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

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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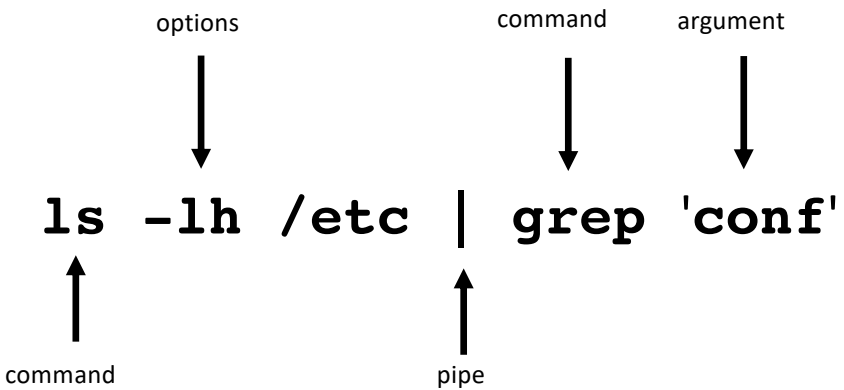
Anatomy of a Typical Command



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
```

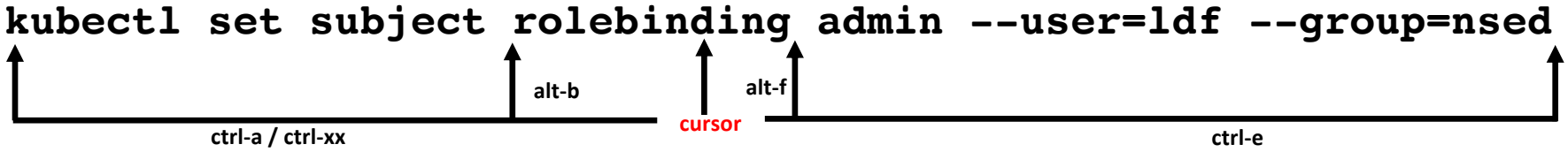
- **`wget`** is similar:

```
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



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

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** '**^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

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!

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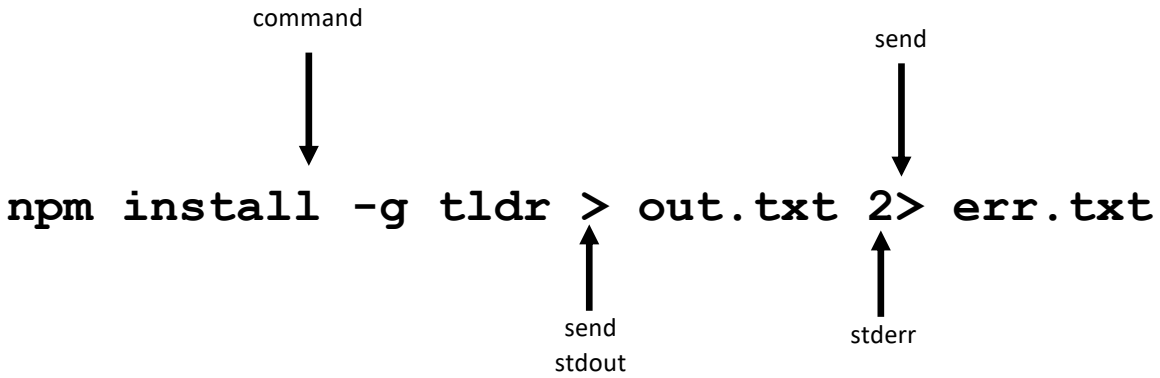
Terminal I/O Streams and Redirection

