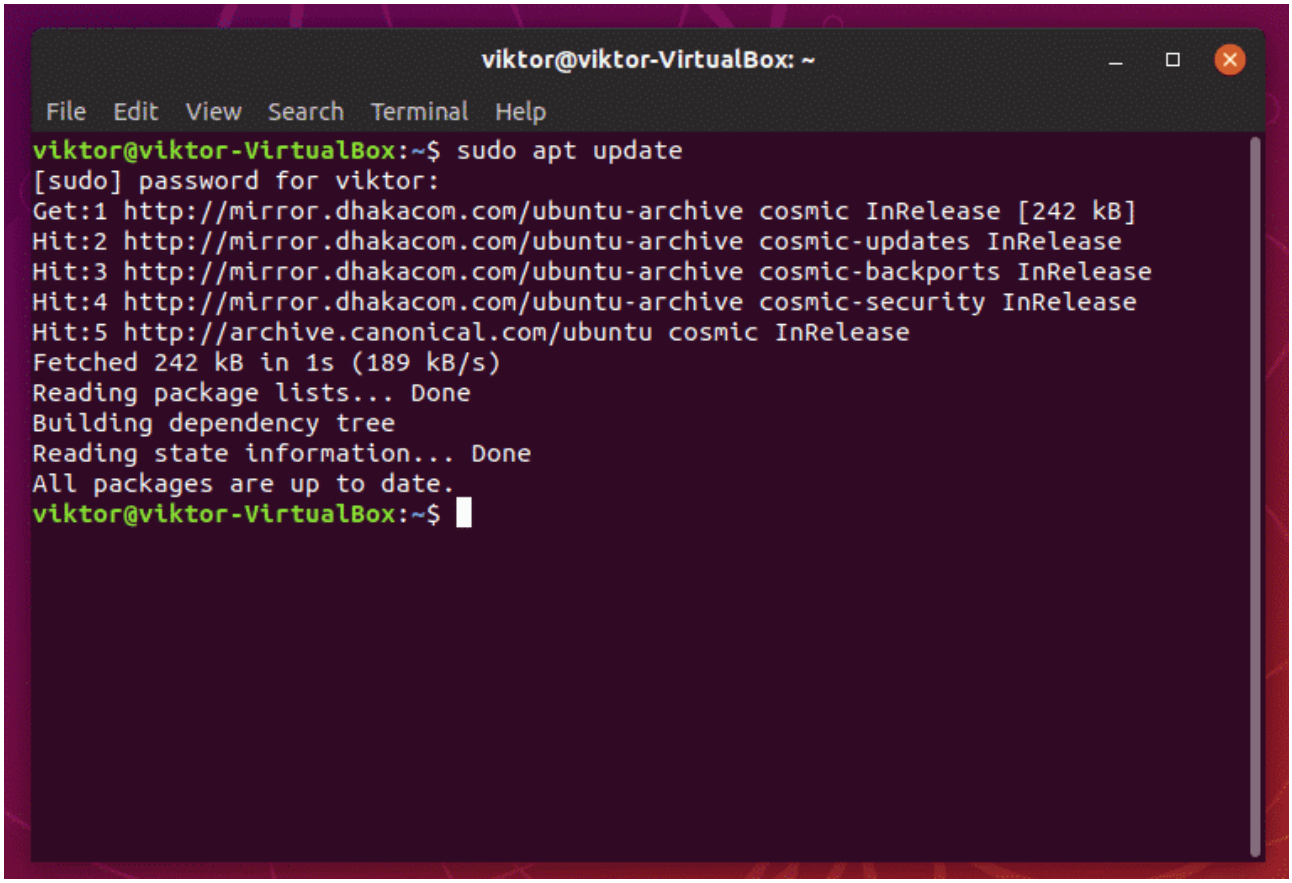
Simple Shell (Multi-Processing)



1. Objectives

1. Familiarity with system calls in Unix environment.
2. Introduction to processes and multi-processing.
3. Introduction to signal handling in Unix environment.

2. Problem Statement

It is required to implement a Unix shell program. A shell is simply a program that conveniently allows you to run other programs. Read up on your favorite shell to see what it does.

