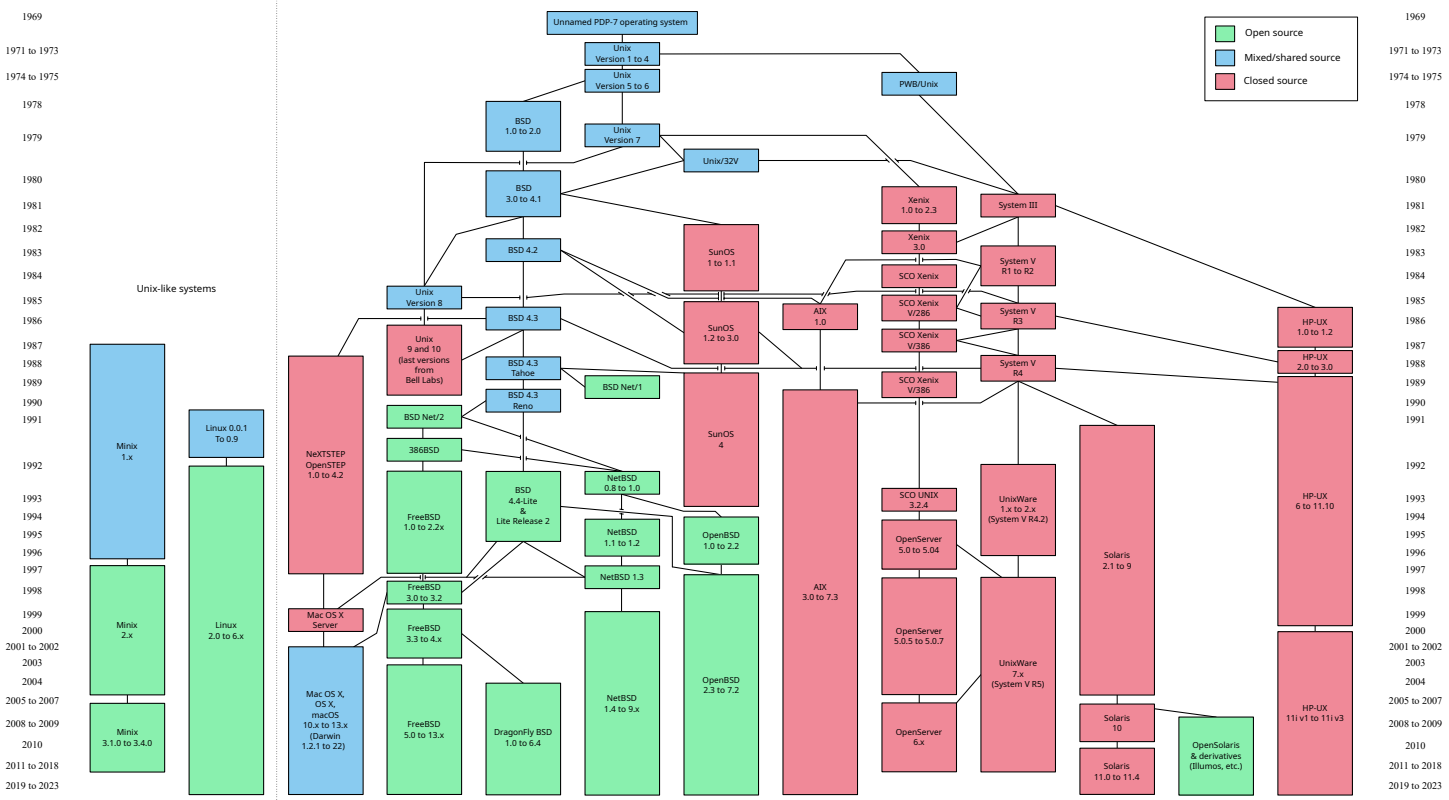
Introduction to Unix/Linux shell ¶

What is (was) Unix

- Multi-user, multi-tasking Operating System
- Developed in the late 1960s at AT&T's Bell Labs
- Family or lineage of operating systems


