CSE 314
Operating System Sessional

Session 1

Introduction to the Linux CLI (Command Line Interface)

</ The Shell

- GUIs are limited
  - Can only interact what the programmer allows in the UI
  - Makes easy tasks easy
- Textual interface = Full advantage
  - Also known as “Shell” (command line interface)
  - Various implementations
  - Linux / MacOS: Bourne Again SHell (bash)
  - Makes difficult tasks possible!

</ The Shell

- `username@machine_name:~$`
    - Your username
    - The name of the machine you are on
    - The directory you are in (~)
    - $ indicates you are a normal user
    - # ⇒ superuser (“Run as administrator”)

</ Handy Shortcuts

- **<CTRL> + <ALT> + T** : Open terminal
- **<CTRL> + D** : Close terminal
- **<CTRL> + L** : Clear terminal screen
- **<CTRL> + A/E** : Jump to beginning/end of line
- **<CTRL> + K/U** : Delete everything ahead/before of cursor
- **<CTRL> + Y** : Paste text cut by <CTRL> + K/U
- **<CTRL> + LEFT / RIGHT** : Move by word
- **TAB** : Auto-complete matching file names
- **<CTRL> + C** : Cancel current command
- **UP / DOWN** : Cycles between recently used commands

</ Copy & Paste

- Double click (or select) something with a mouse to copy and click the middle button to paste
- <CTRL> + SHIFT + C => Copy
- <CTRL> + SHIFT + V => Paste

</ Some Basic Commands

- date
- echo
  - Simply prints the arguments passed
  - Hello world → Two separate arguments
  - “Hello world” → A single argument
  - Can use quotes (“”) or escape sequences (\)

</ Environment Variables

- Where to find these programs (date, echo, ...)?
    - Environment Variable
    - $PATH ⇒ Lists the paths to look for commands
    - Can modify it to include more directories
        - Usually in dotfiles (aka shell configuration files)
        - .bashrc, .profile, .bash_aliases
- which CMD ⇒ Prints path to CMD if it exists

</ Exploring the Shell

- pwd
  - Prints the path of the current directory (Print Working Directory)
  - Path on the shell is a sequence of folders, separated by /
  - /home/terrarium
  - / ⇒ Top of the filesystem
    - aka the “Root” directory
- cd pathname
  - Moves to the directory under pathname
  - Path can be absolute or relative