Your shell must support the following commands:

1. The internal shell command "exit" which terminates the shell
   - **Concepts**: shell commands, exiting the shell.
   - **System calls**: exit()
2. A command with no arguments
   - **Example**: ls, cp, rm ...etc

- **Details**: Your shell must block until the command completes and, if the return code is abnormal, print out a message to that effect.
- **Concepts**: Forking a child process, waiting for it to complete and synchronous execution.
- **System calls**: fork(), execvp(), exit(), waitpid()

3. A command with arguments
   - **Example**: ls –l
   - **Details**: Argument 0 is the name of the command.
   - **Concepts**: Command-line parameters.
4. A command, with or without arguments, executed in the background using &.
   - **Example**: firefox &
   - **Details**: In this case, your shell must execute the command and return immediately, not blocking until the command finishes.
   - **Concepts**: Background execution, signals, signal handlers, processes and asynchronous execution.
   - **Requirements**: You have to show that the opened process will be nested as a child process to the shell program via opening the task manager found in the operating system like the one shown in figure 1. Additionally you have to write in a log file (basic text file) when a child process is terminated (main application will be interrupted by a SIGCHLD signal). So you have to implement an interrupt handler to handle this interrupt and do the corresponding action to it.
5. Shell builtin commands
   - **Commands**: cd & echo
   - **Details**: for the case of:
     - **cd**: Cover all the following cases (**assume no spaces in path**):
       - cd
       - cd ~
       - cd ..
       - cd absolute_path
       - cd relative_path_to_current_working_directory
     - **echo**: Prints the input after evaluating all expressions (**assume input to echo must be within double quotations**).
       - echo "wow" => wow
       - export x=5
       - echo "Hello $x" => Hello 5
6. Expression evaluation
   - **Commands**: export

- **Details**: Set values to variables and print variables values. No mathematical operations is needed.
- **Export Details**: Accept input of two forms, either a string without spaces, or a full string inside double quotations.
- **Example**:
  - export x=-l
  - ls $x => Will perform ls -l
  - export y="Hello world"
  - echo "$y" => Hello world

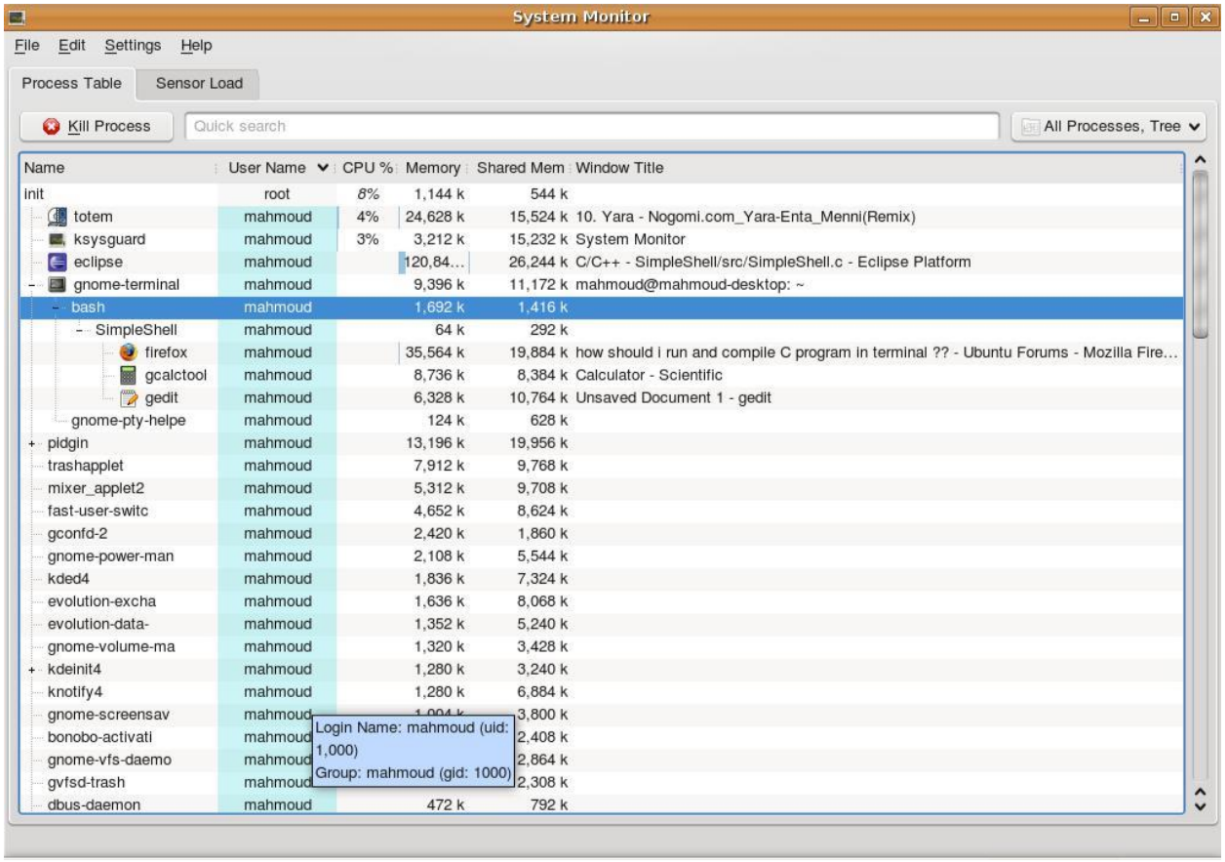


*Figure 1 Firefox, Calculator and Gedit are child processes to the SimpleShell process**

