Introduction to Unix/Linux

Operating Systems UE 2022W

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Motivation

- What is an Operating System?
- UNIX, Linux, . . . ?
- Why C?

What is an Operating System?

The operating system as . . .

1. An extended machine
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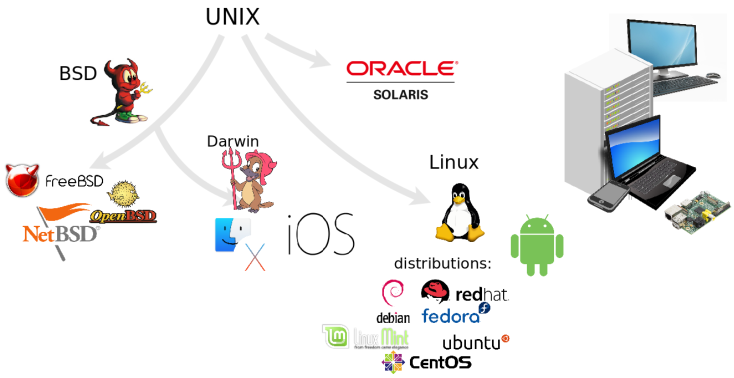
Important mechanisms: Processes, virtual memory, file system, . . .

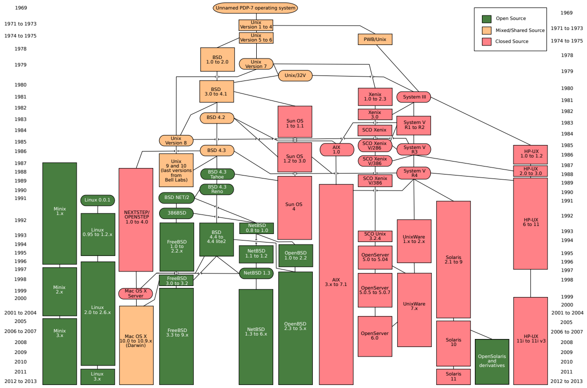
Unix

Unix-family OS everywhere



Unix

Evolution of Unix and Unix-like systems



Source: Wikipedia

The C Programming Language

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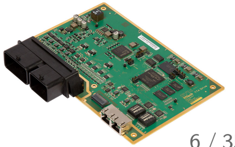
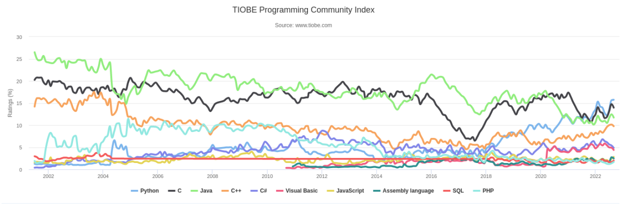
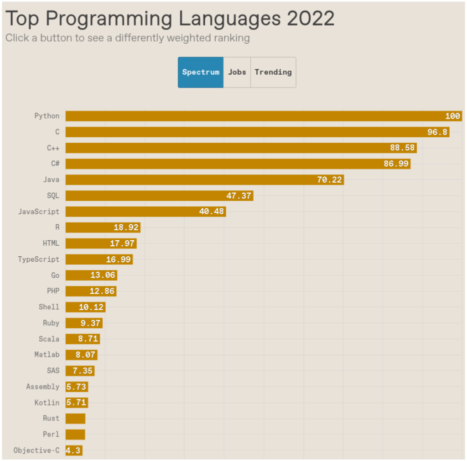


Relevance of C I

- Appeared 1972 when UNIX was ported to C
- Has not lost popularity and importance!
- Tools (compiler, debugger, profiler, . . .) improved over time



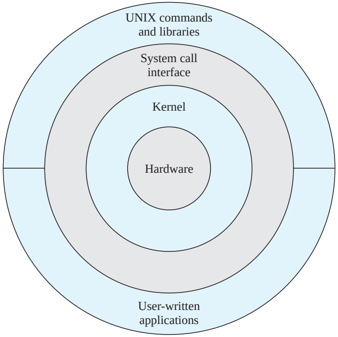
Relevance of C II



Source: IEEE Spectrum Rating of programming languages, 2022
`https://spectrum.ieee.org/top-programming-languages-2022`

