SOFE 3950U / CSCI 3020U: Operating Systems

TUTORIAL #8: Signals and Data Structures Part II

Objectives

- Learn the fundamentals of signals and data structures in C
- Gain experience writing multiprocessor code and data structures

Important Notes

- Work in groups of **four** students
    - All reports must be submitted as a PDF on blackboard, if source code is included submit everything as an archive (e.g. zip, tar.gz)
- Save the file as <tutorial_number>_<first student's id>.pdf (e.g. tutorial8_100123456.pdf)

If you cannot submit the document on Blackboard then please contact the TA (Jonathan Gillett) with your submission on slack at **http://sofe3950u.slack.com** or send him an email via **jonathan.gillett@uoit.net**.

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Notice

It is recommended for this lab activity and others that you save/bookmark the following resources as they are very useful for C programming.

- http://en.cppreference.com/w/c
- http://www.cplusplus.com/reference/clibrary/
- http://users.ece.utexas.edu/~adnan/c-refcard.pdf
- http://gribblelab.org/CBootcamp

The following resources are helpful as you will need to use signals and data structures to complete the task.

- http://www.gnu.org/software/libc/manual/html_node/Standard-Signals.html#Standard-Signals
- http://www.gnu.org/software/libc/manual/html_node/Signaling-Another-Process.html
- http://www.gnu.org/software/libc/manual/html_node/Process-Completion.html#Process-Completion
- http://www.gnu.org/software/libc/manual/html_node/Signaling-Another-Process.html
- http://www.thegeekstuff.com/2013/02/c-binary-tree/
- http://www.learn-c.org/en/Binary_trees

Conceptual Questions

1. What is an Abstract Data Type (ADT)?

An ADT is a model for data types where the data type is defined by its behavior (operations you can perform on it) rather than its implementation. Think of it as the interface in object-oriented programming, where the focus is on what operations the data type can perform, not on how these operations are implemented.

2. Explain the difference between a queue (FIFO) and a stack (LIFO).

- **Queue**: It's like waiting in line at a coffee shop; the first person in line is the first one served (FIFO - First In, First Out). Useful when order matters.

- **Stack**: It's like a stack of books; you add one on top and take the top one off when needed (LIFO - Last In, First Out). Great for situations like undo mechanisms where the most recent action is the first to be reversed.

3. Name and briefly explain three types of data structures.

Array: A fixed-size container that holds elements of the same type, allowing quick access via index. Its main drawback is its fixed size.
Linked List: A sequence of nodes where each node points to the next, allowing easy insertion and deletion. Traversing it is slower than an array due to the lack of direct element access.
Graph: A set of nodes connected by edges. Extremely versatile for representing complex relationships, like social networks or maps.

4. Explain what a binary tree is, what are some common operations of a binary tree?

A binary tree is a tree data structure where each node has up to two children. It's essential for efficient searching and sorting, with operations like insertion, deletion, and traversal (in-order, pre-order, post-order). It lays the foundation for more complex structures like binary search trees and AVL trees.

5. Explain what a hash table (dictionary) is, what are common operations of a hash table?

A hash table maps keys to values using a hash function to compute an index into an array of buckets, where the value is stored. Operations include insertion, deletion, and lookup, which are typically very efficient. Hash tables are ideal for scenarios requiring quick access to data through unique keys, like database indexing or caching systems.

Application Questions

All of your programs for this activity can be completed using the template provided, where you fill in the remaining content. A makefile is not necessary, to compile your programs use the following command in the terminal. **If you do not have clang then**

replace clang with gcc, **if you are still having issues please use -std=gnu99 instead of c99.**

```
clang -Wall -Wextra -std=c99 <program name>.c -o <program name>
```

Example:

```
clang -Wall -Wextra -std=c99 question1.c -o question1
```

You can then execute and test your program by running it with the following command.

```
./<program name>
```

Example:

```
./question1
```

Template

```
#include <stddef.h>
#include <stdlib.h>
#include <stdio.h>
#include <stdbool.h>
#include <unistd.h>
#include <signal.h>
#include <sys/types.h>
#include <sys/wait.h>

int main(void)
{ ... }
```

Notice

You must have the program **process** in the same location as your source code, compile the included source file **sigtrap.c** as process using the following commands. You can use **clang** or **gcc**, you will need to use **-std=gnu99** in order for the code to compile properly.

```
clang -Wall -Wextra -std=gnu99 sigtrap.c -o process
```

