

Processes

processes practice for CSC420 Operating Systems Spring 2022 Lyon College

README

- This file accompanies lectures on the shell and `bash(1)`. To gain practice, you should type along in your own Org-mode file. You have to have Emacs and my `.emacs` file installed on your PC or the Pi you're working with.
- This section is based on chapter 10 of Shotts, *The Linux Command Line* (2e), NoStarch Press (2019).
- To make this easier, use the auto expansion (`<s`). This will only work if you have my `.emacs` file ([from GDrive](#)) installed.
- Add the following two lines at the top of your file, and activate each line with `C-c C-c` (this is confirmed in the echo area as `Local setup has been refreshed`):

```
#+PROPERTY: header-args:bash :results output
```

- Remember that `C-M-\` inside a code block indents syntactically (on Windows, this may only work if you have a marked region - set the mark with `C-SPC`).

Hide Org-mode emphasis markers

- []

Add the string `"(setq-default org-hide-emphasis-markers t)"` to your `$HOME/.emacs` file so that you don't see the emphasis markers in Org-mode. Then show the last line of the file to make sure it worked.

Tip: you need the commands `echo`, `~>>`, `tail`.

```
echo "(setq-default org-hide-emphasis-markers t)" >> $HOME/.emacs
tail -1 $HOME/.emacs
```

Overview

- Modern operating systems are *multitasking*, which means they create an illusion of doing more than one thing at once.
- They do this by rapidly switching from one executing program to another.
- The **kernel** manages this through clever **process management**, which really is clever **memory management**.
- This is illustrated in the figure 1. The simple program is all over the computer's memory.

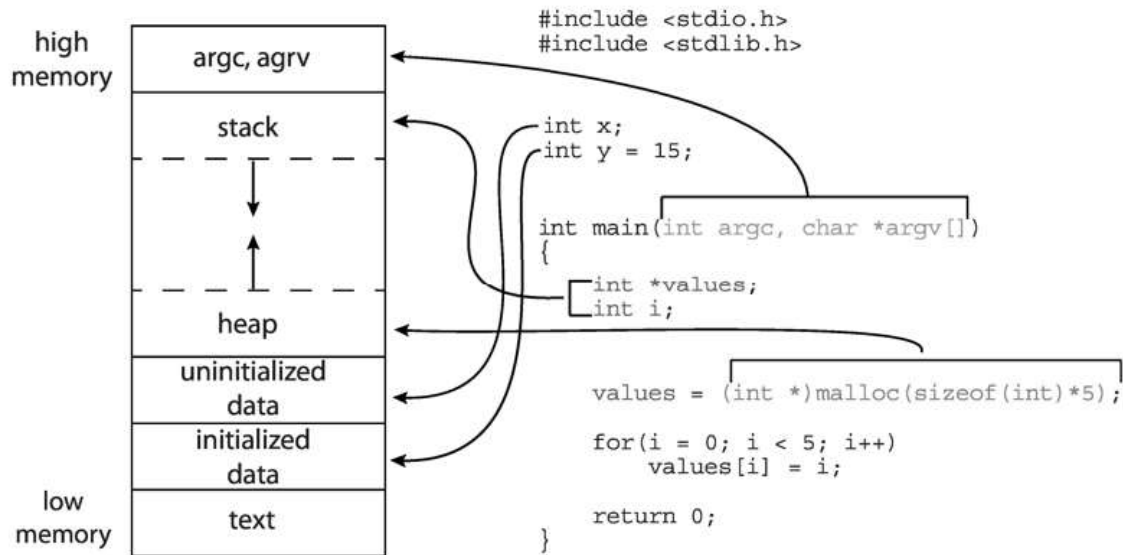


Figure 1: Memory Layout of a C Program (Source: Silberschatz et al)

- As always, let's focus on stuff we can do ourselves. This includes a bunch of new shell commands:

| COMMAND | MEANING |
|----------|--|
| ps | Report a snapshot of current processes |
| top | Display tasks |
| jobs | List active jobs |
| bg | Place a job in the background |
| fg | Place a job in the foreground |
| kill | Send a kill signal to process |
| killall | Kill processes by name |
| shutdown | Shut down or reboot the system |

How a process works

- When the OS starts up, the **kernel** launches the **init** program, which in turn runs a series of shell scripts (in `/etc`) that start all the system services.
- [] Check `/etc` out now - you find e.g. the directory `/etc/cups`, which contains scripts for the Common UNIX Printing System (CUPS).
- Many of the services are *daemon* programs - they just sit in the background and do their thing without a user interface (UI).
- **init** itself is a daemon, also called **systemd**. The shell program **systemctl** allows indirect access to all services.
- []

Grab a daemon!

