

Assignment1

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Program 1

How did I design my program

In Program 1, the task is to fork the process in user mode. Firstly, I use `fork()` function to fork a child process. Then, I use `execve()` function to execute the test program. At the same time, use `waitpid()` function to let parent process wait the child process until it terminates and send signals back. Then I handle different signals and print corresponding information.

The following are the steps:

1. Fork a child process to execute the test program.
2. Parent process receives SIGCHLD signal When child process finishes execution.
3. Print out termination information of child process.

How to set up development environment

In Program1, no additional development environment is needed to be set up.

How to execute my program

The following are the steps to execute the program:

1. Go to folder `program1`.
2. In terminal, type `make all` to compile all programs.
3. In terminal, type `./program1 ./testProgram`. Notice that `./testProgram` need to be replaced by the name of the test program, e.g. `./abort` if the test program is `abort`.

Screenshot of my program output

Output for all cases:

```

+++++
Process start to fork
I'm the Parent Process, my pid = 23293
I'm the Child Process, my pid = 23294
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGINT program

Parent process receives SIGCHLD signal
child process get SIGINT signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23295
I'm the Child Process, my pid = 23296
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGINT program

```

```

Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGPIPE program

Parent process receives SIGCHLD signal
child process get SIGPIPE signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23297
I'm the Child Process, my pid = 23298
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGKILL program

Parent process receives SIGCHLD signal
child process get SIGKILL signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23299
I'm the Child Process, my pid = 23300
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGSTOP program

Parent process receives SIGCHLD signal
child process get SIGSTOP signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23301
I'm the Child Process, my pid = 23302
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGTRAP program

Parent process receives SIGCHLD signal
child process get SIGTRAP signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23304
I'm the Child Process, my pid = 23305
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGABRT program

Parent process receives SIGCHLD signal
child process get SIGABRT signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23307
I'm the Child Process, my pid = 23308
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGSEGV program

```

```
Child process start to execute test program:
```

```
-----CHILD PROCESS START-----
```

```
This is the SIGFPE program
```

```
Parent process receives SIGCHLD signal
```

```
child process get SIGFPE signal
```

```
Process start to fork
```

```
I'm the Parent Process, my pid = 23310
```

```
I'm the Child Process, my pid = 23311
```

```
Child process start to execute test program:
```

```
-----CHILD PROCESS START-----
```

```
This is the SIGSEGV program
```

```
Parent process receives SIGCHLD signal
```

```
child process get SIGSEGV signal
```

```
+++++
```

```
Process start to fork
```

```
I'm the Parent Process, my pid = 23313
```

```
I'm the Child Process, my pid = 23314
```

```
Child process start to execute test program:
```

```
-----CHILD PROCESS START-----
```

```
This is the normal program
```

```
-----CHILD PROCESS END-----
```

```
Parent process receives SIGCHLD signal
```

```
Normal termination with EXIT STATUS = 0
```

```
+++++
```

```
Process start to fork
```

```
I'm the Parent Process, my pid = 23315
```

```
I'm the Child Process, my pid = 23316
```

```
Child process start to execute test program:
```

```
-----CHILD PROCESS START-----
```

```
This is the SIGILL program
```

```
Parent process receives SIGCHLD signal
```

```
child process get SIGILL signal
```

```
+++++
```

```
Process start to fork
```

```
I'm the Parent Process, my pid = 23318
```

```
I'm the Child Process, my pid = 23319
```

```
Child process start to execute test program:
```

```
-----CHILD PROCESS START-----
```

```
This is the SIGQUIT program
```

```
Parent process receives SIGCHLD signal
```

```
child process get SIGQUIT signal
```

```
+++++
```

```
Process start to fork
```

```
I'm the Parent Process, my pid = 23321
```

```
I'm the Child Process, my pid = 23322
```

```

Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGHUP program

Parent process receives SIGCHLD signal
child process get SIGHUP signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23323
I'm the Child Process, my pid = 23324
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGALRM program

Parent process receives SIGCHLD signal
child process get SIGALRM signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23356
I'm the Child Process, my pid = 23357
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGBUS program

Parent process receives SIGCHLD signal
child process get SIGBUS signal
+++++
Process start to fork
I'm the Parent Process, my pid = 23359
I'm the Child Process, my pid = 23360
Child process start to execute test program:
-----CHILD PROCESS START-----
This is the SIGTERM program

Parent process receives SIGCHLD signal
child process get SIGTERM signal

```

What did I learn from the tasks

In this task, I learned the following knowledge:

1. I learned how to create a child process.
2. I learned how to execute programs in the process using `execve()` function.
3. I also learned the knowledge about the terminated signals.

Program 2

How did I design my program

In Program 2, this program will create a kernel thread. In the thread, this program will fork a child process and let it execute another program. The parent process will wait until the child process terminates and send signals back, and then print out corresponding information.