- 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"
```

*From the gnu parallel 2018 book at https://doi.org/10.5281/zenodo.1146014

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

the evergreens

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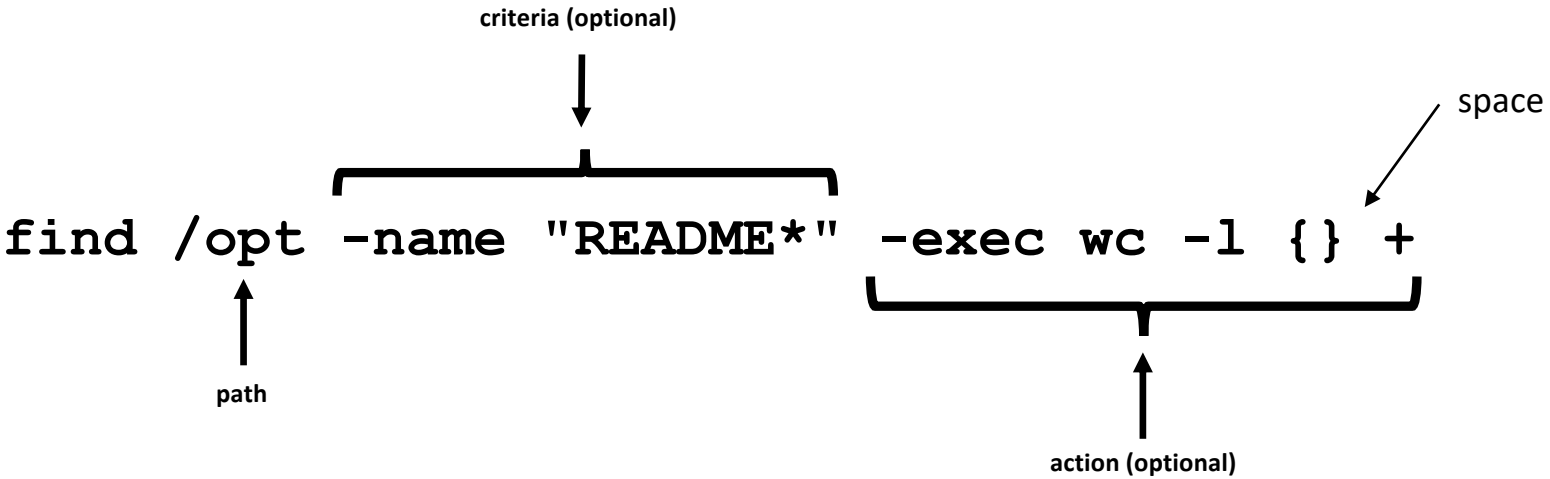
find: search files based on criteria



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

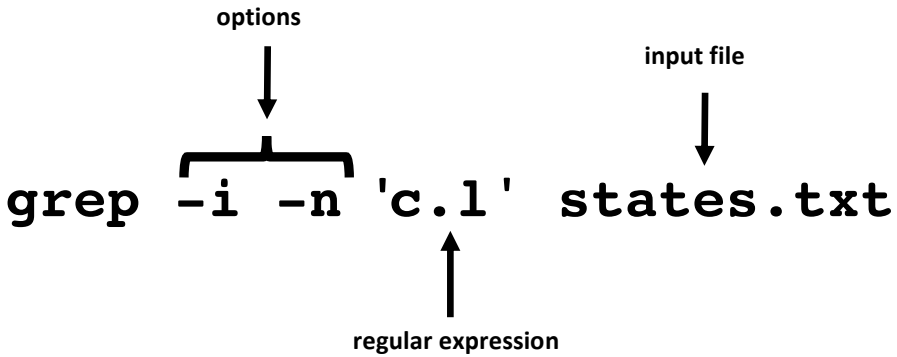
- **`grep`** originally was a command "**g**lobal **r**egular **e**xpression **p**rint" or '**`g/re/p`**' in the **`ed`** text editor

- 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

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 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]$' 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$' /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-MgN0H1joIoDVoIC7/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 for each line of input

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

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

awk patterns 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
```

- 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

awk Examples

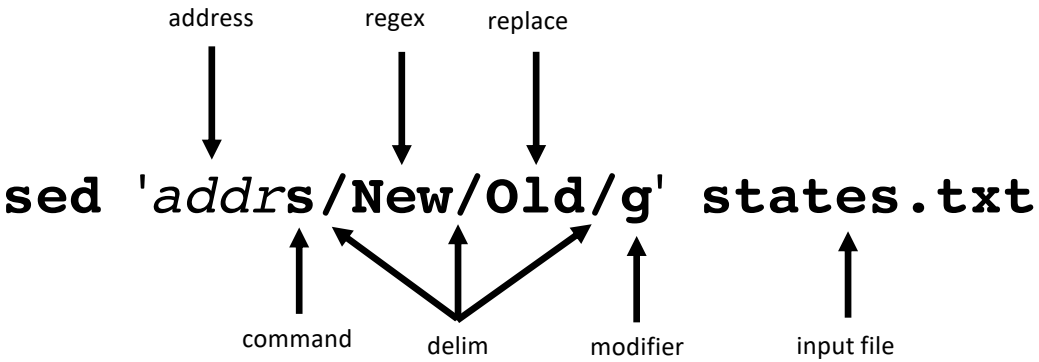
- awk **'{print $1}'** states.txt
- awk **'/New/{print $1}'** states.txt
- awk **NF > 0** prose.txt # print lines that has at least one field (skip blank lines)
- awk **'{print NF, $0}'** states.txt #fields in each line and the line
- awk **'{print length($0)}'** states.txt #chars in each line
- awk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

sed: parse and transform text

- **`sed`** is a **s**tream **ed**itor
- 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

back to toc

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

back to toc

ssh config (~/.ssh/config)