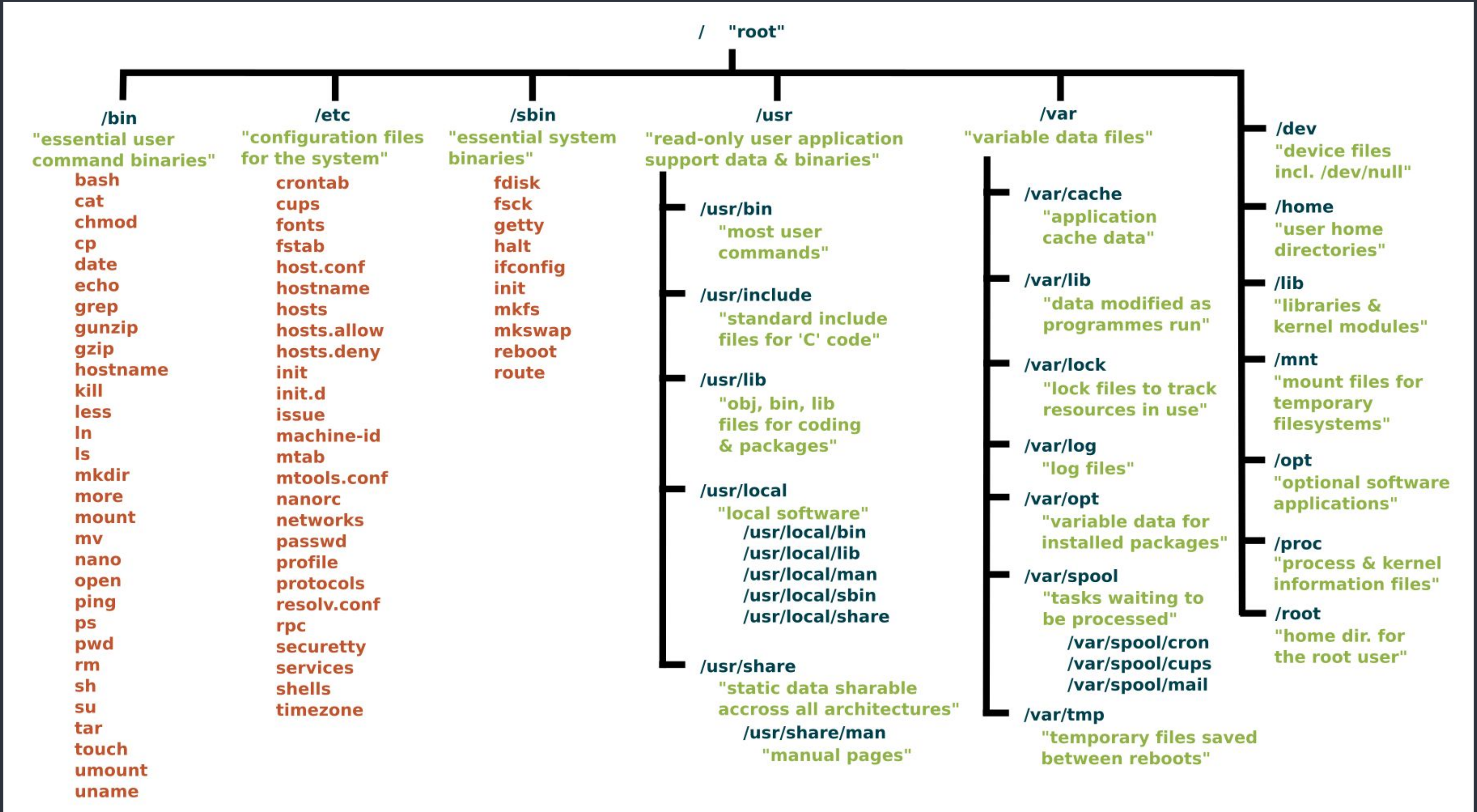
</ Paths

- Absolute path
  - Starts with /
  - Specifies the full location
- Relative path
  - Based on the current working directory
  - . current directory
  - .. parent of the current directory
- Home directory represented by ~
- Previously working directory represented by -
- Just type “cd” without anything else ⇒ Takes you to home directory

</ Which one to use?

- Use whichever is shorter!
- In scripts or programs, use absolute paths (recommended)

</ Linux File System



</ Helpful Commands

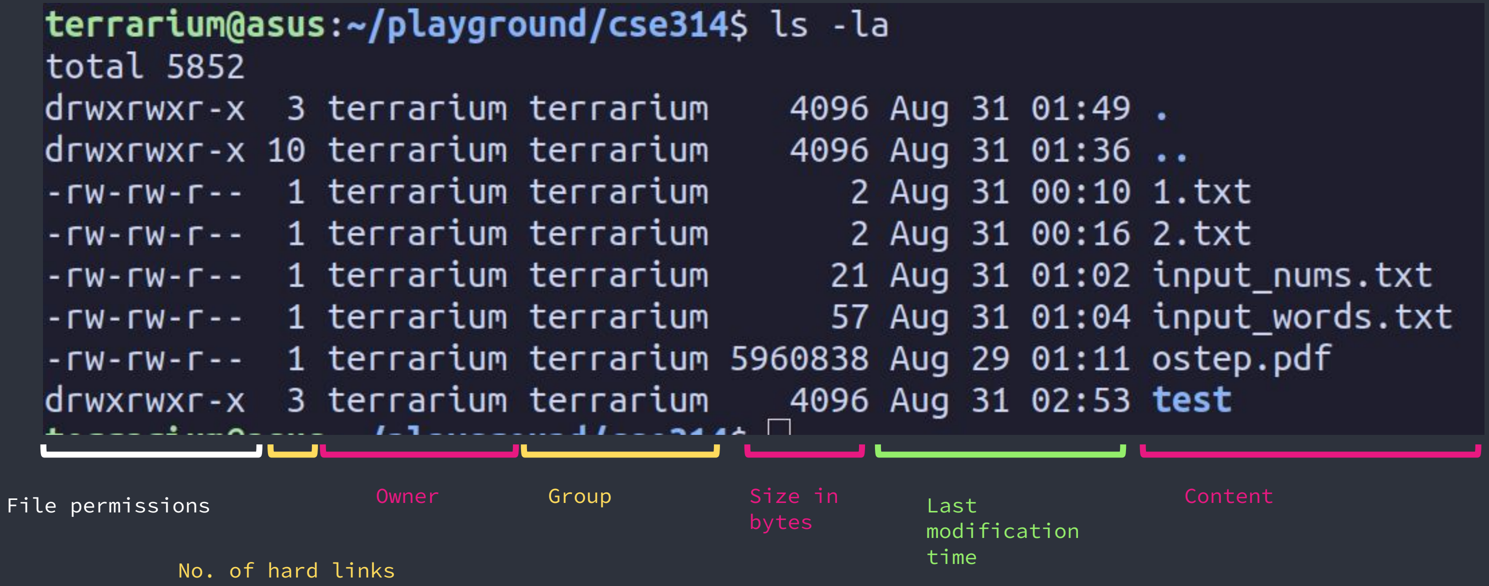
- cd : Change directory
- ls : List contents in directory
- mkdir : Make directory
- mv : Move or change name of something
- touch : Create files
- rm : Remove something
- cp : Copy something

</ Listing files and directories

- `ls [OPTION]... [FILE]...`
  - Lists information about directory or file
  - -a Lists the hidden files as well
  - -l List in details
  - -R List subdirectories recursively
  - -S Sort by file size
  - -F Append / for dirs, * for executables, @ for symbolic links