The following are the steps:

1. Find corresponding files in kernel and export the below 4 functions using EXPORT_SYMBOL: `kernel_clone` (/kernel/fork.c), `do_execve` (/fs/exec.c), `getname_kernel` (/fs/namei.c), `do_wait` (/kernel/exit.c). After modifications, we should recompile the kernel.
2. When initiating the module, we should create a kernel thread using `kthread_create()` function to run `my_fork()`.
3. `my_fork()` uses `kernel_clone()` to fork a child process, and the child process will run test program using `my_exec()` function. Then it will use `my_wait()` to receive terminated signals of the child process and print out corresponding information. In details, `my_exec()` function will locate the test file and start execution using `do_execve()` function. And `my_wait()` function will get the terminated signal of the child process using `do_wait()` function.
4. If the kernel thread is created successfully, the program will wake up the thread.

How to set up development environment

1. Download kernel source code and use apt to install required packages.
2. Find corresponding files in kernel and export the below 4 functions using EXPORT_SYMBOL: `kernel_clone` (/kernel/fork.c), `do_execve` (/fs/exec.c), `getname_kernel` (/fs/namei.c), `do_wait` (/kernel/exit.c).
3. Type `make menuconfig` in terminal to configure the kernel and type `make` to compile the kernel.
4. Type `sudo make modules_install` in terminal to install kernel modules and type `sudo make install` to install the kernel.

How to execute my program

The following are the steps to execute the program:

1. Go to folder `program2`.
2. Compile the test file using `gcc -o test test.c` and move test file to pre-defined location using `cp ./test /tmp/test`.
3. Generate kernel file using `make all`.
4. Insert the kernel module file into kernel using `insmod program2.ko`, remove the kernel module file out using `rmmod program2`, use `dmesg` to display messages.