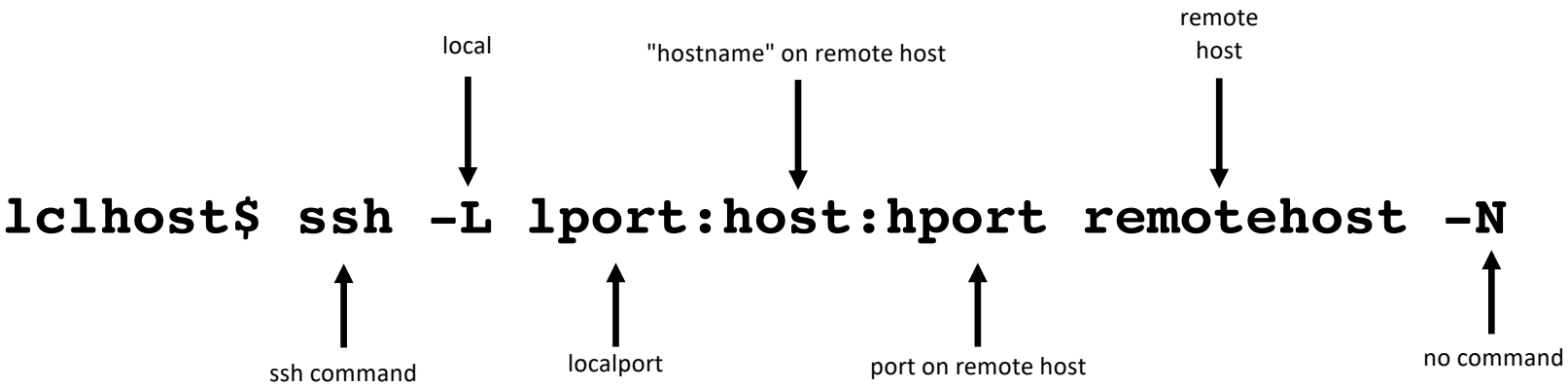
```
Host login1
  hostname login1.ornl.gov
  User km0

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*



* simplest form

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

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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 -1 | 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 $(\ls -1 *.txt); do echo "$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

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Programming Language Platforms

- Interpreted programming platforms available on most systems
  - Python - covered a bit
  - Perl - not covered
  - awk - covered some
  - Bash - covered some
- Compiled programming platforms available on most systems
  - C - cover some in this section
  - Fortran - not covered
- Additionally, a build system called **`Make`** is available

Elements of **C** Program Development

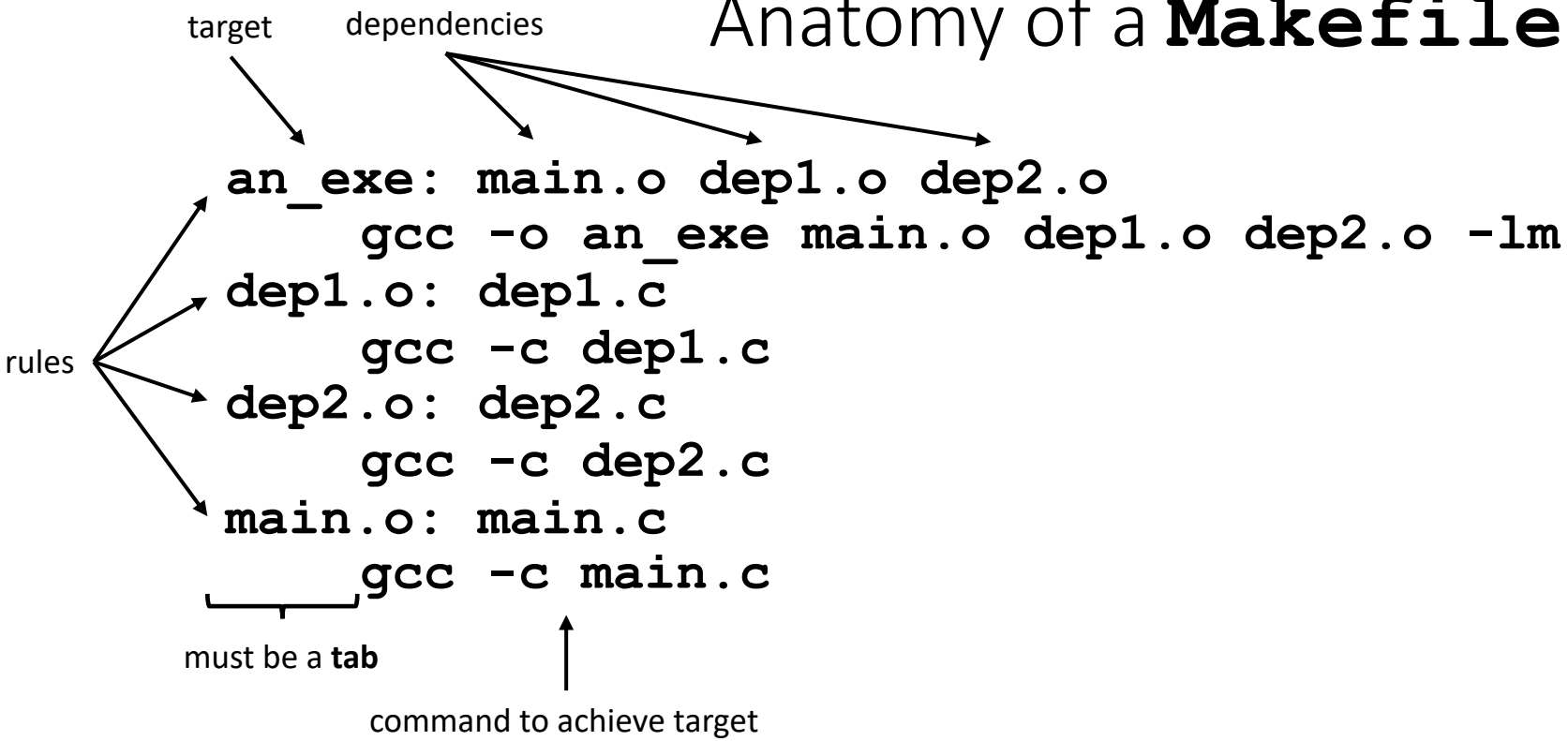