Open source
Mixed/shared source
Closed source
Unix-like systems
1969
1971 to 1973
1974 to 1975
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001 to 2002
2003
2004
2005 to 2007
2008 to 2009
2010
2011 to 2018
2019 to 2023
Unnamed PDP-7 operating system
Unix Version 1 to 4
Unix Version 5 to 6
Unix Version 7
PWB/Unix
BSD 1.0 to 2.0
Unix/32V
BSD 3.0 to 4.1
BSD 4.2
SunOS 1 to 1.1
Xenix 1.0 to 2.3
Xenix 3.0
SCO Xenix
SCO Xenix V/286
SCO Xenix V/386
System III
System V R1 to R2
System V R3
System V R4
Unix Version 8
BSD 4.3
SunOS 1.2 to 3.0
AIX 1.0
HP-UX 1.0 to 1.2
HP-UX 2.0 to 3.0
Unix 9 and 10 (last versions from Bell Labs)
BSD 4.3 Tahoe
BSD 4.3 Reno
BSD Net/1
BSD Net/2
386BSD
SunOS 4
AIX 3.0 to 7.3
HP-UX 6 to 11.10
NeXTSTEP OpenSTEP 1.0 to 4.2
FreeBSD 1.0 to 2.2x
BSD 4.4-Lite & Lite Release 2
NetBSD 0.8 to 1.0
NetBSD 1.1 to 1.2
NetBSD 1.3
OpenBSD 1.0 to 2.2
SCO UNIX 3.2.4
OpenServer 5.0 to 5.04
OpenServer 5.0.5 to 5.0.7
OpenServer 6.x
UnixWare 1.x to 2.x (System V R4.2)
UnixWare 7.x (System V R5)
Solaris 2.1 to 9
Solaris 10
Solaris 11.0 to 11.4
OpenSolaris & derivatives (Illumos, etc.)
HP-UX 11i v1 to 11i v3
Minix 1.x
Minix 2.x
Minix 3.1.0 to 3.4.0
Linux 0.0.1 To 0.9
Linux 2.0 to 6.x
FreeBSD 3.0 to 3.2
FreeBSD 3.3 to 4.x
FreeBSD 5.0 to 13.x
Mac OS X Server
Mac OS X, OS X, macOS 10.x to 13.x (Darwin 1.2.1 to 22)
DragonFly BSD 1.0 to 6.4
NetBSD 1.4 to 9.x
OpenBSD 2.3 to 7.2

Unix - key aspects

- Multi-User & Multi-Tasking
- Hierarchical File System (root directory and subdirectories)
- "Everything is a File" Philosophy (system resources & hardware devices)
- Command-Line Interface (CLI): **shell** interpreter
- Pipes and Redirection (chain single-purpose commands & resources/devices)

Jupyter & Unix shell

There are several ways to run shell commands directly within a Jupyter Notebook:

- Using the Exclamation Mark (`!`)
- Using Cell Magics (`%%bash`, `%%sh`, `%%script`)
- Using Python's `subprocess` Module

Using the Exclamation Mark (!)

Inside a code cell, prefix the shell command you want to run with an exclamation mark:

In [1]:
```
!pwd # Print working directory
```

```
/home/jupyter-mpenagaricano/Programming-for-AI
```

In [2]:
```
!ls # List all files
```

```
0_Index.ipynb  10.txt.utf-8  1b_unix_shell.ipynb  img  README.md
```

In [3]:
```
!for x in {1..5}; do echo $x ; done # print numbers from 1 to 5
```

```
1
2
3
4
5
```

NOTE: Depending on the host OS, the shell will be different. Our host is running Ubuntu 22.04, a linux distribution:

In [4]:

```
!cat /etc/os-release
```

```
PRETTY_NAME="Ubuntu 22.04.5 LTS"
NAME="Ubuntu"
VERSION_ID="22.04"
VERSION="22.04.5 LTS (Jammy Jellyfish)"
VERSION_CODENAME=jammy
ID=ubuntu
ID_LIKE=debian
HOME_URL="https://www.ubuntu.com/"
SUPPORT_URL="https://help.ubuntu.com/"
BUG_REPORT_URL="https://bugs.launchpad.net/ubuntu/"
PRIVACY_POLICY_URL="https://www.ubuntu.com/legal/terms-and-policies/pri
UBUNTU_CODENAME=jammy
```

Capturing shell output into a Python Variable

You can assign the standard output of a shell command to a Python variable using the `variable = !command` syntax:

In [5]:
```
files = !ls
print(type(files))
```

```
<class 'IPython.utils.text.SList'>
```

In [6]:
```
import IPython
#help(IPython.utils.text.SList)
```

In [7]:

```
files = !ls
for x in files :
    print(type(x),x)
```

```
<class 'str'> 0_Index.ipynb
<class 'str'> 10.txt.utf-8
<class 'str'> 1b_unix_shell.ipynb
<class 'str'> img
<class 'str'> README.md
```

Using Python Variables in Shell Commands

You can pass Python variables into your shell commands by enclosing the variable name in curly braces `{}` :

In [8]:

```
dirname = "img"
!ls {dirname}
```

```
Unix_history-simple.svg
```

Using Cell Magics (`%%bash`, `%%sh`, `%%script`)

With Cell Magics, you can run multiple lines of shell script within a single cell:

In [9]:

```
%%bash
echo "STARTING THE SCRIPT (dir: $(pwd))"
for f in * /dev/null ; do
    if [ -d ${f} ] ; then
        echo "  ${f}: directory"
    elif [ -f ${f} ] ; then
        echo "  ${f}: regular file"
    else
        echo "  ${f}: not regular file"
    fi
done
echo "SCRIPT FINISHED!!"
```

```
STARTING THE SCRIPT (dir: /home/jupyter-mpenagaricano/Programming-for-A
  0_Index.ipynb: regular file
  10.txt.utf-8: regular file
  1b_unix_shell.ipynb: regular file
  img: directory
  README.md: regular file
  /dev/null: not regular file
SCRIPT FINISHED!!
```

%%sh vs %%bash

- `sh` (Bourne Shell): Developed at Bell Labs in the late 1970s. It was the original standard Unix shell.
- `bash` (Bourne-Again Shell): Created for the GNU Project in the late 1980s as a free software replacement and enhancement for `sh`.
    - Includes almost all features of `sh` but adds many modern conveniences:
    - Command History, Tab Completion, Arrays, Brace Expansion, Extended Globbing, Ritcher Arithmetic, Process Substitution...

Using `%%script <interpreter>`

You can run the cell content with a specific interpreter (e.g., perl, tcl, java...).

In [10]:
```
%%script perl
print("Hello World!!\n");
```

```
Hello World!!
```

In [11]:
```
%%script tclsh
puts "Hello World!!"
```

```
Hello World!!
```

In [12]:
```
%%script javash
System.out.println("Hello World!!")
```

```
Couldn't find program: 'javash'
```

Using Python's `subprocess` Module

Python's built-in `subprocess` module allows more fine-grained control, error handling, capturing stderr separately, or handling complex interactions. This is the standard Python way to run external commands from Python scripts.

In [13]:

```
import subprocess

# Run a command and capture output.
#  capture_output=True captures stdout and stderr
#  check=True raises error if command fails
#  text=true decodes stdin, stdout and stderr using the given/default e
result = subprocess.run(['ls','img'], capture_output=True, text=True, c

print("Return Code:", result.returncode)
print("Stdout:")
print(" ",result.stdout)
print("Stderr:")
print(" ",result.stderr)
```

```
Return Code: 0
Stdout:
  Unix_history-simple.svg

Stderr:
```

Unix-like terminal commands

1. Getting Help
2. Navigation & Directory Listing
3. File & Directory Manipulation
4. Viewing File Contents
5. Searching, filtering and sorting
6. System Information & Monitoring
7. User & Permissions
8. Networking
9. Process Management
10. Archiving & Compressing

Unix commands - Getting Help

`man` - an interface to the system reference manuals

- `man command_name` : Display the manual page for a program, utility or function. Press `q` to quit.