Screenshot of my program output

Output for all cases:

```
[114213.053998] [program2] : Module_init Xinyu Xie 119020059
[114213.054000] [program2] : module_init create kthread start
[114213.054122] [program2] : module_init kthread start
[114213.054171] [program2] : The child process has pid = 27153
[114213.054210] [program2] : This is the parent process, pid = 27152
[114213.054221] [program2] : child process
[114213.191248] [program2] : get SIGABRT signal
[114213.191250] [program2] : child process terminated
[114213.191251] [program2] : The return signal is 6
[114218.067006] [program2] : Module_exit./my
```

```
[114218.104833] [program2] : Module_init Xinyu Xie 119020059
[114218.104834] [program2] : module_init create kthread start
[114218.104953] [program2] : module_init kthread start
[114218.105314] [program2] : The child process has pid = 27204
[114218.105315] [program2] : This is the parent process, pid = 27201
[114218.105343] [program2] : child process
[114220.106481] [program2] : get SIGALRM signal
[114220.106482] [program2] : child process terminated
[114220.106483] [program2] : The return signal is 14
[114223.113811] [program2] : Module_exit./my
```

```
[114223.162518] [program2] : Module_init Xinyu Xie 119020059
[114223.162520] [program2] : module_init create kthread start
[114223.162653] [program2] : module_init kthread start
[114223.162720] [program2] : The child process has pid = 27244
[114223.162722] [program2] : This is the parent process, pid = 27243
[114223.162743] [program2] : child process
[114223.385864] [program2] : get SIGBUS signal
[114223.385866] [program2] : child process terminated
[114223.385868] [program2] : The return signal is 7
[114228.178847] [program2] : Module_exit./my
```

```
[114228.216698] [program2] : Module_init Xinyu Xie 119020059
[114228.216700] [program2] : module_init create kthread start
[114228.216902] [program2] : module_init kthread start
[114228.216975] [program2] : The child process has pid = 27287
[114228.216976] [program2] : This is the parent process, pid = 27286
[114228.216985] [program2] : child process
[114228.314990] [program2] : get SIGFPE signal
[114228.314991] [program2] : child process terminated
[114228.314992] [program2] : The return signal is 8
[114233.235124] [program2] : Module_exit./my
```



```
[114233.275587] [program2] : Module_init Xinyu Xie 119020059
[114233.275588] [program2] : module_init create kthread start
[114233.275690] [program2] : module_init kthread start
[114233.275812] [program2] : The child process has pid = 27330
[114233.275813] [program2] : This is the parent process, pid = 27329
[114233.275823] [program2] : child process
[114233.335586] [program2] : get SIGHUP signal
[114233.335587] [program2] : child process terminated
[114233.335588] [program2] : The return signal is 1
[114238.287131] [program2] : Module_exit./my
```

```
[114238.339683] [program2] : Module_init Xinyu Xie 119020059
[114238.339685] [program2] : module_init create kthread start
[114238.339825] [program2] : module_init kthread start
[114238.339893] [program2] : The child process has pid = 27372
[114238.339895] [program2] : This is the parent process, pid = 27371
[114238.339958] [program2] : child process
[114238.511666] [program2] : get SIGILL signal
[114238.511668] [program2] : child process terminated
[114238.511669] [program2] : The return signal is 4
[114243.347940] [program2] : Module_exit./my
```

```
[114243.397541] [program2] : Module_init Xinyu Xie 119020059
[114243.397543] [program2] : module_init create kthread start
[114243.397587] [program2] : module_init kthread start
[114243.397616] [program2] : The child process has pid = 27414
[114243.397618] [program2] : This is the parent process, pid = 27413
[114243.397659] [program2] : child process
[114243.456580] [program2] : get SIGINT signal
[114243.456583] [program2] : child process terminated
[114243.456584] [program2] : The return signal is 2
[114248.405996] [program2] : Module_exit./my
```

```
[114248.449411] [program2] : Module_init Xinyu Xie 119020059
[114248.449413] [program2] : module_init create kthread start
[114248.449485] [program2] : module_init kthread start
[114248.449550] [program2] : The child process has pid = 27456
[114248.449551] [program2] : This is the parent process, pid = 27455
[114248.449556] [program2] : child process
[114248.509999] [program2] : get SIGKILL signal
[114248.510045] [program2] : child process terminated
[114248.510046] [program2] : The return signal is 9
[114253.459226] [program2] : Module_exit./my
```

```
[114253.509502] [program2] : Module_init Xinyu Xie 119020059
[114253.509504] [program2] : module_init create kthread start
[114253.509584] [program2] : module_init kthread start
[114253.511192] [program2] : The child process has pid = 27498
[114253.511193] [program2] : This is the parent process, pid = 27496
[114253.511351] [program2] : child process
[114253.570794] [program2] : Normal termination with EXIT STATUS = 0
[114258.517677] [program2] : Module_exit./my
```

```
[114258.581778] [program2] : Module_init Xinyu Xie 119020059
[114258.581779] [program2] : module_init create kthread start
[114258.581930] [program2] : module_init kthread start
[114258.582447] [program2] : The child process has pid = 27540
[114258.582449] [program2] : This is the parent process, pid = 27538
[114258.582451] [program2] : child process
[114258.642838] [program2] : get SIGPIPE signal
[114258.642840] [program2] : child process terminated
[114258.642841] [program2] : The return signal is 13
[114263.590744] [program2] : Module_exit./my
```

```
[114263.646784] [program2] : Module_init Xinyu Xie 119020059
[114263.646786] [program2] : module_init create kthread start
[114263.646846] [program2] : module_init kthread start
[114263.646895] [program2] : The child process has pid = 27581
[114263.646901] [program2] : This is the parent process, pid = 27580
[114263.646921] [program2] : child process
[114263.830860] [program2] : get SIGQUIT signal
[114263.830862] [program2] : child process terminated
[114263.830863] [program2] : The return signal is 3
[114268.653477] [program2] : Module_exit./my
```

```
[114268.697648] [program2] : Module_init Xinyu Xie 119020059
[114268.697650] [program2] : module_init create kthread start
[114268.697722] [program2] : module_init kthread start
[114268.697789] [program2] : The child process has pid = 27624
[114268.697790] [program2] : This is the parent process, pid = 27623
[114268.697810] [program2] : child process
[114268.834293] [program2] : get SIGSEGV signal
[114268.834294] [program2] : child process terminated
[114268.834295] [program2] : The return signal is 11
[114273.705796] [program2] : Module_exit./my
```

```
[114273.745629] [program2] : Module_init Xinyu Xie 119020059
[114273.745631] [program2] : module_init create kthread start
[114273.745754] [program2] : module_init kthread start
[114273.746101] [program2] : The child process has pid = 27667
[114273.746102] [program2] : This is the parent process, pid = 27665
[114273.746117] [program2] : child process
[114273.803096] [program2] : get SIGSTOP signal
[114273.803098] [program2] : child process terminated
[114273.803099] [program2] : The return signal is 19
[114278.755008] [program2] : Module_exit./my
```



```

[114279.806891] [program2] : Module_init Xinyu Xie 119020059
[114279.806892] [program2] : module_init create kthread start
[114279.806980] [program2] : module_init kthread start
[114279.807013] [program2] : The child process has pid = 27723
[114279.807014] [program2] : This is the parent process, pid = 27722
[114279.807021] [program2] : child process
[114279.870267] [program2] : get SIGTERM signal
[114279.870268] [program2] : child process terminated
[114279.870269] [program2] : The return signal is 15
[114284.817787] [program2] : Module_exit./my

[114284.857847] [program2] : Module_init Xinyu Xie 119020059
[114284.857848] [program2] : module_init create kthread start
[114284.858046] [program2] : module_init kthread start
[114284.858071] [program2] : The child process has pid = 27770
[114284.858073] [program2] : This is the parent process, pid = 27769
[114284.858130] [program2] : child process
[114284.988443] [program2] : get SIGTRAP signal
[114284.988445] [program2] : child process terminated
[114284.988445] [program2] : The return signal is 5
[114289.864404] [program2] : Module_exit./my

```

What did I learn from the tasks

In this task, I learned the following knowledge:

1. I learned how to modify the kernel files and how to recompile the kernel.
2. I learned how to insert and remove modules to the kernel.
3. I also get a better understanding of the fork() function and the relationship between parent process and child process.

Bonus

How did I design my program

In Bonus part, this program will create process tree. The process trees will display all current processes information and their relationships in the tree data structure.