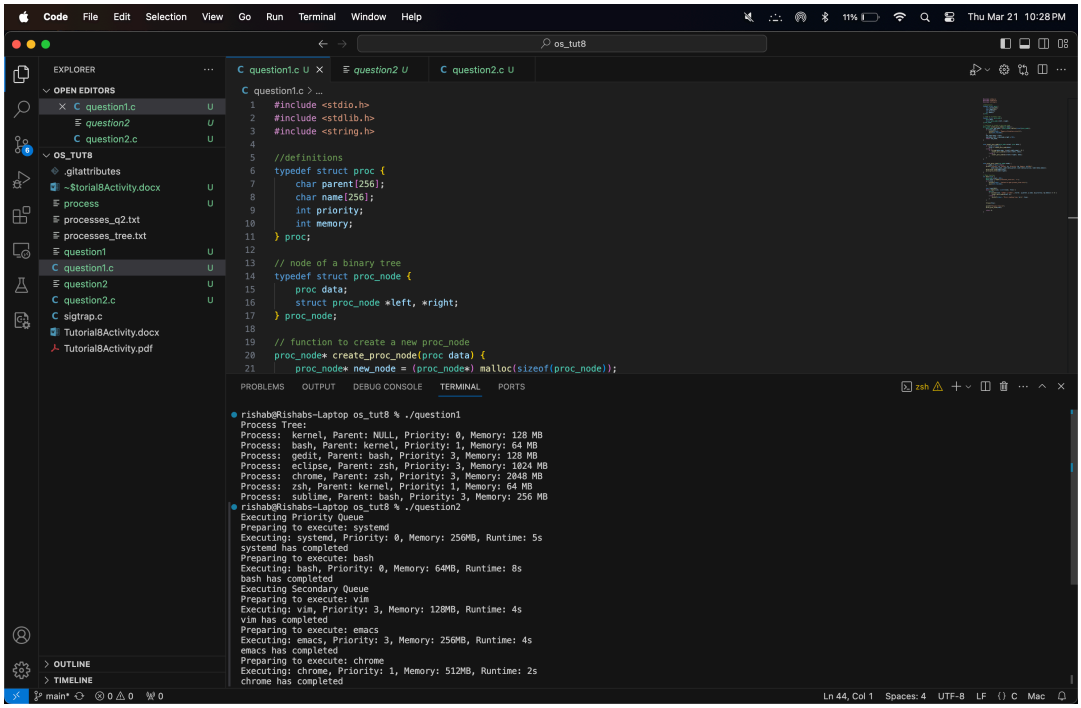
1. Create a program that does the following.
    - Create a structure called **proc** that contains the following
        - **parent,** character array of 256, name of the parent process
        - **name**, character array of 256 length
        - **priority,** integer for the process priority
        - **memory**, integer for the memory in MB used by process
    - Create a binary tree data structure called **proc_tree** which contains the proc data structure.
    - Create the necessary functions to interact with your binary tree data structure, you will need to add items to your tree and iterate through it.
    - Your program then reads the contents of a file called **process_tree.txt (7 LINES)**, which contains a **comma separated** list of the parent, name, priority, and memory.
    - Read the contents of the file and create your binary tree, add the children to the parent based on the name of the parent.
    - Print the contents of your binary tree (you likely need to use **recursion**!) displaying the contents of each parent, and the children of each parent.

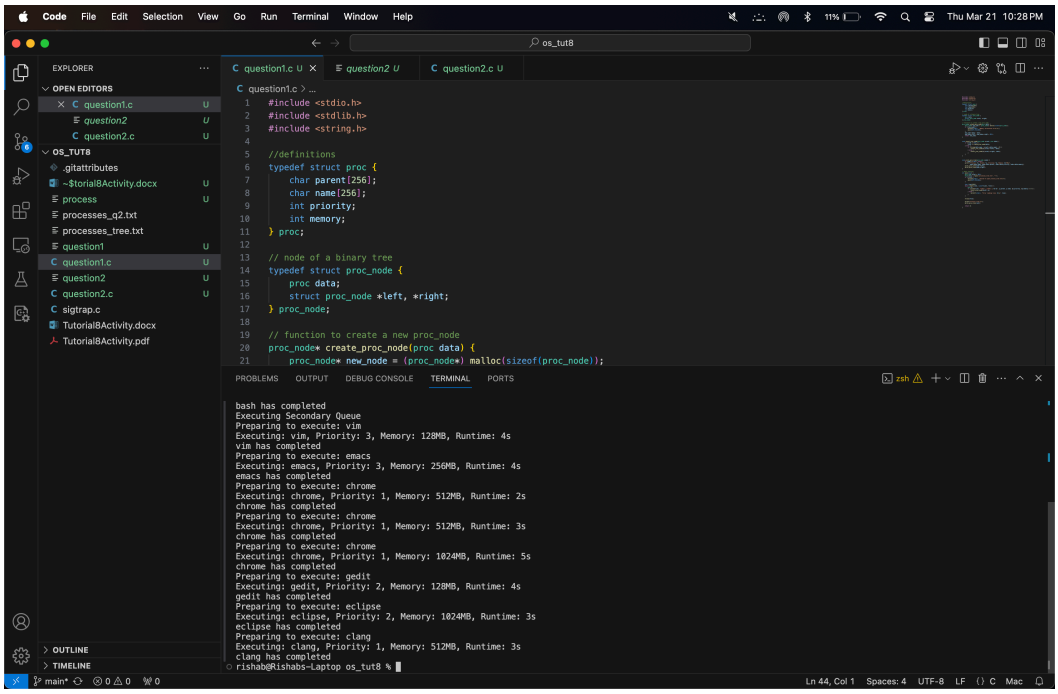
2. Create a simple host dispatch shell that does the following.
    - Create a structure called **proc** that contains the following
        - **name**, character array of 256 length
        - **priority,** integer for the process priority
        - **pid**, integer for the process id
        - **address** integer index of memory in **avail_mem** allocated
        - **memory,** integer for the memory required
        - **runtime,** integer for the running time in seconds
        - **suspended,** boolean indicating process has been suspended
    - Create a **FIFO** queue called **priority** which will be populated with real time priority processes (priority 0).
    - Create a second **FIFO** queue called **secondary,** which will be populated with secondary priority processes.
    - Create an array of **length 1024** called **avail_mem**, use #define MEMORY 1024, **initialize it to 0** to indicate all memory is free.
    - Read in the processes from the file **processes_q2.txt**, the file contains a comma separated list of the **name, priority, memory,** and **runtime** you must initialize the **pid and address to 0** in your process structure, it is set when you execute the processes.

