Using Fork and Pipe

Methods & Tools for Software Engineering (MTSE)
Fall 2020

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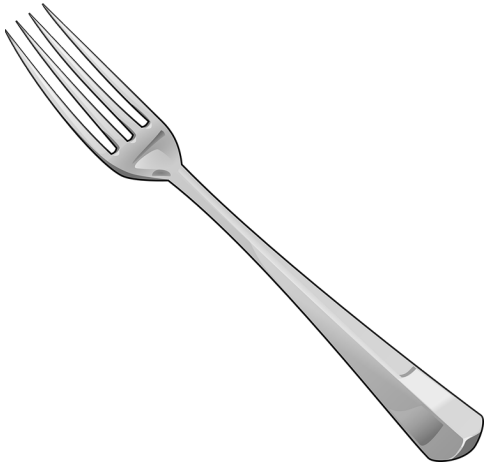

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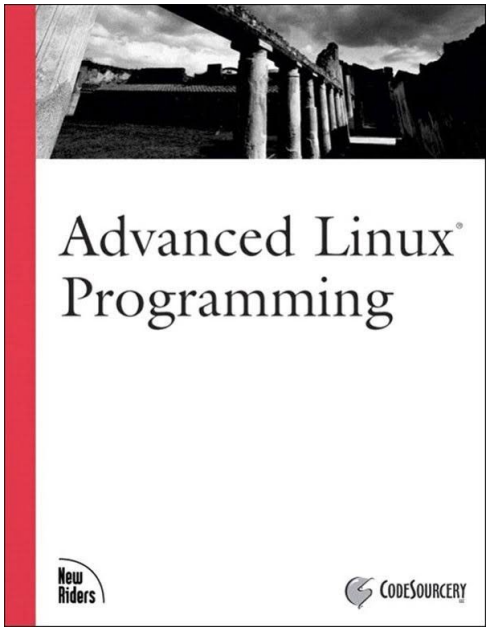
Additional Information

Advanced Linux Programming

- Chapter 2.1 (Interacting with Execution Environment)
- Chapter 3 (Processes)
- Chapter 5.4 (Pipes)



The book is available from the links below

https://github.com/MentorEmbedded/advancedlinuxprogramming/blob/gh-pages/alp-folder/advanced-linux-programming.pdf

https://github.com/MentorEmbedded/advancedlinuxprogramming/tree/gh-pages

Compiled vs. Interpreted

- Compiled code is running directly on your machine as a process
- Interpreted code is loaded into the memory of the virtual machine process (e.g., JVM), and then the virtual machines reads that data and interprets it as code

Stack Overflow

Stack can overflow when there are "too many" function calls, e.g., a recursive program f() where f calls itself and goes into an infinite loop. The system will create a call stack entry for every function call invocation. Eventually, the call stack will grow and overwrite some other part of memory that it is not supposed to resulting in undefined behavior (usually results in a segmentation fault).