The following are the steps:

1. Get all processes information from position `/proc/[pid]/status`. If considering all threads, get all threads information from position `/proc/<pid>/task/<tid>/status`. Store the information of each process or thread in struct and use a linked list to store all struct nodes.
2. Loop through the linked list storing all process information, for each process, find its parent process and update both parent and child pointers. After finishing looping, the relationship of parent and child processes are built.
3. Print the process tree rooted according to the arguments given, by default print the process tree with pid=1 as root.

How to set up development environment

In Bonus, using the environment set up in program2, no additional development environment is needed to be set up.

How to execute my program

The following are the steps to execute the program:

1. Go to folder **bonus**.
 2. Generate all programs using **make all**.
 3. Run **./build/pstree [pid] [args]** to print out the process tree.
- **pid**: show the process tree with the given pid, by default pid=1.
 - **args**: You can choose from the following 5 options.
 - **-p**: show process id.
 - **-l**: do not truncate long lines.
 - **-A**: use ASCII line drawing characters.
 - **-c**: don't compact identical subtrees.
 - **-T**: hide threads.

Screenshot of my program output

- default case:

```

vagrant@csc3150:~/csc3150/CSC3150-Assignment1/source/bonus$ ./build/pstree
systemd+-systemd-journal
|-lvm2mdad
|-systemd-udev
|-dhclient
|-2*[iscsid]
|-cron
|-accounts-daemon---2*[{accounts-daemon}]
|-atd
|-systemd-logind
|-dbus-daemon
|-acpid
|-lxcfs---3*[{lxcfs}]
|-rsyslogd---3*[{rsyslogd}]
|-sshd+-sshd---sshd---bash
|   `--sshd---sshd---bash---bash
|-unattended-upgr---{unattended-upgr}
|-mdadm
|-2*[agetty]
|-irqbalance
|-polkitd---2*[{polkitd}]
|-systemd---(sd-pam)
|-sh---node+-10*[{node}]
|   |-node+-13*[{node}]
|   |   |-2*[bash]
|   |   `--bash---pstree
|   |-node+-12*[{node}]
|   |   |-node---6*[{node}]
|   |   `--cpptools---27*[{cpptools}]
|   `--node---12*[{node}]
|-remote-dev-srv---launcher.sh---ld-linux-x86-64+-81*[{ld-linux-x86-64}]
|   |-fsnotifier
|   |-ion.clangd.main---5*[{ion.clangd.main}]
|   `--bash
|-6*[test]
`--2*[cpptools-srv---15*[{cpptools-srv}]

```

- add specific root pid

```

vagrant@csc3150:~/csc3150/CSC3150-Assignment1/source/bonus$ ./build/pstree 12068
remote-dev-srv---launcher.sh---ld-linux-x86-64+-80*[{ld-linux-x86-64}]
|   |-fsnotifier
|   |-ion.clangd.main---5*[{ion.clangd.main}]
|   `--bash