</ Listing files and directories

- `ls -la`



```
terrarium@asus:~/playground/cse314$ ls -la
total 5852
drwxrwxr-x  3 terrarium terrarium    4096 Aug 31 01:49 .
drwxrwxr-x 10 terrarium terrarium    4096 Aug 31 01:36 ..
-rw-rw-r--  1 terrarium terrarium       2 Aug 31 00:10 1.txt
-rw-rw-r--  1 terrarium terrarium       2 Aug 31 00:16 2.txt
-rw-rw-r--  1 terrarium terrarium      21 Aug 31 01:02 input_nums.txt
-rw-rw-r--  1 terrarium terrarium      57 Aug 31 01:04 input_words.txt
-rw-rw-r--  1 terrarium terrarium 5960838 Aug 29 01:11 ostep.pdf
drwxrwxr-x  3 terrarium terrarium    4096 Aug 31 02:53 test
```

</ Listing files and directories

- Everything is a file in Linux
- Directories are a special type of file
  - contains a list of filenames and their corresponding inode numbers
  - inode is a data structure that stores information about files such as permissions, ownership, and file location on the disk.
- The size 4096 bytes is the smallest unit of space that the filesystem can allocate
  - aka “Default Block Size”

</ Creating directories

- `mkdir [OPTION]... DIRECTORY...`
    - `-p   Create parent directories as needed, do nothing if it exists`
    - `-m   Provide file mode like: rwxrw-r-- (more on this later!)`
    - `-v   Verbose output`

</ Creating files

- `touch [OPTION]... FILE...`

</ Moving and renaming

- `mv [OPTIONS]... SRC... DEST`
    - `-i   Prompt before overwriting`
    - No “-r” option

</ Moving and renaming

- mv OLD NEW
    - if 'new' is a directory: 'old' is moved inside 'new'
    - if 'new' does not exist: 'old' is renamed to 'new'
    - if 'new' is a file, and 'old' is file: 'old' replaces 'new', and the previous content of 'new' is lost forever!!
    - if 'new' is a file, and 'old' is directory: it's an error (cannot overwrite a file with a directory)

For file also, mv 2.txt 3.txt
2.txt er nam 3.txt hoye jabe...and content 2.txt er ta thakbe

</ Copying files and directories

- `cp [OPTION]... SRC... DEST`
    - `-r` Recursive copy
    - `-i` Interactive prompt

</ Removing

- `rm [OPTION]... [FILE]...`
  - No way to undo!
  - `-f`   Never prompt (needed for write-protected files)
  - `-i`   Always prompt
  - `-r`   Remove recursively (needed for directory removal)
  - `-v`   Verbose print
- Kill your system (DON'T!): `sudo rm -rf /`
- Use preventive measures (aliases)

</ Exercise

- Create 4 files named project_<your_id>.java, project_<your_id>.js, project_<your_id>.html, and project_<your_id>.css.
- Then, create a directory called web_project. Inside web_project, create subdirectories named backend, frontend, and styles. Move the .java file to backend, the .js and .html files to frontend, and the .css file to styles.

</ Exercise

- Create 4 files named old_report.docx, draft.docx, old_photo.png, and snapshot.png. Create two directories named documents and images.
  - Rename draft.docx to final_report.docx.
  - Move all .docx files to the documents directory.
  - Move all .png files to the images directory.
  - List the contents of both documents and images directories. ls -la documents
  - Now move all files beginning with old to a new directory named archived mv old* archived/ For same directory

</ I/O Redirection

- Default input from keyboard, default output to screen
- I/O redirection allows us to change this
  - `<` get input from a file other than keyboard (stdin)
  - `>` output to a file other than the screen (stdout)
  - `>>` append output to a file
  - `2>` Redirects stderr
  - `&>` Redirects both stderr and stdout
    - `ls /nonexistent &> all_output.txt`
    - `ls /nonexistent > all_output.txt 2>&1`
    - redirect stderr to wherever stdout is going

</ I/O Redirection

- `cat nonexistent.txt 2> error.log`
  - Here, the cat program attempts to open the given file. This will redirect the error message if the given file does not exist
- `cat < nonexistent.txt 2> error.log`
  - The same does not apply here. This is because the shell itself attempts to open the file, hence the error is generated by the shell, not the cat program.
  - Workaround: `{ cat < nonexistent.txt; } 2> error.log`
  - The command is placed inside a subshell {}. The error generated by the shell is captured by 2>

</ Piping

- Pass the output of one command directly as input to another command
- command1 | command2 | command3 …
- `ls /bin /usr/bin | sort | uniq | less`
  - List all files in /bin and /usr/bin, sort them, remove duplicates, then display using less pager

sort -n file.txt;Here n for numerical sorting..eita ascending order e sort kore..for descending order -nr should be used

- `sort path/to/file | uniq -c | sort -nr` For frequency count
  - Display number of occurrences of each line, sorted by the most frequent
- Extremely powerful and versatile!

uniq each line k ekta word hisabe treat kore

- Difference between >> and |?
  - >>   Append output to files
  - | Chain commands