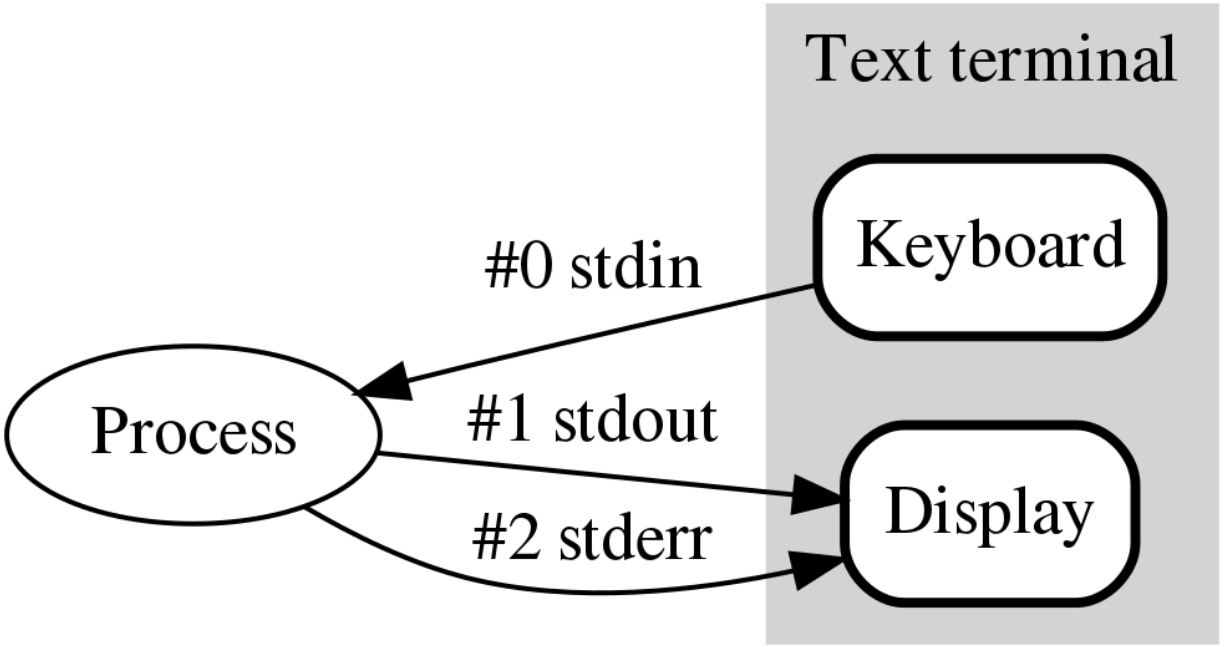
PROCESS

What is a “Process”?

- What is a process:
  - *“A running instance of a program”*
  - *Examples:*
    - *Each of the two instances of Chrome*
    - *The shell and the ls command executed, each is a process*

- Advanced programmers use multiple processes to
  - Do several tasks at once
  - Increase robustness (one process fails, other still running)
  - Make use of already-existing processes

Standard input, output, and error



https://en.wikipedia.org/wiki/File:Stdstreams-notitle.svg

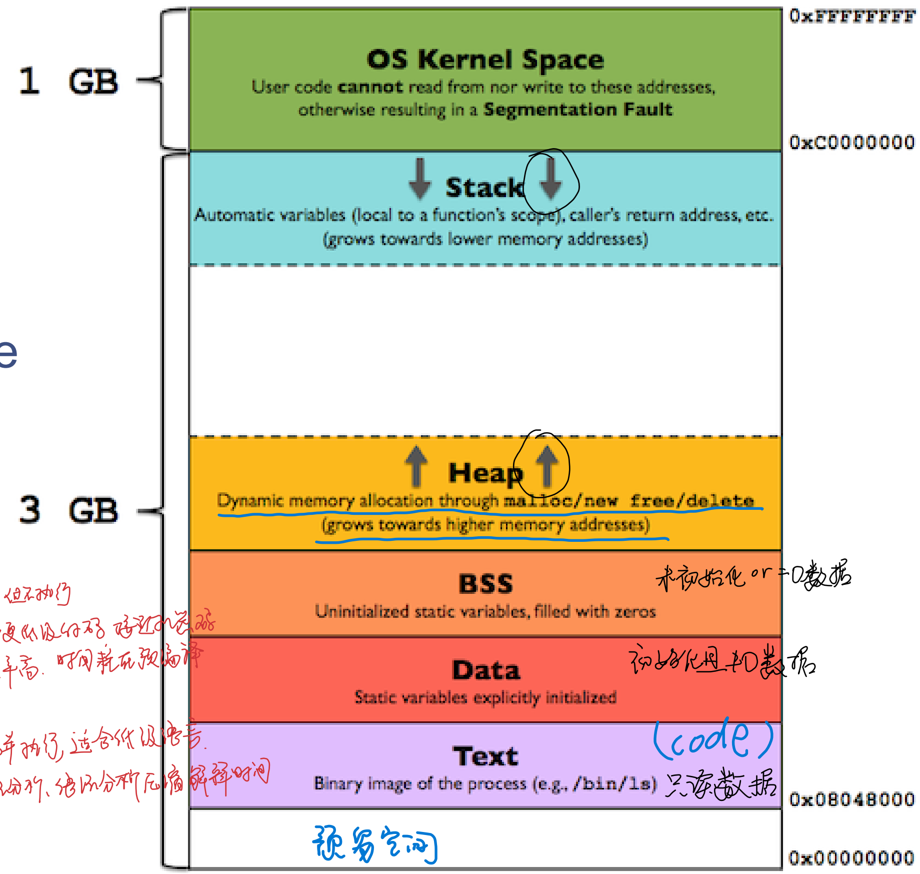
- Let's change stdin, stdout, and stderr

The "Guts" of a Process!