3. Problem Description

1. Your command shell should take the user command and its parameter(s), i.e., "ls" and "–l" in this example, and convert them into C strings. (Recall that a C string terminates with a null string, i.e., \0.)
2. The command shell should create a child process via **fork()**.
3. The child process passes the C strings—the command and parameter(s)—to **execvp()**.
4. The child exits if **execvp()** returns error.

5. The parent process, i.e., the command shell, should wait, via waitpid(pid_t pid, int *statusPtr, int options) , for the child process to finish.
6. The command shell gets the next command and repeats the above steps. The command shell terminates itself when the user types exit.
7. No zombie process should ever exist, you can read more about zombie processes and how to handle them at the Reading & Resources section.

In case a user wants to execute the command in background (i.e. as a background process), he/she writes & at the end of the command. For example, a user command can be:

```
firefox &
```

In this case, your command shell should not wait for the child by skipping the Step 5.

You should keep a log file (basic text file) for your shell program such that whenever a child process terminates, the shell program appends the line “Child process was terminated” to the log file. To do this, you have to write a signal handler that appends the line to the log file when the SIGCHLD signal is received.

Pseudocode

The shell program should be written as following pseudocode:

```
function parent_main()
    register_child_signal(on_child_exit())
    setup_environment()
    shell()


function on_child_exit()
    reap_child_zombie()
    write_to_log_file("Child terminated")


function setup_environment()
    cd(Current_Working_Directory)


function shell()
    do
        parse_input(read_input())
        evaluate_expression():
```

```
        switch(input_type):
            case shell_builtin:
                execute_shell_bultin();
            case executable_or_error:
                execute_command():

    while command_is_not_exit


function execute_shell_bultin()
    swirch(command_type):
        case cd:
        case echo:
        case export:


function execute_command()
    child_id = fork()
    if child:
        execvp(command parsed)
        print("Error)
        exit()
    else if parent and foreground:
        waitpid(child)
```

Notes

- You should register the SIGCHLD signal at the beginning of your main as shown in this example, so when a child dies, the parent process receives SIGCHLD (or SIGCLD) signal.
- To see the set of all signals supported on your system, type, kill –l.
- Use a process monitor package to monitor your processes. Provide a screenshot for your shell parent process and some child processes spawned as background processes. Suggested packages: KSysguard or Gnome-System-Monitor.
- Reading this article about waitpid(pid_t pid, int *statusPtr, int options) is a must.

4. Deliverables

- Complete C source code, commented thoroughly and clearly.
- A report that includes:
  - A description of the overall organization of your code and the major functions.

    - Sample runs.
    - screenshots for the processes hierarchy in KSysguard (or any similar package) during the execution of your shell program.
- A 3-min (tolerance of 30 seconds only) video that shows the output of the next test case.

Test Case

Open your shell.

Execute the following commands.

```
ls
mkdir test
ls
ls -a -l -h
export x="-a -l -h"
ls $x
```

Execute the following commands in the same session, but **show** that shell is stuck and cannot execute other commands while firefox is open.

Note: In order for this test to work correctly, firefox has to be closed before executing this command. Also, if firefox is not available, you may use 'gedit' instead.

```
firefox
```

Close the firefox.

Open the log file, show us its content, then close it.

Execute the following commands in the same session, but **show** that shell is not stuck and can execute other commands while firefox is open.

```
firefox &
```

Open the log file, show us its content, then close it.

Open the system monitor and expand all running processes under your shell process.

Open the system monitor and **Search** for all firefox processes.

Execute the following command in the same session, it should show us an error message.

```
heyy
```

Execute the following command in the same session, it should close the shell from the first time you execute it.

```
exit
```

That's it!

Lab requirements

- Students will be working individually.
- You can only use C programming language.
- Use Ubuntu operating system for development.
- Submit the deliverables using the submission form provided in your class.
- If the submitted code cannot replicate the same video scenario, then this will be considered cheating and the "cheating and plagiarism" policy will be applied.

Readings & Resources

- What is a zombie process in Linux?
- Process states & dealing with zombie processes
- Linux Signals
- Important notes on wait() and repeaing zombies
- sigaction(2) — Linux manual page
- signal(2) — Linux manual page