</ Piping

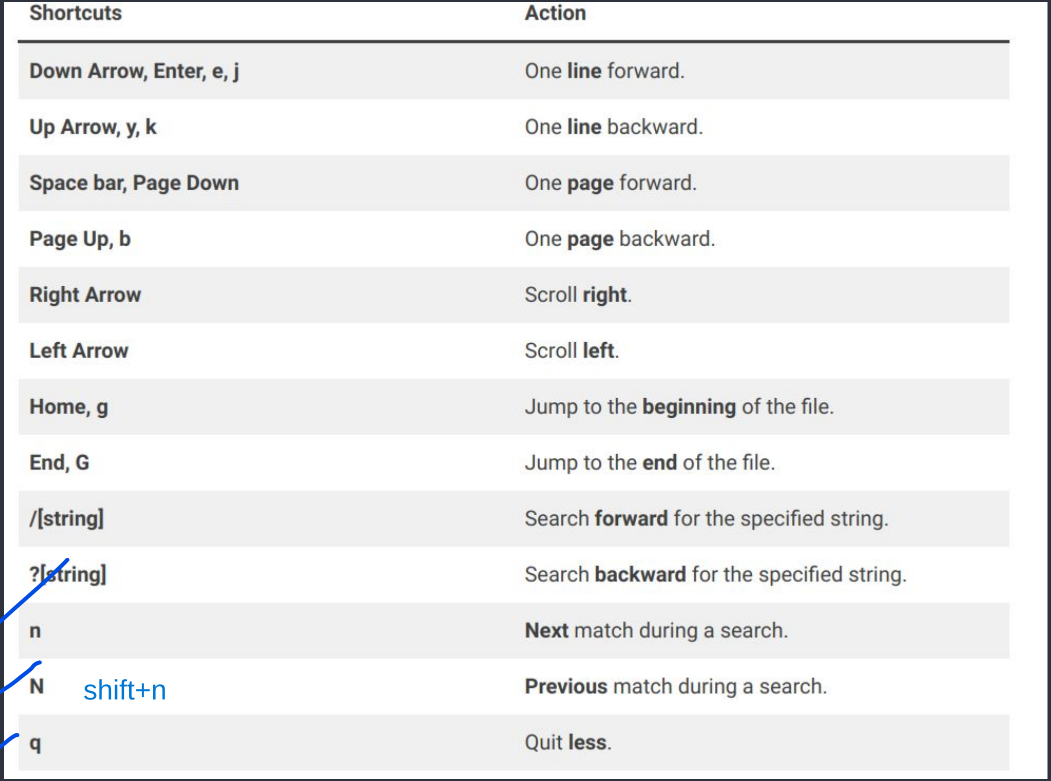
- Counting the frequency of words from a file:
- `tr -c '[:alnum:]' '\n' < file.txt | tr '[:upper:]' '[:lower:]' | sort | uniq -c | sort -nr | head -10`
  input substitution
- Explanation:
  - tr takes two arguments: PATTERN1 and PATTERN2, and it replaces PATTERN1 with PATTERN2
  - tr -c '[:alnum:]' '\n' this replaces all non-alphanumeric characters (tabs, spaces, etc) with newlines
  - tr '[:upper:]' '[:lower:]' converts all words to lowercase
  - The rest of the command sorts and displays the words by frequencies

</ How to remember the options?

- `CMD --help`
- `man CMD`
- `tldr CMD (more on this later)`
- `Copilot for bash (more on this later)`

</ less Pager

- Shows a file's contents one screen at a time
- Real-time monitoring: less +F FILENAME



Shortcuts	Action
Down Arrow, Enter, e, j	One **line** forward.
Up Arrow, y, k	One **line** backward.
Space bar, Page Down	One **page** forward.
Page Up, b	One **page** backward.
Right Arrow	Scroll **right**.
Left Arrow	Scroll **left**.
Home, g	Jump to the **beginning** of the file.
End, G	Jump to the **end** of the file.
/[string]	Search **forward** for the specified string.
?[string]	Search **backward** for the specified string.
n	**Next** match during a search.
N shift+n	**Previous** match during a search.
q	Quit **less**.

</ Viewing Files

- `less`
- `head`
- `tail`
  - Follow with `-f` or `-F`

For real time monitoring ...file e ki ki add kortesi
tail -F err.txt

- `cat`
- `wc` For counting lines ....cat err.txt | wc -l

</ Executing scripts

- In order to execute any script, we type ./script_name
- ./ is shorthand for "the current directory." When you type ./script_name, you are explicitly telling the shell to look in the current directory and execute script_name from there.
- Without the ./, the shell would only look for script_name in the directories listed in the PATH variable.
- The script must have a special line called “shebang” or “hashbang”