每个进程被创建时，分配一个4GB虚拟地址空间

Process of a 32bit architecture

- The main components of a process:
  - An executable piece of code (a program)
  - Data that is input or output by the program
  - Execution context (information about the program needed by OS)



compile & interprete C++, C, Pascal

compile: running directly on your machine as a process

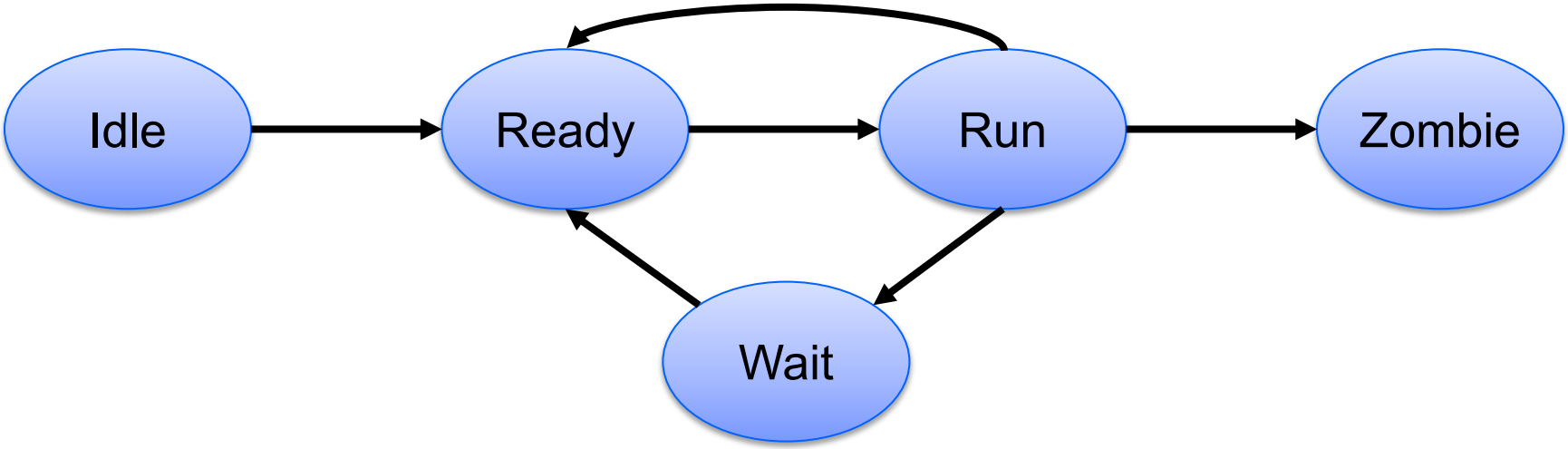
interprete: Loaded into the memory of the virtural machine progress (JVM), and then the virtural machine reads that data and interprete it as code.

Java: interpreted on JVM, can't run directly

python.

https://gabrieletolomei.wordpress.com/miscellanea/operating-systems/in-memory-layout/

Life Cycle of a (Unix) Process



Idle	state when the process is creating
Ready	ready to run
Run	executing
Wait	waiting for resources (CPU, disk, network, etc.)
Zombie	ended, waiting to be collected