Unix Anatomy

- User space – Kernel space
  - Kernel routines run in privileged mode (*kernel mode*), includes device drivers
  - User processes request kernel services with *system calls*
- Multi-process and multi-user operating system
  - Run more than one program concurrently
  - Users share resources
- Requires authentication (login)



General Unix Architecture (Source: W. Stallings, “Operating Systems. Internals and Design Principles”)

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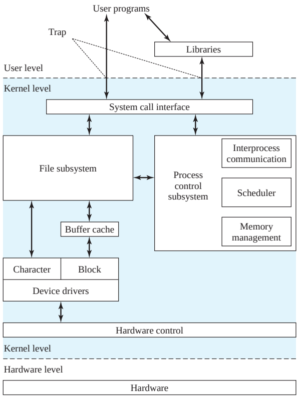
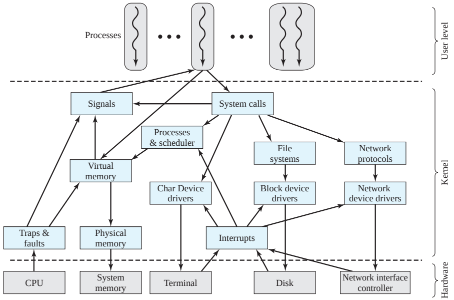


Traditional UNIX Kernel



Linux Kernel Components

(Source: W. Stallings, "Operating Systems. Internals and Design Principles")

The Shell

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- Shell prompt:

```
jdoe@ti1:~$ _
```

Unix Philosophy

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- Write programs that do one thing and do it well. (DOTADIW)
- Write programs to work together.
- Write programs to handle text streams, because that is a universal interface.

= combining small, sharp tools and the use of a common underlying format (the line-oriented, plain text file) to accomplish larger tasks

Executing programs

```
$ echo Hi there
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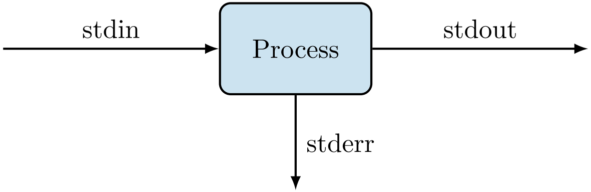
```
$ rev
Hello class
ssalc olleH
```

<Ctrl-D> (EOF token)

Standard Input/Output

- A process communicates with its environment by following channels:
  - Standard input (stdin, 0), redirect with <
  - Standard output (stdout, 1), redirect with >
  - Standard error (stderr, 2), redirect with 2>



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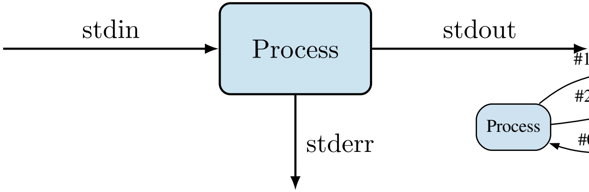
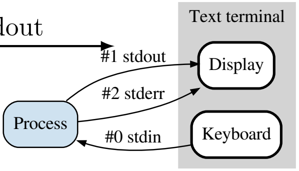
- When started in a shell, the standard I/O is connected to the terminal.





Redirection and Pipes

Redirection to/from files

```
$ echo "Hello class" > somefile
$ cat somefile
Hello class
$ rev < somefile
ssalc olleH
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```
$ echo "More text." >> somefile
$ cat somefile
Hello class
More text.
$ nl somefile
     1  Hello class
     2  More text.
```

Redirection and Pipes (ctd.)

Pipes connect processes with a unidirectional FIFO