In [14]:

```
#!man man
```

In [15]:

```
#!man 1 printf
```

In [16]:

```
#!man 3 printf
```

`command_name --help` - try to get help from a command

Many commands has the option `--help` or `-h`

In [17]:
```
#!man --help
```

Unix commands - Navigation & Directory Listing

`ls` - list directory contents

- `ls` : List current directory contents.
- `ls img` : List the contents of the directory `img`.
- `ls -l` : List in long format (permissions, owner, size, date).
- `ls -a` : List all files, including hidden ones (starting with `.`).

In [18]:

```
!ls img/*.svg
#!ls -l ../Programming-for-AI/img/*.svg
#!ls -l /home/jupyter-mpenagaricano/Programming-for-AI/img/*.svg
```

```
img/Unix_history-simple.svg
```

Bash carries out filename expansion (a process known as **globbing**) on unquoted command-line arguments:

- `*` → any character sequence (could be empty)
- `?` → any single character
- `^` → negating the sense of a match
- `[xy]` → single character from range `x` to `y`
- `{pattern1,pattern2,pattern3}` → any of the three patterns

For example:

- `ae*` : any filename starting with `ae`
- `[ab]*` : any filename starting with `a` or `b`
- `[a-k]*` : any filename starting with letters from `a` to `k`
- `[^ab]*` : any filename NOT starting with `a` or `b`
- `[^A-Z]?` : any filename of length two, not starting with uppercase

In [19]:

```
%%bash
ls img/[^a-z]*
```

```
img/Unix_history-simple.svg
```

`pwd` - print name of current/working directory

`cd` - change directory

- `cd dirname` : Change to the directory `dirname`.
- `cd ..` : Go up one directory level.
- `cd ~` or `cd` : Go to your home directory.
- `cd -` : Go to the previous directory you were in.

In [20]:

```
%%bash
pwd
cd /tmp
pwd
cd
pwd
```

```
/home/jupyter-mpenagaricano/Programming-for-AI
/tmp
/home/jupyter-mpenagaricano
```

Unix commands - File & Directory Manipulation

`cp` - copy files and directories

- `cp src_file dst_file` : Copy file.
- `cp src_file dst_dir/` : Copy file to destination dir.
- `cp -r src_dir dst_dir/` : Recursively copy source dir to destination dir.

There are many options to control metadata and symbolic links

In [21]:
```
#!man cp
```

`mv` - move (rename) files

- `mv old_filename new_filename` : Rename file.
- `mv src_file dst_dir/` : Move file.

`rm` - remove files or directories

- `rm filename` : Remove file.
- `rm -r dirname` : Recursively remove a directory (**USE WITH CAUTION!**).

`mkdir` - make directories

`rmdir` - remove empty directories

Unix commands - Viewing File Contents

`cat` - concatenate files and print on the standard output

`more` & `less` - View file content page by page (scrolling & searching)

`head` - output the first part of files

- `head filename` : Output the first 10 lines of the file.
- `head -n 20 filename` : Output the first 20 lines of the file.
- `head -n -20 filename` : Output all the lines of the file except the last 20.
- `head -c 123 filename` : Output the first 123 bytes (characters?) of the file.

`tail` - output the last part of files

Unix commands - Searching, sorting, filtering and transforming

`grep pattern filename` - print lines that match patterns

`find` - search recursively for files and directories (based on name, size, ...)

- `find . -name "*.txt"` : Find files ending in `.txt` within the current directory (recursively)
- `find /home/user -type d -name "my_project"` : Find a directory named `my_project` within `/home/user`

`sort` - sort lines of text files

`uniq` - report or omit repeated lines

`tr` - translate, squeeze or delete characters

`cut` - remove sections from each line

Unix commands - Archiving & Compressing

`tar` - an archiving utility (Create or extract archive files)

- `tar -cf archive.tar dirname` : Create an uncompressed archive from directory.
- `tar -xf archive.tar` : Extract an uncompressed archive in the current directory.
- `tar -czvf archive.tgz dirname` : Create a (GNU) zip archive from directory.
- `tar -xzf archive.tgz` : Extract a (GNU) zip archive in the current directory.