```

- add option **-p**

```

vagrant@csc3150:~/csc3150/CSC3150-Assignment1/source/bonus$ ./build/pstree 1 -p
systemd(1)─┬─systemd-journal(428)
            │├─lvmetad(459)
            │├─systemd-udevd(478)
            │├─dhclient(911)
            │├─iscsid(1051)
            │├─iscsid(1052)
            │├─cron(1054)
            │├─accounts-daemon(1056)─┬─{accounts-daemon}(1063)
            │                       │└─{accounts-daemon}(1066)
            │├─atd(1059)
            │├─systemd-logind(1061)
            │├─dbus-daemon(1062)
            │├─acpid(1069)
            │├─lxcfs(1074)─┬─{lxcfs}(1083)
            │              │├─{lxcfs}(1085)
            │              │└─{lxcfs}(12718)
            │├─rsyslogd(1079)─┬─{rsyslogd}(1093)
            │                 │├─{rsyslogd}(1094)
            │                 │└─{rsyslogd}(1095)
            │├─sshd(1089)─┬─sshd(8451)──sshd(8506)──bash(8507)
            │              │└─sshd(20900)──sshd(20955)──bash(20956)──bash(20960)
            │├─unattended-upgr(1105)──{unattended-upgr}(1197)
            │├─mdadm(1111)
            │├─agetty(1150)
            │├─agetty(1159)
            │├─irqbalance(1166)
            │├─polkitd(1170)─┬─{polkitd}(1172)
            │                 │└─{polkitd}(1175)
            │├─systemd(1256)──(sd-pam)(1257)
            │├─sh(3675)──node(3685)─┬─{node}(3686)
            │                       │├─{node}(3687)
            │                       │├─{node}(3688)
            │                       │├─{node}(3689)
            │                       │├─{node}(3690)
            │                       │├─{node}(3691)
            │                       │├─{node}(3698)
            │                       │├─{node}(3699)
            │                       │├─{node}(3700)
            │                       │├─{node}(3701)
            │                       │├─node(3722)─┬─{node}(3723)
            │                       │           │├─{node}(3724)
            │                       │           │├─{node}(3725)
            │                       │           │├─{node}(3726)
            │                       │           │├─{node}(3727)
            │                       │           │├─{node}(3731)
            │                       │           │├─{node}(3745)
            │                       │           │├─{node}(3746)
            │                       │           │├─{node}(3747)
            │                       │           │├─{node}(3748)
            │                       │           │├─{node}(17747)
            │                       │           │├─{node}(20461)
            │                       │           │├─{node}(28655)
            │                       │           │├─bash(17746)
            │                       │           │├─bash(20460)
            │                       │           │└─bash(28654)──pstree(29507)
            │                       └─node(19713)─┬─{node}(19714)
            │                                   │├─{node}(19715)
            │                                   │├─{node}(19716)
            │                                   │├─{node}(19717)
            │                                   │├─{node}(19718)
            │                                   │├─{node}(19719)
            │                                   │├─{node}(19720)
            │                                   │├─{node}(19721)
            │                                   │├─{node}(19722)
            │                                   │├─{node}(19723)
            │                                   │└─{node}(19737)
            │├─{node}(3722)─┬─{node}(3723)
            │               │├─{node}(3724)
            │               │├─{node}(3725)
            │               │├─{node}(3726)
            │               │├─{node}(3727)
            │               │├─{node}(3731)
            │               │├─{node}(3745)
            │               │├─{node}(3746)
            │               │├─{node}(3747)
            │               │├─{node}(3748)
            │               │├─{node}(17747)
            │               │├─{node}(20461)
            │               │├─{node}(28655)
            │               │├─bash(17746)
            │               │├─bash(20460)
            │               │└─bash(28654)──pstree(29507)
            │├─{node}(19713)─┬─{node}(19714)
            │                 │├─{node}(19715)
            │                 │├─{node}(19716)
            │                 │├─{node}(19717)
            │                 │├─{node}(19718)
            │                 │├─{node}(19719)
            │                 │├─{node}(19720)
            │                 │├─{node}(19721)
            │                 │├─{node}(19722)
            │                 │├─{node}(19723)
            │                 │└─{node}(19737)
            │├─{node}(3722)─┬─{node}(3723)
            │               │├─{node}(3724)
            │               │├─{node}(3725)
            │               │├─{node}(3726)
            │               │├─{node}(3727)
            │               │├─{node}(3731)
            │               │├─{node}(3745)
            │               │├─{node}(3746)
            │               │├─{node}(3747)
            │               │├─{node}(3748)
            │               │├─{node}(17747)
            │               │├─{node}(20461)
            │               │├─{node}(28655)
            │               │├─bash(17746)
            │               │├─bash(20460)
            │               │└─bash(28654)──pstree(29507)
            │├─{node}(19713)─┬─{node}(19714)
            │                 │├─{node}(19715)
            │                 │├─{node}(19716)
            │                 │├─{node}(19717)
            │                 │├─{node}(19718)
            │                 │├─{node}(19719)
            │                 │├─{node}(19720)
            │                 │├─{node}(19721)
            │                 │├─{node}(19722)
            │                 │├─{node}(19723)
            │                 │└─{node}(19737)
            │├─{node}(3722)─┬─{node}(3723)
            │               │├─{node}(3724)
            │               │├─{node}(3725)
            │               │├─{node}(3726)
            │               │├─{node}(3727)
            │               │├─{node}(3731)
            │               │├─{node}(3745)
            │               │├─{node}(3746)
            │               │├─{node}(3747)
            │               │├─{node}(3748)
            │               │├─{node}(17747)
            │               │├─{node}(20461)
            │               │├─{node}(28655)
            │               │├─bash(17746)
            │               │├─bash(20460)
            │               │└─bash(28654)──pstree(29507)
            │├─{node}(19713)─┬─{node}(19714)
            │                 │├─{node}(19715)
            │                 │├─{node}(19716)
            │                 │├─{node}(19717)
            │                 │├─{node}(19718)
            │                 │├─{node}(19719)
            │                 │├─{node}(19720)
            │                 │├─{node}(19721)
            │                 │├─{node}(19722)
            │                 │├─{node}(19723)
            │                 │└─{node}(19737)
            │├─{node}(3722)─┬─{node}(3723)
            │               │├─{node}(3724)
            │               │├─{node}(3725)
            │               │├─{node}(3726)
            │               │├─{node}(3727)
            │               │├─{node}(3731)
            │               │├─{node}(3745)
            │               │├─{node}(3746)
            │               │├─{node}(3747)
            │               │├─{node}(3748)
            │               │├─{node}(17747)
            │               │├─{node}(20461)
            │               │├─{node}(28655)
            │               │├─bash(17746)
            │               │├─bash(20460)
            │               │└─bash(28654)──pstree(29507)
            │├─{node}(19713)─┬─{node}(19714)
            │                 │├─{node}(19715)
            │                 │├─{node}(19716)
            │                 │├─{node}(19717)
            │                 │├─{node}(19718)
            │                 │├─{node}(19719)
            │                 │├─{node}(19720)
            │                 │├─{node}(19721)
            │                 │├─{node}(19722)
            │                 │├─{node}(19723)
            │                 │└─{node}(19737)
            │├─{node}(3722)─┬─{node}(3723)
            │               │├─{node}(3724)
            │               │├─{node}(3725)
            │               │├─{node}(3726)
            │               │├─{node}(3727)
            │               │├─{node}(3731)
            │               │├─{node}(3745)
            │               │├─{node}(3746)
            │               │├─{node}(3747)
            │               │├─{node}(3748)
            │               │├─{node}(17747)
            │               │├─{node}(20461)
            │               │├─{node}(28655)
            │               │├─bash(17746)
            │               │├─bash(20460)
            │               │└─bash(28654)──pstree(29507)
            │├─{node}(19713)─┬─{node}(19714)
            │                 │├─{node}(19715)
            │                 │├─{node}(19716)
            │                 │├─{node}(19717)
            │                 │├─{node}(19718)
            │                 │├─{node}(19719)
            │                 │├─{node}(19720)
            │                 │├─{node}(19721)
            │                 │├─{node}(19722)
            │                 │├─{node}(19723)
            │                 │└─{node}(19737)
            │├─{node}(3722)─┬─{node}(3723)
            │               │├─{node}(3724)
            │               │├─{node}(3725)
            │               │├─{node}(3726)
            │               │├─{node}(3727)
            │               │├─{node}(3731)
            │               │├─{node}(3745)
            │               │├─{node}(3746)
            │               │├─{node}(3747)
            │               │├─{node}(3748)
            │               │├─{node}(17747)
            │               │├─{node}(20461)
            │               │├─{node}(28655)
            │               │├─bash(17746)
            │               │├─bash(20460)
            │               │└─bash(28654)──pstree(29507)
            │├─{node}(19713)─┬─{node}(19714)
            │                 │├─{node}(19715)
            │                 │├─{node}(19716)
            │                 │├─{node}(19717)
            │                 │├─{node}(19718)
            │                 │├─{node}(19719)
            │                 │
```

```

|---{node}(19931)
|---node(19754)---{node}(19755)
|               |---{node}(19756)
|               |---{node}(19757)
|               |---{node}(19758)
|               |---{node}(19759)
|               |---{node}(19760)
|               `---{node}(19760)
|---cpptools(19781)---{cpptools}(19782)
|                   |---{cpptools}(19783)
|                   |---{cpptools}(19784)
|                   |---{cpptools}(19785)
|                   |---{cpptools}(19786)
|                   |---{cpptools}(19787)
|                   |---{cpptools}(19788)
|                   |---{cpptools}(19789)
|                   |---{cpptools}(19790)
|                   |---{cpptools}(19791)
|                   |---{cpptools}(19792)
|                   |---{cpptools}(19793)
|                   |---{cpptools}(19794)
|                   |---{cpptools}(19795)
|                   |---{cpptools}(19796)
|                   |---{cpptools}(19819)
|                   |---{cpptools}(19820)
|                   |---{cpptools}(19821)
|                   |---{cpptools}(19822)
|                   |---{cpptools}(19823)
|                   |---{cpptools}(19824)
|                   |---{cpptools}(19825)
|                   |---{cpptools}(19847)
|                   |---{cpptools}(19848)
|                   |---{cpptools}(19849)
|                   |---{cpptools}(19850)
|                   |---{cpptools}(29365)
|                   `---{cpptools}(29365)
|---node(19724)---{node}(19725)
|               |---{node}(19726)
|               |---{node}(19727)
|               |---{node}(19728)
|               |---{node}(19729)
|               |---{node}(19730)
|               |---{node}(19731)
|               |---{node}(19732)
|               |---{node}(19733)
|               |---{node}(19734)
|               |---{node}(19735)
|               |---{node}(19736)
|               `---{node}(19736)