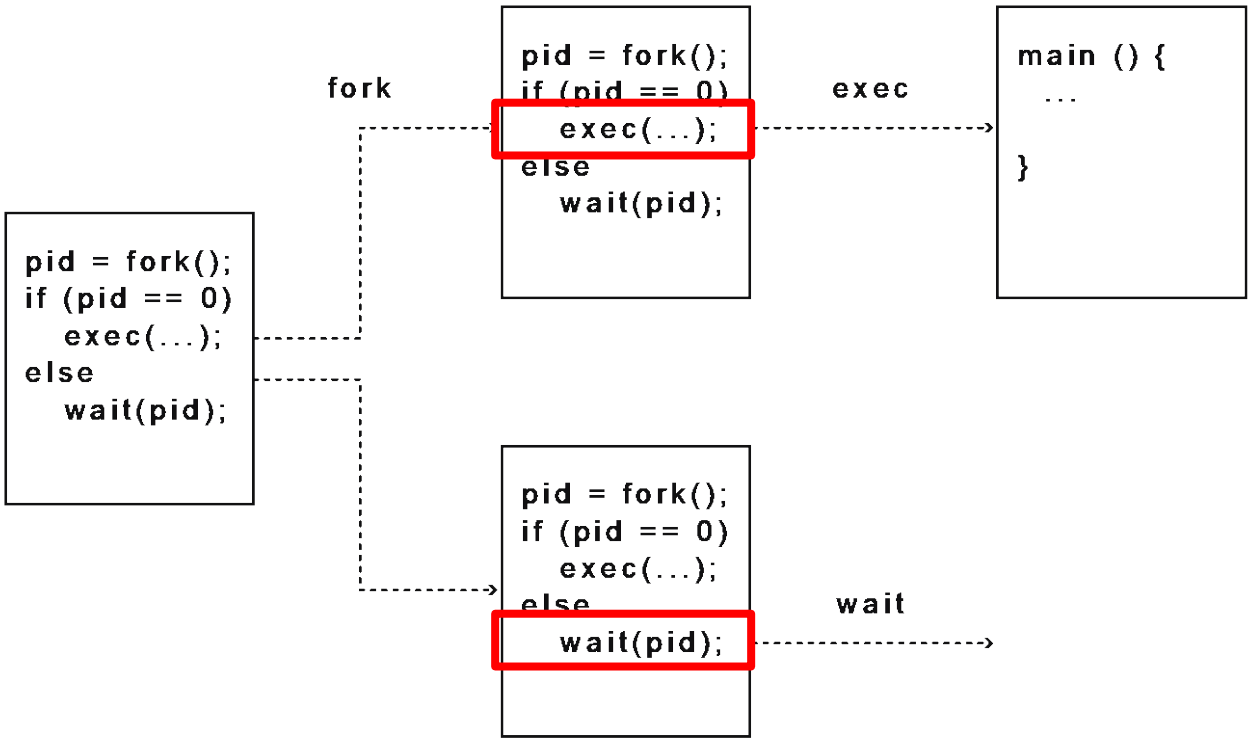
https://www.cs.miami.edu/home/burt/learning/Csc521.111/notes/process-life-cycle.html

Let's Dissect a Process!

- Windows:
  - Task manager

- Unix-like (Mac and Linux):
  - In the terminal type:
    - `ps` or `top` or `htop`
    - `ps -f` for full details

UNIX Process Management



UNIX Process Management System Calls

`fork()`

- Create a copy of current process and start it as a child

`execv() / execl() / …`

- Load an executable into the current process and run it

`wait() / waitpid()`

- Wait for a child process to finish

`kill()`

- Send a signal (e.g., `SIGTERM`, `SIGKILL`, `SIGINT`) to another process

The Parent of a Process

- Each process (with some exceptions) has a parent process (indicated by `ppid` – parent process identifier)

- Can we get this information within a program?
  - YES!
  - Use `getpid()` and `getppid()` `libc` functions defined in `unistd.h`

```
// c++ -o main main.cpp
#include <unistd.h>
#include <iostream>

int main(void) {
  std::cout << "my pid: " << getpid()
            << " ppid: " << getppid() << "\n";
}
```