vim filename
shift o...then

</ Executing scripts

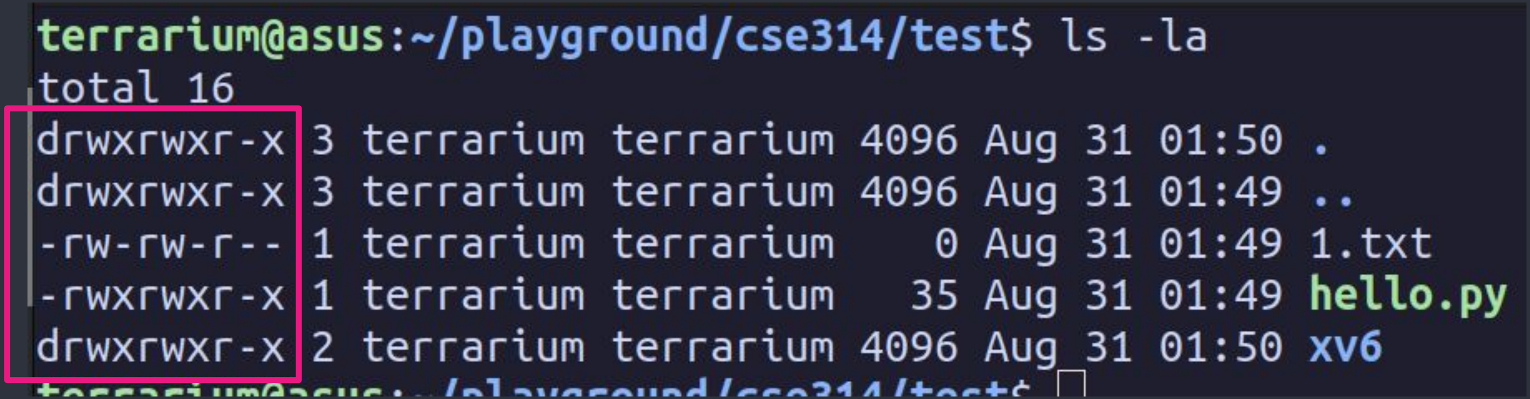
- The shebang is a character sequence at the beginning of a script file that indicates which interpreter should be used to execute the script. It is typically written as #! followed by the path to the interpreter.
- #!/usr/bin/python3
  - This shebang line tells the system to use /usr/bin/python3 to interpret the script.

last used command gula dekhar jonno ctrl + r press korte hbe

1 0 1 1   0 1 1   0 1   1 0 1 1 0 0 1   1 0   1 1 0 1 1   0 1 1   0 1   1 1 0 1 1 0   1 1 0 1 1 1   1 1 0 1

</ Permissions

- Access rights to files and directories are defined in terms of read access, write access, and execution access.
- Type `ls -la` in the terminal:



```
terrarium@asus:~/playground/cse314/test$ ls -la
total 16
drwxrwxr-x 3 terrarium terrarium 4096 Aug 31 01:50 .
drwxrwxr-x 3 terrarium terrarium 4096 Aug 31 01:49 ..
-rw-rw-r-- 1 terrarium terrarium    0 Aug 31 01:49 1.txt
-rwxrwxr-x 1 terrarium terrarium   35 Aug 31 01:49 hello.py
drwxrwxr-x 2 terrarium terrarium 4096 Aug 31 01:50 xv6
terrarium@asus:~/playground/cse314/test$
```

</ Permissions

$$\underbrace{\texttt{d}}\underbrace{\texttt{rwx}}_{\text{user}}\underbrace{\texttt{rwx}}_{\text{group}}\underbrace{\texttt{rwx}}_{\text{other}}$$

d	Directory
l	Symbolic link
s	Socket

r	read
w	write
x	execute

Linux e multiple user thakte pare...tader ekta grp e rakha jai.......grp er bairer user der jonno last 3 bit indicate kore

- for normal file
l for shortcut

Root user hisabe login er jonno: sudo -i

</ Users in Linux

- **Root User**: Always present. Highest privilege level
- **Default User**: Created during installation, usually one user with administrative privileges.
- **System Users:** Non-human users that are used by various system services and processes. Limited or no login capabilities and exist primarily for the purpose of running background services or daemons.
- `cut -d: -f1 /etc/passwd` proti line er first word k split kore

</ Permissions

r	read
w	write
x	execute

- -rw-r--r-- means it is a file which has read and write permissions for the owner, read permission for group and read permission for others.
- This means, only the owner of the file can read and write. The rest can only read.
- However, sometimes you may need to write or execute something that you don’t have permission for. What do you do in this case?

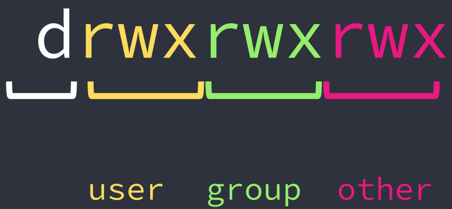
</ Permissions

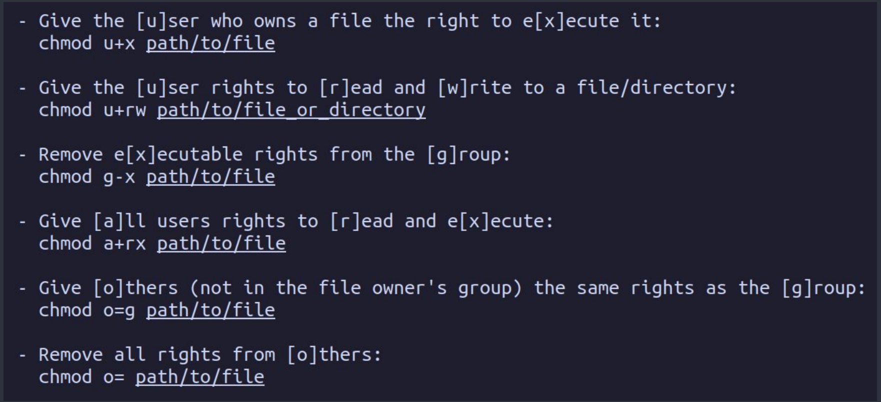
r	read
w	write
x	execute

- You can change permissions using **chmod**
- Each permission segment can be set using bits by the owner
  - For example: chmod 755 FILE
  - 755 => 111 101 101 => rwx r-x r-x