```

```

|---remote-dev-serv(12068)---launcher.sh(12073)---ld-linux-x86-64(12175)---{ld-linux-x86-64}(12190)
|                   |---{ld-linux-x86-64}(12191)
|                   |---{ld-linux-x86-64}(12192)
|                   |---{ld-linux-x86-64}(12193)
|                   |---{ld-linux-x86-64}(12194)
|                   |---{ld-linux-x86-64}(12195)
|                   |---{ld-linux-x86-64}(12196)
|                   |---{ld-linux-x86-64}(12197)
|                   |---{ld-linux-x86-64}(12198)
|                   |---{ld-linux-x86-64}(12199)
|                   |---{ld-linux-x86-64}(12200)
|                   |---{ld-linux-x86-64}(12201)
|                   |---{ld-linux-x86-64}(12202)
|                   |---{ld-linux-x86-64}(12203)
|                   |---{ld-linux-x86-64}(12204)
|                   |---{ld-linux-x86-64}(12205)
|                   |---{ld-linux-x86-64}(12206)
|                   |---{ld-linux-x86-64}(12207)
|                   |---{ld-linux-x86-64}(12210)
|                   |---{ld-linux-x86-64}(12211)
|                   |---{ld-linux-x86-64}(12212)
|                   |---{ld-linux-x86-64}(12213)
|                   |---{ld-linux-x86-64}(12214)
|                   |---{ld-linux-x86-64}(12215)
|                   |---{ld-linux-x86-64}(12216)
|                   |---{ld-linux-x86-64}(12217)
|                   `---{ld-linux-x86-64}(12217)

