** commands
- Accommodate the **grep** within **awk**
- Accommodate the two **tr** commands within **awk** commands (hint: use **awk**'s **gsub** built-in function)

Practice and Exercises

- Create a file titled the words that start with letter 'C' (**fill the __**):
 - `grep -i '^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`

Practice and Exercises

- 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**)

Practice and Exercises

Muammar Gaddafi was a Libyan politician. He was in the news a few years ago. News agencies spelled his name differently like so:

- **Muammar al-Kaddafi** (BBC)
- **Moammar Gadhafi** (Associated Press)
- **Muammar al-Qadhafi** (Al-Jazeera)
- **Mu' ammar Al-Qadhafi** (US Department of State)

Your task is to come up with a Regular expression that will match with all the above occurrences. (Hint: use extended regular expression)

- Test with both **grep** and **awk** by putting the above lines in a file as well as a *heredoc*

Practice and Exercises

- 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, make appropriate changes and add the contents presented in previous slides to it. How will you test if it works?

Practice and Exercises

- Run **yes** for 5 seconds using **timeout**, collect the output in file x.txt
- 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**