Octal notation

- Or by symbolic notation





```
- Give the [u]ser who owns a file the right to e[x]ecute it:
  chmod u+x path/to/file

- Give the [u]ser rights to [r]ead and [w]rite to a file/directory:
  chmod u+rw path/to/file_or_directory

- Remove e[x]ecutable rights from the [g]roup:
  chmod g-x path/to/file

- Give [a]ll users rights to [r]ead and e[x]ecute:
  chmod a+rx path/to/file

- Give [o]thers (not in the file owner's group) the same rights as the [g]roup:
  chmod o=g path/to/file

- Remove all rights from [o]thers:
  chmod o= path/to/file
```

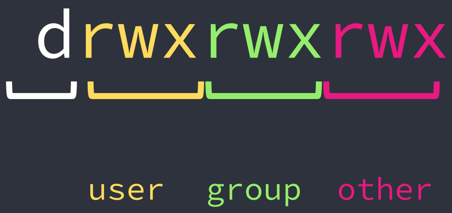
Say first time kono command fail korlo....seijonno age sudo add kora hoi..amra chaile sudp !! use korte pari...eita last failed command oikhane bosaye dei

</ Permissions

r	read
w	write
x	execute

- You can also change owner or group for a file:
  - chown username <FILE>
  - chgrp groupname <FILE>

lower previlege theke higher previlege e owner er permission deyar jonno sudo add kora lagbe sobar first e...tokhon ./filename dile kaj hbe na...er age sudo likha lagbe



Q: Two files may have the same permission bits, but still one needs sudo to write, and another does not. Why?

</ Permissions for Directories

r	read
w	write
x	execute

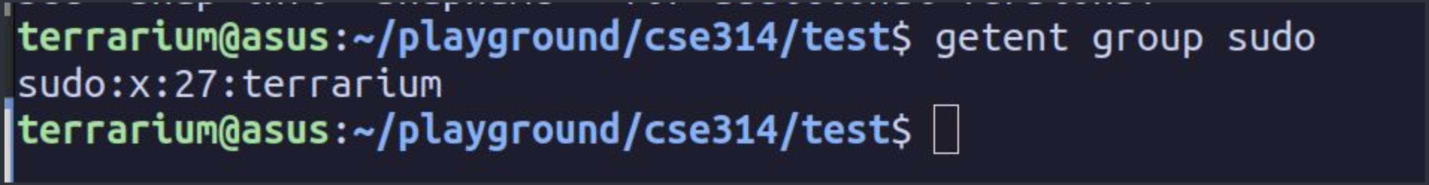
- If you have write permission for a directory, you can create new entries (files/folders/etc).
- If you have read permission for a directory, you may list ls the directories contents.
- If you have execute permission for a directory, you may change chdir into that directory.

That means we can enter into that directory

$$\underbrace{\texttt{d}}\underbrace{\texttt{rwx}}_{\texttt{user}}\underbrace{\texttt{rwx}}_{\texttt{group}}\underbrace{\texttt{rwx}}_{\texttt{other}}$$

</ Permissions

- Switch users: su [user]
- The default user belongs to a special group called “sudo”
- Members of the sudo group are granted the ability to execute commands with superuser (root) privileges by using the sudo command.
- View all groups:getent group
    - groupname:passwd:groupID:user1,user2,user3...



```
terrarium@asus:~/playground/cse314/test$ getent group sudo
sudo:x:27:terrarium
terrarium@asus:~/playground/cse314/test$ 
```

</ Permissions

- Execute command as a superuser: `sudo CMD`
- Add new user: `sudo adduser USERNAME`
- Delete user: `sudo userdel -r USERNAME`

- `sudo usermod -aG groupname username`
  - -a: Appends the user to a group. Without this, the user would be removed from all other groups not listed.
  - -G: Specifies the groups to which the user should be added.
- sudo can be dangerous if used without caution!