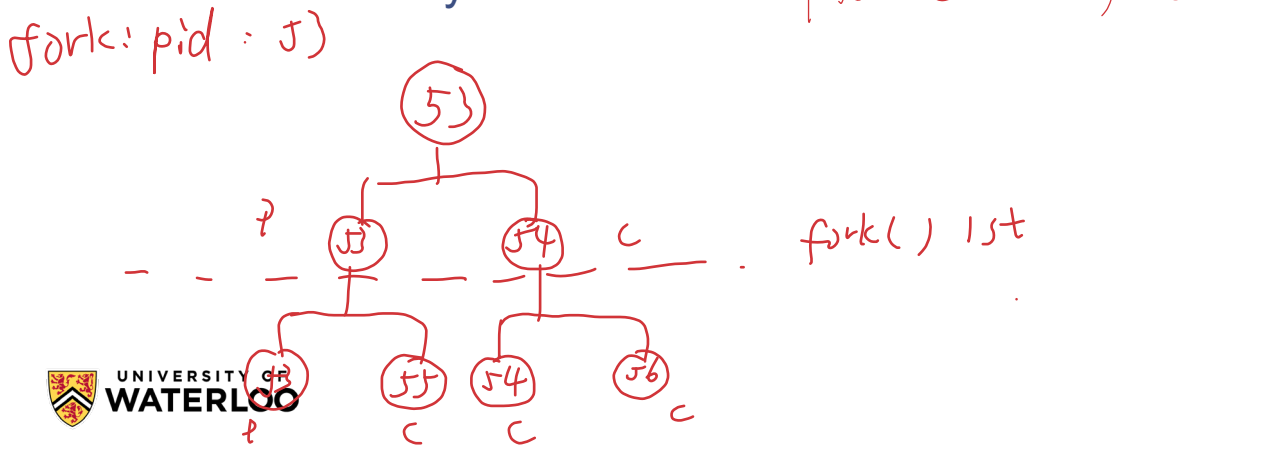
child 节点

父节点

Creating a Process

- Using a `system`
  - Runs a shell (as a subprocess) to run the given commands

- Why using `system` is not recommended:
  - The call to system relies on the installed shell
  - It brings the shell's:
    - Features
    - limitations
    - Security flaws



Creating a Process - fork() system call

Forks an execution of the process

- after a call to `fork()`, a new process is created (called child)
- the original process (called parent) continues to execute concurrently
- in the parent, `fork()` returns the process `id` of the child that was created
- in the child, `fork()` return `0` to indicate that this is a child process
- The parent and child are independent

Man(ual) Page

- `man 2 fork`

exec() – executing a program in a process

`exec()` series of functions are used to start another program in the current process

- after a call to `exec()` the current process is replaced with the image of the specified program
- different versions allow for different ways to pass command line arguments and environment settings
- `int execv(const char *file, char *const argv[ ])`
  - `file` is a path to an executable
  - `argv` is an array of arguments. By convention, `argv[0]` is the name of the program being executed

Man page

- `man 3 exec`

kill() – sending a signal

A process can send a signal to any other process

- usually the parent process sends signals to its children
- `int kill(pid_t pid, int sig)`
  - send a signal `sig` to a process `pid`
- useful signal: `SIGTERM`
  - asks a process to terminate

When a parent process exits, the children processes are terminated

It's a good practice to kill and wait for children to terminate before exiting

Man page

- `man 2 kill`

Signals

- A special message sent to a process
- Signals are asynchronous
- Different types of signals (defined in `signum.h`)
  - `SIGTERM`: Termination
  - `SIGINT`: Terminal interrupt (Ctrl+C)
  - `SIGKILL`: Kill (can't be caught or ignored)
  - `SIGBUS`: BUS error
  - `SIGSEGV`: Invalid memory segment access
  - `SIGPIPE`: Write on a pipe with no reader, Broken pipe
  - `SIGSTOP`: Stop executing (can't be caught or ignored)
- Handling a signal:
  - Default *disposition*
  - Signal handler procedure
- Sending signal from one process to another process (`SIGTERM`, `SIGKILL`)