```

```

|-{ld-linux-x86-64}(12218)
|-{ld-linux-x86-64}(12219)
|-{ld-linux-x86-64}(12220)
|-{ld-linux-x86-64}(12221)
|-{ld-linux-x86-64}(12222)
|-{ld-linux-x86-64}(12224)
|-{ld-linux-x86-64}(12227)
|-{ld-linux-x86-64}(12228)
|-{ld-linux-x86-64}(12234)
|-{ld-linux-x86-64}(12235)
|-{ld-linux-x86-64}(12236)
|-{ld-linux-x86-64}(12238)
|-{ld-linux-x86-64}(12241)
|-{ld-linux-x86-64}(12243)
|-{ld-linux-x86-64}(12244)
|-{ld-linux-x86-64}(12245)
|-{ld-linux-x86-64}(12247)
|-{ld-linux-x86-64}(12248)
|-{ld-linux-x86-64}(12249)
|-{ld-linux-x86-64}(12252)
|-{ld-linux-x86-64}(12556)
|-{ld-linux-x86-64}(12557)
|-{ld-linux-x86-64}(12559)
|-{ld-linux-x86-64}(12562)
|-{ld-linux-x86-64}(12564)
|-{ld-linux-x86-64}(12577)
|-{ld-linux-x86-64}(12579)
|-{ld-linux-x86-64}(12580)
|-{ld-linux-x86-64}(12591)
|-{ld-linux-x86-64}(12592)
|-{ld-linux-x86-64}(12593)
|-{ld-linux-x86-64}(12594)
|-{ld-linux-x86-64}(12595)
|-{ld-linux-x86-64}(12638)
|-{ld-linux-x86-64}(12662)
|-{ld-linux-x86-64}(12665)
|-{ld-linux-x86-64}(12666)
|-{ld-linux-x86-64}(12701)
|-{ld-linux-x86-64}(12702)
|-{ld-linux-x86-64}(12751)
|-{ld-linux-x86-64}(12769)
|-{ld-linux-x86-64}(12819)
|-{ld-linux-x86-64}(12820)
|-{ld-linux-x86-64}(13394)
|-{ld-linux-x86-64}(13516)
|-{ld-linux-x86-64}(13517)
|-{ld-linux-x86-64}(13575)
|-{ld-linux-x86-64}(13577)
|-{ld-linux-x86-64}(13952)
|-{ld-linux-x86-64}(13953)
|-{ld-linux-x86-64}(13994)
|-{ld-linux-x86-64}(20233)
|-{ld-linux-x86-64}(29216)
|-{ld-linux-x86-64}(29338)
|-{ld-linux-x86-64}(29502)
|fsnotifier(12251)
|ion.clangd.main(12664)---{ion.clangd.main}(12667)
|                                     |{ion.clangd.main}(12668)
|                                     |{ion.clangd.main}(12669)
|                                     |{ion.clangd.main}(12732)
|                                     |--{ion.clangd.main}(12733)
|bash(13576)
|test(15088)
|test(16328)
|test(17096)
|test(19507)
|cpptools-srv(25075)---{cpptools-srv}(25076)
|                                     |{cpptools-srv}(25077)
|                                     |{cpptools-srv}(25078)
|                                     |{cpptools-srv}(25079)
|                                     |{cpptools-srv}(25080)
|                                     |{cpptools-srv}(25081)
|                                     |{cpptools-srv}(25082)
|                                     |{cpptools-srv}(25083)
|                                     |{cpptools-srv}(25084)
|                                     |{cpptools-srv}(25085)
|                                     |{cpptools-srv}(25086)
|                                     |{cpptools-srv}(25087)
|                                     |{cpptools-srv}(25088)
|                                     |{cpptools-srv}(25089)

```



```

| {cpptools-srv}(25089)
| {cpptools-srv}(25090)
|-test(26068)
|-test(27667)
`-cpptools-srv(28985)---{cpptools-srv}(28986)
| {cpptools-srv}(28987)
| {cpptools-srv}(28988)
| {cpptools-srv}(28989)
| {cpptools-srv}(28990)
| {cpptools-srv}(28991)
| {cpptools-srv}(28992)
| {cpptools-srv}(28993)
| {cpptools-srv}(28994)
| {cpptools-srv}(28995)
| {cpptools-srv}(28996)
| {cpptools-srv}(28997)
| {cpptools-srv}(28998)
| {cpptools-srv}(28999)
| {cpptools-srv}(29000)