In the code block 1,

1. run the command `systemctl status`,
2. tee its output to a text file `systemctl.txt`
3. `grep` for the login daemon program `logind`

```
systemctl status | tee systemctl.txt | grep logind
```

- If a program (like `init`) can launch other programs, it's a *parent process* producing a *child process*.
- **How does the kernel maintain control?** By assigning a *process ID* (PID) to every process.
- Processes are assigned in ascending order beginning with `init`, which has PID 1.
- The **kernel** also tracks process memory and readiness to resume execution. Like files, processes have owners and userIDs.

Viewing processes statically

- The `ps` program has a lot of options (check `ps(1)`)
- []

Run `ps` without options.

```
ps
```

| PID | TTY | TIME | CMD |
|-----|------|----------|------|
| 18 | tty1 | 00:00:00 | bash |
| 19 | tty1 | 00:00:00 | ps |

- The result is confusing because you're inside another program now.
- []

Open a shell (in Emacs with `M-x shell` or a terminal) and type `ps`. You should see something like this:

| PID | TTY | TIME | CMD |
|-------|-------|----------|------|
| 12254 | pts/1 | 00:00:00 | bash |
| 12257 | pts/1 | 00:00:00 | ps |

- **What this means:**
 - You see two PID - the shell program and the `ps` program
 - TTY ("teletype") is the *controlling terminal* for the process
 - TIME is the amount of CPU time consumed by the process
- []

Run `ps` again, this time add the option `x`

```
ps x
```

```
PID TTY      STAT   TIME COMMAND
 21 tty1     S       0:00 bash
 22 tty1     R       0:00 ps x
```

- `ps x` (no dash!) shows all processes regardless of what terminal they are controlled by. `?` indicates no terminal (like daemons).
- []

How many processes that you own that have no terminal?

```
ps x | grep ? | wc -l
```

```
1
```

- []

List only the first 5 lines of the `ps x` listing.

```
ps x | head -5
```

```
PID TTY      STAT   TIME COMMAND
 29 tty1     S       0:00 bash
 30 tty1     R       0:00 ps x
 31 tty1     S       0:00 head -5
```

- The column `STAT` reveals the current status of the process, see table 1.

| STATE | MEANING |
|-------|---|
| R | Running or ready to run |
| S | Sleeping, waiting for an event (e.g. keystroke) |
| D | Uninterruptible sleep, waiting for I/O (e.g. disk) |
| T | Stopped, received instruction to stop |
| Z | Zombie child process, abandoned by parent |
| < | High priority (not <i>nice</i> - more CPU time) |
| N | Low priority (<i>nice</i>) - served once < are done |

There may be more characters denoting exotic process characteristics (see `ps(1)`). E.g. *s* is a *session leader*, *+* is a *foreground* process, and *l* is multi-threaded.

- []

You get even more information with the option `aux`. Redirect the output of `ps aux` to a file `psaux.txt`, and print only the first 5 lines.

```
ps aux | tee psaux.txt | head -5
```

| USER | PID | %CPU | %MEM | VSZ | RSS | TTY | STAT | START | TIME | COMMAND |
|--------|-----|------|------|-------|------|------|------|-------|------|---------|
| root | 1 | 0.0 | 0.0 | 8940 | 328 | ? | Ss1 | 16:17 | 0:00 | /init |
| root | 32 | 0.0 | 0.0 | 8940 | 224 | tty1 | Ss | 16:17 | 0:00 | /init |
| marcus | 33 | 0.0 | 0.0 | 16664 | 1568 | tty1 | S | 16:17 | 0:00 | bash |
| marcus | 34 | 0.0 | 0.0 | 18660 | 1896 | tty1 | R | 16:17 | 0:00 | ps aux |

- You should see PID 1, the init program. The splash options means that you can see a splash screen during boot.
- Table 1 shows some header definitions

| HEADER | MEANING |
|--------|-------------------------------------|
| USER | User ID - this is the process owner |
| %CPU | CPU usage in percent |
| %MEM | Memory usage in percent |
| VSZ | Virtual memory size |
| RSS | Resident set size - RAM use in kB |
| START | Process starting time and date |

- []

Why is the CPU usage of init zero, while the Memory usage is non-zero? How much RAM does the program actually use?

ANSWER: The init program only runs during the booting process, but as part of the **kernel** it is loaded into the central memory. It occupies 8MB.

Viewing processes dynamically

- ps provides a snapshot, but top provides a real-time view.
- [] Open a terminal (in or outside of Emacs) and run top. You can stop the command with C-c or q.
- top refreshes every three seconds and shows the top system processes. It includes a summary at the top and a table sorted by CPU activity at the bottom.