```
$ cat somefile | rev | nl
     1  ssalc olleH
     2  .txet eroM
```

In these examples, redirection and pipes are set up by the shell.

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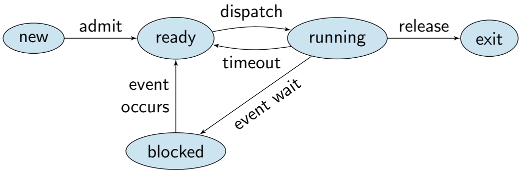

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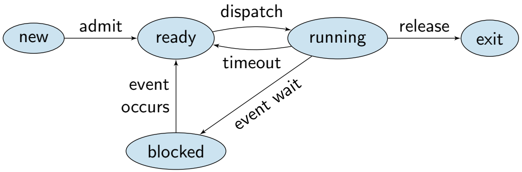

  - `ps` – snapshot of current processes
  - `pstree` – display process hierarchy

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  - $<$**Ctrl+Z** $>$ stops currently active job
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  - `fg` *n* – continue job *n* in foreground
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- Multiple commands:

Command sequence	Resulting behaviour
`cmd1 ; cmd2`	Execute commands subsequently
`cmd1 && cmd2`	Execute `cmd2` only if `cmd1` succeeds
`cmd1 || cmd2`	Execute `cmd2` only if `cmd1` fails
`cmd1 & cmd2`	Start `cmd1` in background and `cmd2` in foreground
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- Example:

```
$ (sleep 10; date) > outfile &
```

Filesystem Organisation

- Hierarchical structure of files
- Wide range of input/output resources are simple streams of bytes exposed through the filesystem name space $\rightarrow$ "everything is a file"
  - Documents
  - Directories
  - Character-, block special files (devices; e.g. hard-drives, keyboards, printers)
  - Named pipes
  - Sockets (e.g. TCP/IP sockets, UNIX domain sockets)
  - Symbolic links

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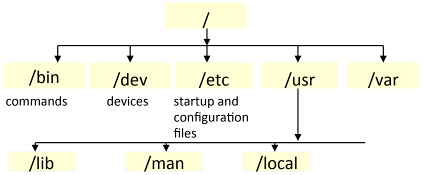


Filesystem Hierarchy Standard[1] I

- / Primary hierarchy (root directory)
  - `/bin`: Essential command binaries (for all users)
  - `/etc`: Configuration files
  - `/dev`: Devices
  - `/lib`: Libraries essential for the binaries in `/bin` and `/sbin`
  - `/home`: Users' home directories
  - `/media`: Mount points for removable media
  - `/mnt`: Temporarily mounted file systems
  - `/opt`: Optional application software packages
  - `/proc`: Virtual filesystem providing process and kernel information as files
  - `/sbin`: Essential system binaries

Filesystem Hierarchy Standard[2] II

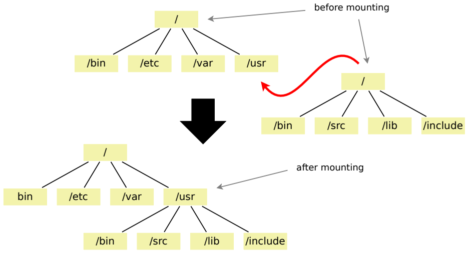
- `/usr`: Secondary hierarchy for shareable, read-only data (contains the majority of multi-user utilities and applications)
- `/usr/local`: Tertiary hierarchy for local data, specific to the host
- `/var`: Variable files, whose content is expected to continually change during normal operation of the system (log files, spools, temporary e-mails)

[1] `http://www.pathname.com/fhs/`

[2] `http://www.pathname.com/fhs/`

Mounting File Systems

- All files and directories appear under the root directory, even if they are stored on different physical or virtual devices
- File system to be mounted is either:
  - locally available (hard-drive partitions, removable media)
  - a network resource (e.g. using NFS),
  - or contained in a file itself (e.g. loop device for ISO-Images)
- Advantage: different file systems concurrently in use



Navigating through the File System

- cd – change directory