- When reading the file **processes_q2.txt** add each process with a priority of 0 to the **priority** queue, add the remaining processes to the **secondary** queue.
- Iterate through all of the processes in the **priority** queue first, **pop()** each item from the queue and execute the **process** binary using fork and exec.
    - Mark the memory needed in the **avail_mem** array as used **(1)**, set the **address** member of the struct to the starting index where the memory is allocated in the avail_mem array.
    - Before **process** is executed, print the **name, priority, pid, memory, and runtime** of the process.
    - Run the process for the specified **runtime** and then send it the signal **SIGTSTP** to terminate it.
    - Ensure that you use the **waitpid** function to wait until the process has terminated.
    - Free the memory in **avail_mem** used by the process **(set the array entries to 0).**
- Then iterate through all of the processes in the **secondary** queue, **pop()** each item from the queue and execute the **process** binary using fork and exec.
    - If there is **enough memory** available in **avail_mem** array then proceed, otherwise **push()** it back on the queue.
    - Mark the memory needed in the **avail_mem** array as used **(1)**, set the **address** member of the struct to the starting index where the memory is allocated in the avail_mem array.
    - Before **process** is executed, print the **name, priority, pid, memory, and runtime** of the process.
    - **If** the process has already been suspended (**suspended** is true, and **pid** set) then send **SIGCONT** to the process to resume it.
    - Run the process for **1 second** then send **SIGTSTP** to the process to suspend it.
    - If the process was just created, set the **pid** member in the process struct that was returned from **pop()** to the process id returned from **exec().**
    - Decrement the **runtime** member in the process struct by **1.**
    - Set the **suspended** member in the process struct to **true**, indicating the processes has been suspended.
    - Add the process back to the **secondary** queue using **push()**
    - Repeat this for every process in the **secondary queue.**
- For any item in the **secondary** queue that **only has 1 second** of **runtime** left

- Run the process for the specified **runtime** and then send it the signal **SIGINT** to terminate it.
- Ensure that you use the **waitpid** function to wait until the process has terminated.
- **Do not** add the process back to the queue.
- Free the memory in **avail_mem** used by the process **(set the array entries to 0).**

- Once all of the processes have been executed the main program terminates.




Code File Edit Selection View Go Run Terminal Window Help
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os_tut8
EXPLORER
OPEN EDITORS
question1.c U
question2 U
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OS_TUT8
.gitattributes
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process U
processes_q2.txt
processes_tree.txt
question1 U
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question2.c U
sigtrap.c
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OUTLINE
TIMELINE
question1.c U
question2 U
question2.c U
question1.c > ...
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
//definitions
typedef struct proc {
char parent[256];
char name[256];
int priority;
int memory;
} proc;
// node of a binary tree
typedef struct proc_node {
proc data;
struct proc_node *left, *right;
} proc_node;
// function to create a new proc_node
proc_node* create_proc_node(proc data) {
proc_node* new_node = (proc_node*) malloc(sizeof(proc_node));
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS
zsh
bash has completed
Executing Secondary Queue
Preparing to execute: vim
Executing: vim, Priority: 3, Memory: 128MB, Runtime: 4s
vim has completed
Preparing to execute: emacs
Executing: emacs, Priority: 3, Memory: 256MB, Runtime: 4s
emacs has completed
Preparing to execute: chrome
Executing: chrome, Priority: 1, Memory: 512MB, Runtime: 2s
chrome has completed
Preparing to execute: chrome
Executing: chrome, Priority: 1, Memory: 512MB, Runtime: 3s
chrome has completed
Preparing to execute: chrome
Executing: chrome, Priority: 1, Memory: 1024MB, Runtime: 5s
chrome has completed
Preparing to execute: gedit
Executing: gedit, Priority: 2, Memory: 128MB, Runtime: 4s
gedit has completed
Preparing to execute: eclipse
Executing: eclipse, Priority: 2, Memory: 1024MB, Runtime: 3s
eclipse has completed
Preparing to execute: clang
Executing: clang, Priority: 1, Memory: 512MB, Runtime: 3s
clang has completed
rishab@Rishabs-Laptop os_tut8 %
main*
Ln 44, Col 1
Spaces: 4
UTF-8
LF
C
Mac