</ Permissions

- How to write to a restricted file using sudo?
    - sudo echo “hello” > file⇒ This doesn’t work
        - Redirection (>) is not part of the command that sudo is applied to
    - echo “Hello” | sudo tee file
        - tee reads from STDIN, writes to STDOUT or files provided
        - Since this is a program, not a STREAM, we need |, not >>

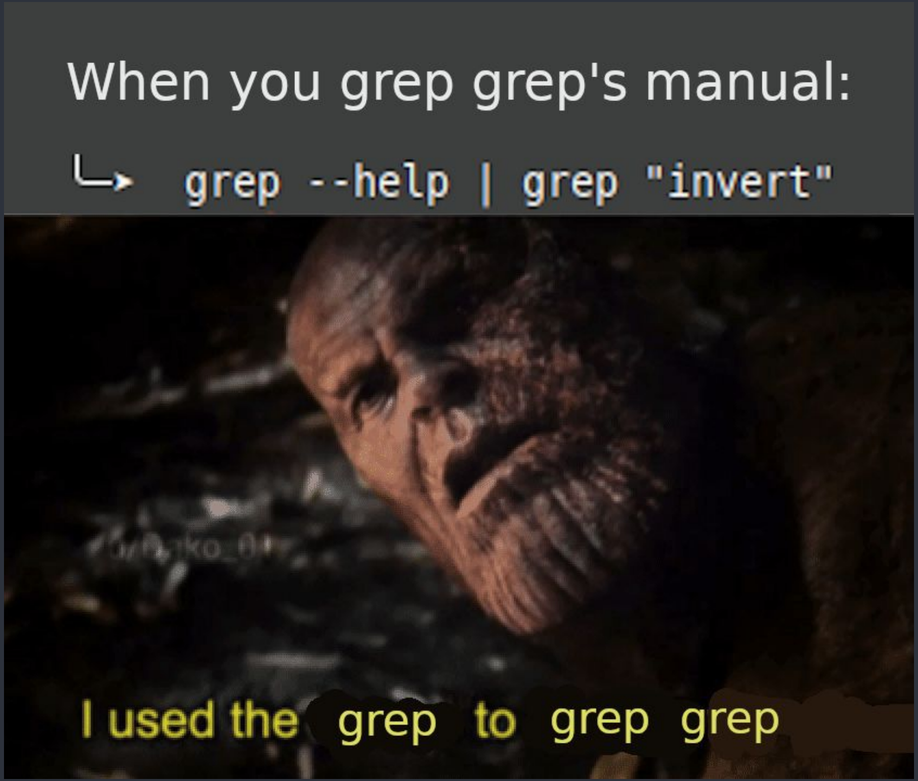
</ Aliases

```
$ alias cd='rm -rf'
```

</ Aliases

- Aliases are handy way to create notations for long commands
    - ll expands to ls -alF
    - alias alias_name='command'
- Aliases are temporary when set within the terminal
    - alias glnice=”git log --oneline --all --decorate --graph”
    - alias rm=”rm -i”
        - every rm command will be interactive, regardless of whether you use -rf or not. This adds an extra layer of safety by preventing accidental deletions.
- On Ubuntu versions 11.04 or later, you can add aliases to ~/.bash_aliases file to make them permanent.

</ Searching within files


When you grep grep's manual:

```
grep --help | grep "invert"
```

</ Searching within files

- grep [options] pattern [file...]
  - pattern: The string or regular expression you want to search for.
  - file...: One or more files where you want to search for the pattern. If no file is specified, grep searches in the standard input (e.g., piped from another command).
- grep "hello" file.txt
- grep -i "hello" file.txt   Case insensitive search
- history | grep “cd”
- grep "^start" file.txt   Search for lines starting with “start”
- grep "end$" file.txt   Search for lines ending with "end"

Eitai substring match hoileo rakhe...bt khali word rakhte hole cat file.txt | grep -iw "hello"

</ Searching within files

- Regex wildcards are allowed. (*.?^$)
- `grep -r "TODO" .`   Search recursively in the current directory
- More options:
    - `-n`   Display line numbers
    - `-w`   Search for word, substring matches are ignored
    - `-c`   Count number of matches
    - `-v`   Invert match (Find lines that do not have the pattern)
- `grep -n -C 2 "error" logfile.txt`
    - Display the match with line numbers and 2 lines of context
- And many more!

</ Searching files and folders

- find [path] [expression]
  - [path]: Specifies the directory where the search begins. If omitted, find starts in the current directory (.)
  - [expression]: Defines the criteria for finding files and directories. This can include options like -name, -type, -size, -mtime, and more.

</ Searching files and folders

- `find /path/to/search -name "filename.txt"`
    - searches for a file named filename.txt within /path/to/search and its subdirectories.
    - Recursive by nature!
    - Limit recursion using -maxdepth NUM
- `find /path/to/search -name "*.txt"`
    - Searches for all files ending with .txt

</ Searching files and folders

- By default, the **find** command searches for both files and directories matching the pattern
- Can specify types:
  - `-type f`   Only regular files
  - `-type d`   Only directories
  - `find /path/to/search -type d -name "dirname"`
- find is even more powerful than you can imagine!

</ Searching files and folders

- `find /path/to/search -type f -name "*.txt" -size +1M`
  - Finds .txt files larger than 1 MB.
- The -exec option in the find command allows you to execute a command on each file or directory that find locates. This is a powerful feature that enables you to automate tasks directly on the files or directories that match your search criteria.