`gzip` , `gunzip` and `zcat` - compress or expand files

- `gzip *` : Compress all files in current directory (rename to *.gz)
- `gunzip *.gz` : Uncompress all compressed files in current directory
- `zcat *.gz`: Print to the standard output the uncompressed content of files

Unix commands - Networking

`ping` - check network connectivity to a host

`ssh username@host` - connect to a remote machine via Secure Shell

`scp` - copy files between hosts over SSH

`wget url` or `curl -O url` - download files from the web

Unix commands - System Information & Monitoring

`uname` - print system information

`df` - report file system disk space usage

`du` - estimate file space usage

`ps` - snapshot of running processes

`top` - display running processes (pid, user, CPU/memory usage)

Unix commands - User & Permissions

`su` - switch user

`sudo` - execute a command as another user

`whoami` - show the current effective username.

`chmod` - change file mode (permissions - read, write, execute)

- `chmod +x script.sh` : Make `script.sh` executable.

`chown` - change file owner and group

- `sudo chown user:group filename`

Unix commands - Process Management

`kill` - send a signal to a process

- `kill pid` or `kill -15 pid` : Send SIGTERM signal (*graceful* termination)
- `kill -9 pid` : Send SIGKILL signal (*ungraceful* termination)

`killall` - kill processes by name

- `sudo killall -9 -u bob` : Terminate all processes owned by bob

Command chaining

Commands can be chained. Every command will be executed based on the success or failure of the preceding command.

- When a command finishes executing, it returns an integer (*exit status*).
    - 0 → the command executed successfully
    - [1-255] → command failed
    - The variable `$?` contains the exit status of the last command

In [22]:

```
%%bash
ls 1b_unix_shell.ipynb
#ls this_file_does_not_exist
echo $?
```

```
1b_unix_shell.ipynb
0
```

Logical AND (&&)

- Syntax: `command1 && command2 && command3 && ...`
- Behaviour:
    - The shell executes `command1`
    - If `command1` succeeds, then the shell executes `command2`
    - If `command2` succeeds, then the shell executes `command3`
    - ...
    - If any command fails, none of the following ones will be executed

In [23]:

```
# Update package lists and then upgrade packages
#!sudo apt update && sudo apt upgrade -y
```

Logical OR (||)

- Syntax: `command1 || command2 || command3 && ...`
- Behaviour:
    - The shell executes `command1`
    - If `command1` fails, then the shell executes `command2`
    - If `command2` fails, then the shell executes `command3`
    - ...
    - If any command succeeds, none of the following ones will be executed

In [24]:

```
# Check if a file contains a specific pattern; if not, print a message
#!grep "ERROR" system.log || echo "No errors found in system.log"
```

Combining && and ||

- Both can be chained together
- Precedence rules: *usually* && tighter than ||
- Use parentheses `( ... )` for clarity

In [25]:

```
# Check if a file contains a specific pattern; if not, print a message
#!make clean && make && ./run_tests || echo "Build or test process fail
#!((make clean && make) && ./run_tests) || echo "Build or test process
```

(&& and ||) vs ;

- `command1 ; command2`
- Executes `command1` and then **allways** executes `command2`

Redirection and Pipes

Every command has three standard communication channels associated with it:

- **Standard Input** (stdin): This is where the command reads its input from. By default, it's connected to the keyboard.
- **Standard Output** (stdout): This is where the command writes its normal output. By default, it's connected to the terminal screen.
- **Standard Error** (stderr): This is where the command writes its error messages. By default, it's also connected to the terminal screen (but it's a separate stream from stdout).

Redirection is about **changing where these streams point to or from**, typically involving files (which could refer to devices).