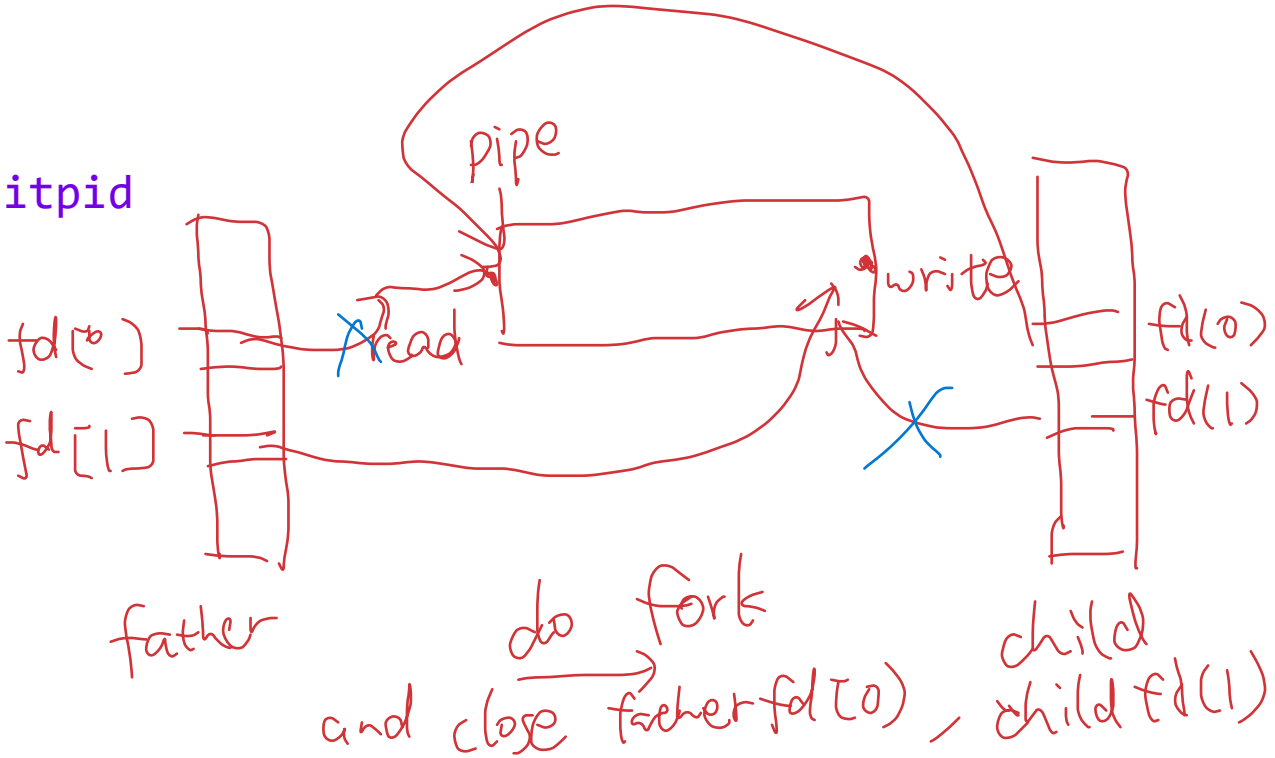
waitpid() – Waiting for a child

A parent process can wait for a child process to terminate

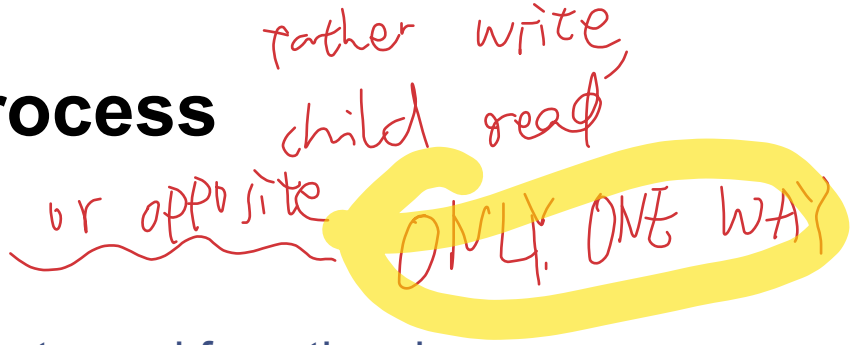
- `pid_t waitpid(pid_t pid, int *status, int options)`
  - block until the process with the specified `pid` terminates
  - the return code from the terminating process is placed in `status`
  - `options` control whether the function blocks or not
    - 0 is a good choice for options

Man page

- `man 2 waitpid`



pipe() and dup2() – Inter-Process Communication



`pipe()` creates a ONE directional pipe

- two file descriptors: one to write to and one to read from the pipe
- a process can use the pipe by itself, but this is unusual
- typically, a parent process creates a pipe and shares it with a child, or between multiple children
- some processes read from it, and some write to it
  - there can be multiple writers and multiple readers
    - although multiple writers is more common