Figure 2: Top view

- The system summary contains a lot of good stuff. Table 1 gives a rundown.

| ROW | FIELD | MEANING |
|-----|-------|---------|
|-----|-------|---------|

| ROW | FIELD | MEANING |
|-----|----------------|---|
| 1 | top | Program name |
| | 21:52:54 | Current time of day |
| | up 2 days 9:49 | <i>uptime</i> since last boot |
| | 1 user | No. of users logged in |
| | load average | No. of processes waiting to run Values < 1.0 means not busy |
| 2 | Tasks: | No. of processes and their states total, running, sleeping, stopped |
| 3 | Cpu(s): | Activities that the CPU performs: us: user processes (not kernel) sy: system processes (kernel) ni: nice (low prio) processes id: idle processes wa: waiting for I/O |
| 4 | Mem: | Physical RAM used |
| 5 | Swap: | Swap space (virtual memory) used |

- top accepts some keyboard commands like h (help) and q (quit).
- top is better than any graphical application (e.g. the Task Manager that you have on your Pi) - it is faster and consumes far less resources.

Controlling processes

Interrupting a process

- As a guinea pig program, we use emacs.
- [] Open a terminal (inside Emacs after splitting the screen with c-x 2 or outside of Emacs), and enter emacs at the prompt. A new Emacs editor window appears. Notice that the terminal prompt does not return.
- [] Close the new Emacs editor manually by clicking on the x in the upper right corner. The prompt in the Shell returns.
- [] Enter emacs again in the shell, and interrupt it with CTRL-C (outside of Emacs, or with C-c C-c on the Emacs *shell*).
- Many programs can be interrupted this way by sending an **interrupt** signal to the **kernel**.

Putting a process in the background

- The terminal has a *foreground* and a *background*. To launch a program so that it is immediately placed into the background, follow it with an ampersand & character
- [] Start Emacs from the shell in the background. An Emacs window should open. Look at the terminal.

- The message that appeared is part of shell *job control*. It means that we have started job number 1 with the PID 13899. If you check the process table with `ps`, you should see the process

```
[1] 13899
```

- []

`grep` the `emacs` process from the process table using the PID.

```
13928 pts/1    00:00:04 emacs
```

- []

The `jobs` command lists the jobs that were launched from our terminal. Try it. You should see something like this:

```
[1]+  Running                  emacs &
```

Returning a process to the foreground

- A process in the background is immune from keyboard input - you cannot interrupt it with `CTRL-C`. To return it to the foreground, use the `fg` command.
- [] On the shell where you started it, return the process to the foreground with the command `fg %1`. The 1 is the `jobspec`.
- [] Kill the Emacs process with `C-c C-c` or `CTRL-C` on the shell where you started it.

Stopping or pausing a process

- []

Start an `emacs` process in a terminal (NOT in an Emacs shell) - it's now in the foreground. If you press `CTRL-z` in the shell, the process is stopped.

```
pi@raspberrypi:~ $ emacs
^Z
[1]+  Stopped                  emacs
pi@raspberrypi:~ $
```

- [] To bring the process back, you can either bring it into the foreground with `fg %1`, or resume the process in the background with `bg %`. Try both.
- **Why would you launch a graphical program from the shell?**
 - The program may not be listed in the GUI
 - You see error messages that otherwise are invisible
 - Some graphical programs have useful command line options

Killing a process

- []

`kill` is used to terminate processes using the PID. Start Emacs from the shell *in the background* (inside or outside of emacs), and then kill it with `kill PID`.

Tip: you get the PID with `ps`, or right after executing the background command.

- `kill` does actually not "kill" the process, it sends it a signal. We have already used some of these signals:

| SIGNAL | MEANING |
|--------|----------------------------------|
| INT | CTRL-C - interrupt process |
| TSTP | CTRL-Z - terminal stop |
| HUP | Hang up (used by daemons) |
| KILL | Kill without cleanup |
| TERM | Terminate with <code>kill</code> |
| STOP | Stop without delay |

- Some of these signals are sent to the target program (identified by PID) while others are sent straight to the kernel.

More process commands

Some fun commands to play with and explore. We already looked at `ps`. You may have to install these.

| COMMAND | MEANING |
|---------------------|---|
| <code>ps</code> | Process list arranged as tree pattern |
| <code>vmstat</code> | System usage snapshot |
| <code>xload</code> | Draws a graph showing system load over time |
| <code>tlod</code> | Draws graph in terminal |

Summary

References

- Silberschatz, Galvin and Gagne (2018). Operating System Concepts - 10th edition, Wiley.

Author: Marcus Birkenkrahe

Created: 2022-04-16 Sat 16:17