```
$ cd
$ pwd
/home/jdoe
$ mkdir test
$ cd test
$ pwd
/home/jdoe/test
$ echo "Hello class" > textfile
$ ls -l
-rw-rw-r--  1 jdoe jdoe   12 Oct  6 11:15 textfile
$ cd .. ; pwd
/home/jdoe
```

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- Filenames
  - **absolute**: start with '/', from the root directory
    e.g. `$ cat /etc/passwd`
  - **relative**: do not start with '/', and are related to the current directory
    e.g. `$ cat ../tmpfile`
    (`.` is the current directory, `..` the parent directory)

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    (`.` is the current directory, `..` the parent directory)
- *Note:* use <**TAB**> for shell completion

Wildcards

- Pattern matching for filename specification

`*`	zero or more characters
`?`	a single character
`[xyz]`	one of ‘x’, ‘y’ or ‘z’
`[a-i]`	one in the range from ‘a’ to ‘i’

- Interpretation and expansion by the shell
- The operation of matching of wildcard patterns to multiple file or path names is referred to as globbing.
- Use wildcards as normal characters by quoting or a preceding backslash (\)

Wildcards

Examples

```
$ ls
myfile  prog  prog.c  proG.c  t1  t2
t3      t4    test1   test1.c
```

```
*
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`*[1-4].c`	test1.c

Permissions

`-rw-rw-r--` ???

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- `chmod` – change file mode bits (= permissions)

Permissions

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- Only user (owner) or root can change permissions

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$ FILE=/tmp/dummy.txt
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- Export to environment for subsequently started processes:

```
$ export FILE
```

at assignment

```
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```

System Variables

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$ echo $PATH
/usr/local/bin:/usr/bin:/usr/local/sbin:
/usr/sbin
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→ If you create a program in a local directory and want to execute it:

```
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$\rightarrow$ If you create a program in a local directory and want to execute it:

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$ ./myprogram
```

- Print environment variables with `env`

Unix Commands I

Examples

- File management

ls	list directory contents
cd	change the working directory
pwd	print filename of working directory
cp, mv	move (rename) files
ln	make links between files
mkdir	make directories
rm, rmdir	remove files and directories
chmod, chown	change file mode bits, owner
du	estimate file space usage
file	determine file type

- Process management

jobs	display status of jobs in current shell session
fg, bg	run job in foreground/background
ps, pstree	snapshot of current processes/process hierarchy
kill	send a signal to a process

Unix Commands II

Examples

- Text processing

cat	concatenate files to standard output
sort	sort lines of text files
nl	number lines of files
wc	print line, word, and byte counts
cut	remove sections from each line
tr	translate or delete characters
tac	contatenate and print files in reverse
rev	reverse lines of a file
grep	print lines matching a pattern
sed	stream editor for filtering and transforming text

Unix Commands III

Examples

- Utilities

echo	print arguments to stdout
more, less	pager
date, cal	print current time and time/calendar
tar	archiving utility
make	build utility
ssh	SSH client (remote login program)
gcc	GNU compiler collection C compiler

- Editors vim, emacs
- . . . and many many more

- see `$ man` *`command`* for more information

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  - accessing a shared resource (file, memory)
- Classification
  - related vs. unrelated processes
    unrelated processes require named resources (system-wide namespace)
  - implicit vs. explicit synchronization
    ensure orderly execution and access to a shared resource

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You already know how to program in an imperative programming language.
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Educational objectives of the programming assignments

- How to write and compile a C program, use options and arguments, basic stream I/O (1a); communicate through stream sockets (1b)
- How to create child processes, communicate through unnamed pipes (2)
- Collaboration of unrelated processes through shared memory and synchronization with semaphores (3)

Summary

- C is still a highly relevant language
- Unix-based OS are ubiquitous
- Introduction to basic Unix concepts and the environment

Material

- Advanced Bash-Scripting Guide
  `http://www.tldp.org/LDP/abs/html/`

Homework

Work through slides “Introduction to C”.
The next lecture will deal with the features specific to C, so you should be familiar with the elements of the C language.