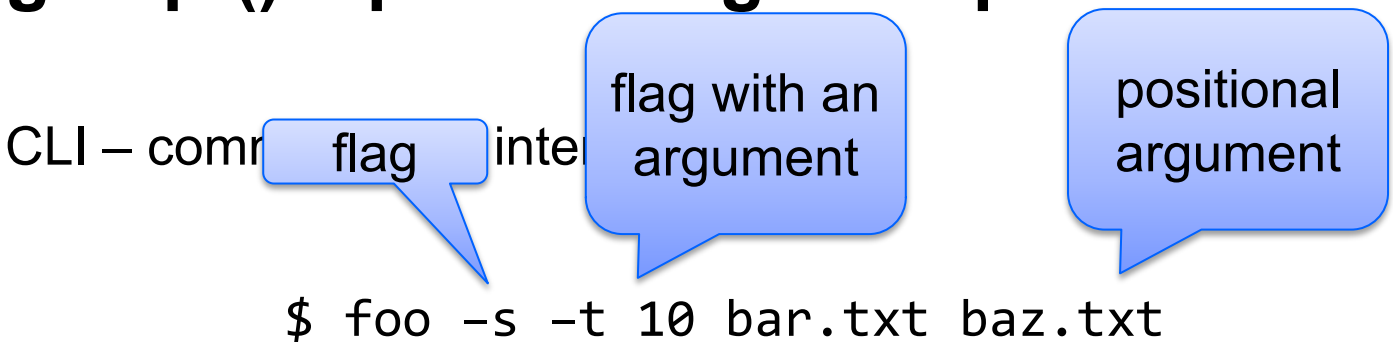
`dup2()` duplicates a file descriptor

- used to redirect standard input, standard output, and standard error to a pipe (or another file)
- `STDOUT_FILENO` is the number of the standard output

Man pages

- `man 2 pipe`
- `man 2 dup2`

getopt() – processing CLI options



At a start of the program, main(argc, argv) is called, where

- `argc` is the number of CLI arguments
- `argv` is an array of 0 terminated strings for arguments
  - e.g., argv[0] is “foo”, argv[1] is “-s”, argv[2] is “-t”, argv[2] is “10”, …

`getopt()` is a library function to parse CLI arguments

- `getopt(argc, argv, “st:”)`
- input: arguments and a string describing desired format
- output: returns the next argument and an option value
- see example in `using_getopt.cpp`

/dev/urandom – Really Random Numbers

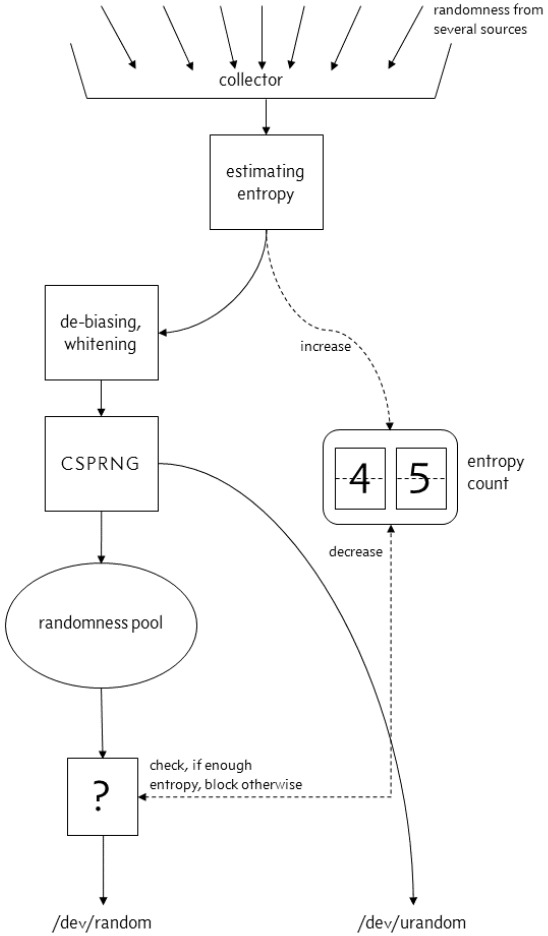
`/dev/urandom` is a special file (device) that provides supply of “truly” random numbers

”infinite size file” – every read returns a new random value

To get a random value, read a byte/word from the file

see `using_rand.cpp` for an example

Have to use it for Assignment 3!



https://www.2uo.de/myths-about-urandom/