Output Redirection (> and >>)

- `command > filename` : Redirects stdout of `command` to `filename`.
    - Overwrites: If `filename` exists, its contents are deleted and replaced.
    - Creates: If `filename` does not exist, it is created.
    - `cat file1 file2 > both_files`

- `command >> filename` : Redirects stdout of `command` to `filename`.
    - Appends: If `filename` exists, the output is added to the end of the file.
    - Creates: If `filename` does not exist, it is created.
    - `grep -B 1 -A 2 "^ERROR:" today_log >> all_errors`

Input Redirection (<)

- `command < filename` : Redirects stdin of `command` to come from `filename`.
    - `grep pattern < /dev/some_device`

Error Redirection (2> ansd 2>>)

- `command 2> error_log.txt`: Redirects stderr to `error_log.txt`. Overwrites the file.
- `command 2>> error_log.txt`: Redirects stderr to `error_log.txt`. Appends to the file.
    - `find / -name secret.txt 2> errors.log` : Finds a file by name, putting permission errors etc. into `errors.log`

Redirecting Both stdout and stderr

- `command > output.log 2>&1`: Redirects stdout to `output.log`, then redirects stderr (`2>`) to the current location of stdout (`&1`). Order matters.
- `command &> output.log` or `command >& output.log` : Bash shortcut to redirect both stdout and stderr. Overwrites.
- `command &>> output.log` : Bash shortcut to append both stdout and stderr.

Pipes (|)

- A pipe (pileline) connects the stdout of one command with the stdin of another command.
- `command1 | command2` : stdout of `command1` is connected to stdin of `command2`.
    - Both commands run in parallel
    - Data doesn't need to be written to disk and read back in; it is buffered in memory between processes.
- `cmd1 | cmd2 | cmd3 | ...` : You can chain multiple commands together:

Exercise: Find the 15 most common words in the Bible and their number of occurrences.

1 - Download the bible from gutenberg.org (**https://www.gutenberg.org/cache/epub/10/pg10.txt (https://www.gutenberg.org/cache/epub/10/pg10.txt)**)

In [26]:
```
#!curl https://www.gutenberg.org/cache/epub/10/pg10.txt -o bible.txt
#!head -30 bible.txt
```

2 - Convert to lowercase and all non alphabet characters to whitespaces

In [27]:
```
!# bible.txt | tr [:upper:] [:lower:] | tr -c '[a-z] \n' ' ' | head
```

3 - Replace all whitespaces by newlines (one word per line)

In [28]:
```
#!cat bible.txt | tr [:upper:] [:lower:] | tr -c '[:alpha:]\n' ' ' | tr
```

4 - Sort the lines (words) alphabetically

In [29]:
```
#!cat bible.txt | tr [:upper:] [:lower:] | tr -c '[:alpha:]\n' ' ' | tr
#!cat bible.txt | tr [:upper:] [:lower:] | tr -c '[:alpha:]\n' ' ' | tr
```

5 - Retain a single occurrence and count them

In [30]:
```
#!cat bible.txt | tr [:upper:] [:lower:] | tr -c '[:alpha:]\n' ' ' | tr
#    sort | uniq -c | head
```

6 - Reverse sort the lines (words) numerically

In [31]:
```
#!cat bible.txt | tr [:upper:] [:lower:] | tr -c '[:alpha:]\n' ' ' | tr
#    sort | uniq -c | sort -n | tail
```

Single command line solution:

In [32]:

```
%%bash
curl https://www.gutenberg.org/cache/epub/10/pg10.txt 2> /dev/null | \
    tr [:upper:] [:lower:] | tr -c '[:alpha:]\n' ' ' | tr ' ' '\n' | \
    sort | uniq -c | sort -nr | \
    head -16 | tail -15
```

```
  64309 the
  51762 and
  34846 of
  13680 to
  12927 that
  12727 in
  10422 he
   9840 shall
   8997 unto
   8997 for
   8854 i
   8473 his
   8235 a
   7964 lord
   7378 they
```