</ Searching files and folders

- `find /path/to/search -type f -name "*.log" -exec rm {} \;`
  - Deletes all .log files but leaves directories and other non-regular files untouched.
  - It uses {} as a placeholder for the matched files or directories and requires \; to terminate the command.
- `find /path/to/search -type f -exec tar -rvf backup.tar {} \;`
  - Creates an archive or backup that includes only regular files and excludes directories
- `find /path/to/search -type f | wc -l`
- Another useful tool is the fuzzy finder (fzf)

</ xargs [optional]

- xargs is a powerful tool that is used to build and execute commands from standard input. It takes input from a pipe or file and passes it as arguments to another command.
- find . -name "*.txt" | xargs rm
  - find . -name "*.txt" searches for all .txt files in the current directory and its subdirectories.
  - The results (file paths) are passed to xargs, which constructs and executes the rm command with those file paths as arguments.
- This is same as   find . -name "*.txt" -exec rm {} \;
- The former can build commands in parallel, thus more efficient

</ Symbolic Links

- Symlinks are special type of file that contains a path to the target file or directory.
- `sudo ln -s /path/to/your/program /usr/local/bin/program_name`
- Here, /usr/local/bin is in $PATH. This makes your program system-wide available.
- `exec bash`   Reloads the shell
- For interested readers: https://askubuntu.com/questions/108771/what-is-the-difference-between-a-hard-link-and-a-symbolic-link

</ Helpful Commands

- !! : Re-run last command
- sudo : Run with elevated privileges
- **clear** : Clear the terminal
  - <CTRL> + L Actually moves to the end of output
- whoami : Print username
- which CMD : Print path to command

</ Some more...

htop	Task manager
df	Display free disk space
du	Display directory size and its contents
ps	Display running processes
kill	Terminate a process by its PID

</ Installing Programs

- apt : Advanced Package Tool
- sudo apt update
  - Refreshes the list of available packages and their versions.
- sudo apt upgrade
  - Upgrades all the installed packages to newest version
- sudo apt install PKG
- sudo apt remove PKG

</ Installing Programs

- sudo apt autoremove
  - Removes unused dependencies
- sudo apt autoclean
  - Removes old packages that have been superseded by newer versions
- Use with combination!
  - sudo apt autoremove && sudo apt autoclean

</ Installing Programs

- To install from standalone installers:
  - sudo dpkg -i your_file.deb
- Unzip .tar files
  - tar -xvf your_file.tar.gz

</ Too Long Didn't Read?

- man CMD   Open command manual
  - TOO VERBOSE!
- CMD --help
  - No examples!
- Your best friend: tldr
  - Install using pip or npm
  - Do not use apt. You may end up with an old version.

PRACTICE

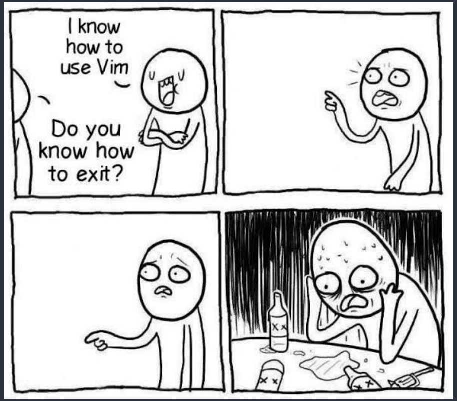
- https://school.brainhackmtl.org/modules/introduction_to_terminal/
- https://cmdchallenge.com/

</ Useful tools

- fzf
- tldr
- Copilot for CLI: https://docs.github.com/en/copilot/using-github-copilot/using-github-copilot-in-the-command-line
- tmux
- ngrok   You can set-up your own ssh using ngrok
- wget, curl
- vim, nano, emacs

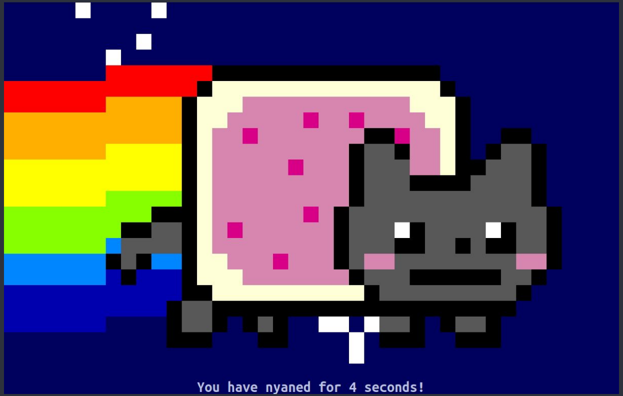
</ Supplementary Lectures and Tools

- https://missing.csail.mit.edu/
  - Recommended to watch at least the first 6 lectures (upto and including Version Control)
- https://explainshell.com/
- vim tutorial: https://www.youtube.com/watch?v=ggSyF1SVFr4
  - Or just type vimtutor in the terminal
- tmux: https://www.youtube.com/watch?v=DzNmUNvnB04



</ Easter eggs 🥚

- telnet towel.blinkenlights.nl
- sudo insults: https://itsfoss.com/sudo-insult-linux/
- sl
- lolcat (Can be used as a pipe)
- figlet
- cmatrix
- moon-buggy
- nyancat



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You have nyaned for 4 seconds!
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Thank You