RTOS, Spring 2015 – Lab #3: Processes and threads

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Objective: to learn the basics of programming with processes and threads using POSIX and Pthreads

1. Background

Make sure you have read and understood Chapters 3 and 4 from the OS textbook ("Process Concept" and "Multithreaded Programming"; in particular 4.4.1 "Pthreads").

2. Hello World with Eclipse

A) Start up Eclipse. If prompted to select/create workspace, say OK
B) Create new "Hello World" project
(New → C Project → Hello World Ansi C Project).
Select Linux GCC compiler, give name to project (es, Lab1) then "Finish"

Note: you can install all this software on your computer at home. It's free. Check VirtualBox.org, Xubuntu.org, Eclipse.org

3. POSIX: Fork a process

A) Replace the existing code with that of the "sample fork program" below.
(The program can be downloaded from http://lia.deis.unibo.it/Courses/RTOS/)
Save (CTRL+S). Build all (CTRL+B) and execute (menu "Run").

```
/**
 * Sample fork program
 */

#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
int value = 5;
int main()
{
       pid_t pid;
       pid = fork();
       if (pid == 0) { /* child process */
              value += 15; printf("CHILD: value = %d\n",value); // LINE A
              return 0;
       }
       else if (pid > 0) { /* parent process */
              printf ("PARENT: value = %d\n",value); // LINE B
              wait(NULL); return 0;
       }
}
```

D) Use system call sleep(1) to introduce delays between instructions, compile again and check the output
E) Modify the program so that
- PARENT and CHILD print the same value, and
- CHILD prints before PARENT.

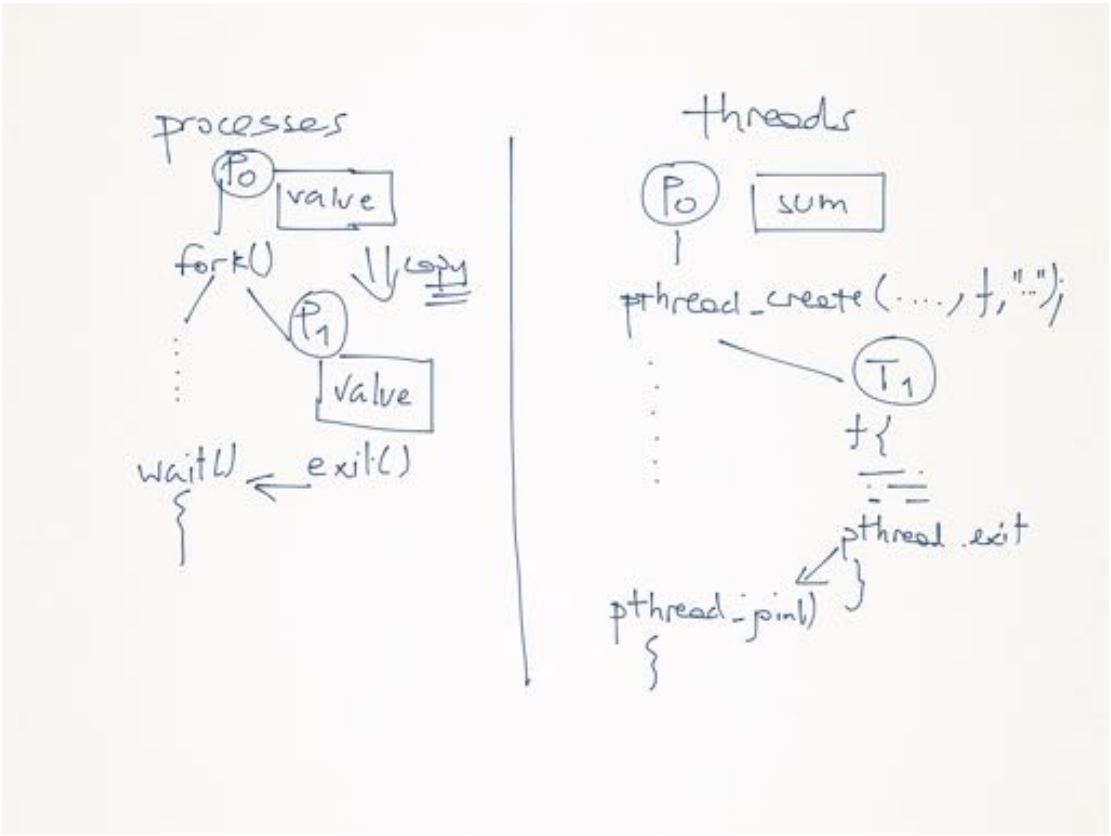
4. Pthreads: use the system calls to create and join