```

- add option `-l`

```

● vagrant@csc3150:~/csc3150/CSC3150-Assignment1/source/bonus$ ./build/pstree 1 -l
systemd+-systemd-journal
| -lvm2md
| -systemd-udev
| -dhclient
| -2*[iscsid]
| -cron
| -accounts-daemon---2*[{accounts-daemon}]
| -atd
| -systemd-logind
| -dbus-daemon
| -acpid
| -lxcfs---3*[{lxcfs}]
| -rsyslogd---3*[{rsyslogd}]
| -sshd+-sshd---sshd---bash
|   `--sshd---sshd---bash---bash
| -unattended-upgr---{unattended-upgr}
| -mdadm
| -2*[agetty]
| -irqbalance
| -polkitd---2*[{polkitd}]
| -systemd---(sd-pam)
| -sh---node+-10*[{node}]
|   | -node+-13*[{node}]
|   |   | -2*[bash]
|   |   |   `--bash---pstree
|   | -node+-12*[{node}]
|   |   | -2*[node---6*[{node}]
|   |   |   `--cpptools---27*[{cpptools}]
|   |   `--node---12*[{node}]
| -remote-dev-serv---launcher.sh---ld-linux-x86-64+-80*[{ld-linux-x86-64}]
|   | -fsnotifier
|   |   | -ion.clangd.main---5*[{ion.clangd.main}]
|   |   `--bash
| -6*[test]
| -2*[cpptools-srv---15*[{cpptools-srv}]

```

- add option `-A`

```

● vagrant@csc3150:~/csc3150/CSC3150-Assignment1/source/bonus$ ./build/pstree 1 -A
systemd+-systemd-journal
|-lvmetad
|-systemd-udev
|-dhclient
|-2*[iscsid]
|-cron
|-accounts-daemon---2*[{accounts-daemon}]
|-atd
|-systemd-logind
|-dbus-daemon
|-acpid
|-lxcfs---3*[{lxcfs}]
|-rsyslogd---3*[{rsyslogd}]
|-sshd+-sshd---sshd---bash
|   `--sshd---sshd---bash---bash
|-unattended-upgr---{unattended-upgr}
|-mdadm
|-2*[agetty]
|-irqbalance
|-polkitd---2*[{polkitd}]
|-systemd---(sd-pam)
|-sh---node+-10*[{node}]
|   |-node+-13*[{node}]
|   |   |-2*[bash]
|   |   `--bash---pstree
|   |-node+-12*[{node}]
|   |   |-2*[node---6*[{node}]]
|   |   `--cpptools---27*[{cpptools}]
|   `--node---12*[{node}]
|-remote-dev-serv---launcher.sh---ld-linux-x86-64+-80*[{ld-linux-x86-64}]
|   |-fsnotifier
|   |-ion.clangd.main---5*[{ion.clangd.main}]
|   `--bash
|-6*[test]
`--2*[cpptools-srv---15*[{cpptools-srv}]]

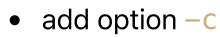
```

```

● vagrant@csc3150:~/csc3150/CSC3150-Assignment1/source/bonus$ ./build/pstree 1 -c
systemd+-systemd-journal
|-lvmetad
|-systemd-udev
|-dhclient
|-iscsid
|-iscsid
|-cron
|-accounts-daemon+-{accounts-daemon}
|   `--accounts-daemon}
|-atd
|-systemd-logind
|-dbus-daemon
|-acpid
|-lxcfs+-{lxcfs}
|   |-{lxcfs}
|   `--{lxcfs}
|-rsyslogd+-{rsyslogd}
|   |-{rsyslogd}
|   `--{rsyslogd}
|-sshd+-sshd---sshd---bash
|   `--sshd---sshd---bash---bash
|-unattended-upgr---{unattended-upgr}
|-mdadm
|-agetty
|-agetty
|-irqbalance
|-polkitd+-{polkitd}
|   `--{polkitd}
|-systemd---(sd-pam)
|-sh---node+-{node}
|   |-{node}
|   |-{node}
|   |-{node}
|   `--{node}

```

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```
| {ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -{ld-linux-x86-64}  
| -fsnotifier  
| -ion.clangd.main+--{ion.clangd.main}  
| | -{ion.clangd.main}  
| | -{ion.clangd.main}  
| | -{ion.clangd.main}  
| | -{ion.clangd.main}
```



```

|-{cpptools-srv}
|-{cpptools-srv}
`-{cpptools-srv}

```

- add option `-t`

```

● vagrant@csc3150:~/csc3150/CSC3150-Assignment1/source/bonus$ ./build/pstree 1 -T
systemd+-systemd-journal
| -lvmetad
| -systemd-udev
| -dhclient
| -2*[iscsid]
| -cron
| -accounts-daemon
| -atd
| -systemd-logind
| -dbus-daemon
| -acpid
| -lxcfs
| -rsyslogd
| -sshd+-sshd---sshd---bash
|   `--sshd---sshd---bash---bash
| -unattended-upgr
| -mdadm
| -2*[agetty]
| -irqbalance
| -polkitd
| -systemd---(sd-pam)
| -sh---node+-node+-2*[bash]
|   |
|   |   | -bash---pstree
|   |   `--sh---cpuUsage.sh---sleep
|   | -node+-2*[node]
|   |   `--cpptools
|   `--node
| -remote-dev-serv---launcher.sh---ld-linux-x86-64+-fsnotifier
|   |
|   |   | -ion.clangd.main
|   |   `--bash
| -6*[test]
| -2*[cpptools-srv]

```

What did I learn from the tasks

In this task, I learned the following knowledge:

1. I learned how and where to find all process information.
2. I learned how to build the relationship of parent and child processes from linked list into a tree data structure.
3. I also get a better understanding of the pstree command and its detailed information.