- The **source code** that is written/edited by a programmer
  - Often split into header files (**`.h`**) and source code files (**`.c`**)
- The compiler **`gcc`** does the following
  - compile (**`-S`**) convert the source code **`(.c)`** to **assembly code `(.s)`**
  - assemble (**`-c`**) -- translate 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 dep3.c #create dep3.o

gcc -o an_exe dep1.o dep2.o dep3.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:

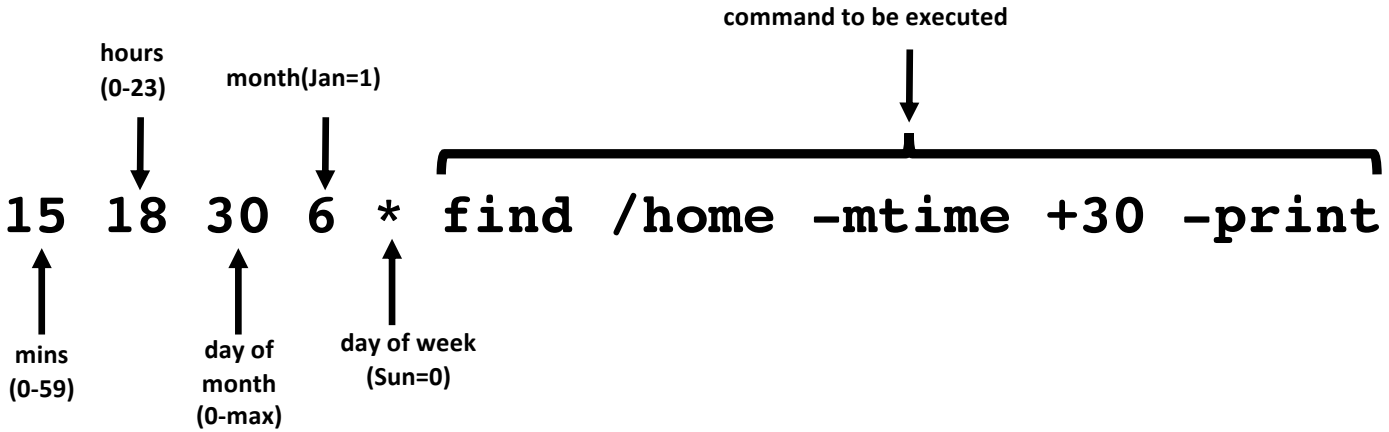
```
echo '15 18 30 6 * find /home -mtime +30 -print' > f00
crontab f00 #add above to system crontab
```

-

```
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

- 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`**

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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
- 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
- https://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`**
- 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`**