A) Create a new project with the "sample thread program" below (adapted from Silberschatz). (http://lia.deis.unibo.it/Courses/RTOS/)
B) Make sure you understand now the program works. Build all and execute.

```
/**
 * Sample thread program
 * [...]
 */

#include <pthread.h>
#include <stdio.h>

int sum; /* this data is shared by the thread(s) */
void *runner(void *param); /* the thread */

int main(int argc, char *argv[])
{
       pthread_t tid; /* the thread identifier */
       pthread_attr_t attr; /* set of attributes for the thread */
       char arg[10]; sprintf(arg,"%d",10);     /* in the book, this value
                                                  is taken from command line */

       /* get the default attributes */
       pthread_attr_init(&attr);

       /* create the thread */
       pthread_create(&tid,&attr,runner,arg);

       /* now wait for the thread to exit */
       pthread_join(tid,NULL);

       printf("sum = %d\n",sum);
}

/**
 * The thread will begin control in this function
 */
void *runner(void *param)
{
       int i, upper = atoi(param); sum = 0;
       if (upper > 0) {
              for (i = 1; i <= upper; i++)
                     sum += i;
       }
       pthread_exit(0);
}
```

C) What is `atoi(param)`?
D) In general, a thread's function has one argument (for example, `runner` has `param`), which may or may not be `NULL`. When could that become useful?

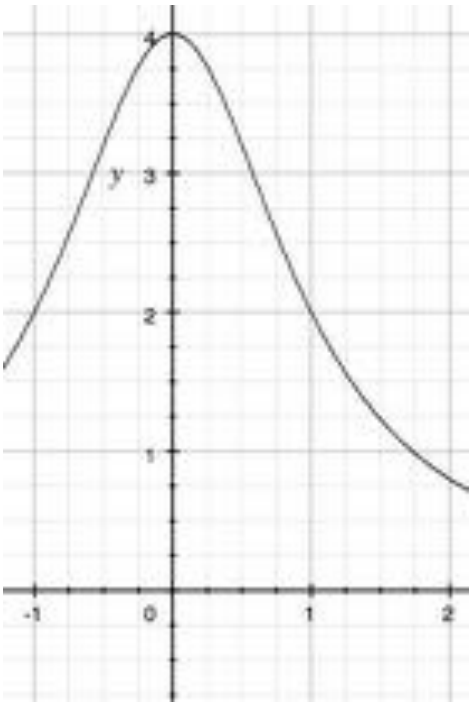
Notice that, to correctly use Pthreads (with Eclipse), you should:
1) #include <pthread.h>
2) add the -pthread option both in the GCC C Compiler and in the GCC C Linker:
->Project->Properties->C/C++ Build->Settings->Tool Settings
->GCC C Compiler->Miscellaneous-> Other flags: add **-pthread**
->Project->Properties->C/C++ Build->Settings->Tool Settings
->GCC C Linker->Miscellaneous-> Linker flags: add **-pthread**


processes
P0
value
fork()
copy
P1
value
wait()
exit()
threads
P0
sum
pthread_create(..., t, "...");
T1
t{
pthread_exit
}
pthread_join()

5. Turn a sequential computation into one that uses concurrent threads

A) Create a new project with the "sequential pi program" below.
(http://lia.deis.unibo.it/Courses/RTOS/)

```
/**
 * Sample pi program
 */

#include <stdio.h>
#include <stdlib.h>
#define N_STEPS (long int) 1000000

int main(void) {

        int i;
        double pi, step, x, sum=0.0;

        step =  1/(double)N_STEPS;

        for(i=0; i<N_STEPS; i++) {
                x = (i+0.5)*step;
                sum+=4.0/(1.0+x*x);
        }

        pi=step*sum;
        printf("Pi = %f\n", pi);
        return EXIT_SUCCESS;
}
```



B) Split the program into threads, so that the computation can be done in parallel by these threads. Use the Pthreads POSIX library.

Useful functions: pthread_attr_init, pthread_create, pthread_join, pthread_exit.
See **man** for information about these functions.

Note: if for some reason you wish to use the math libraries with Eclipse, you should:
1) #include <math.h>
2) add the -lm linking option in the GCC C Linker:
->Project->Properties->C/C++ Build->Settings->Tool Settings
->GCC C Linker->Libraries + **m**

math.h also defines a number of constants, for example π is M_PI
If you want to use these constant definitions, you should:
#define _USE_MATH_DEFINES
and then
#include <math.h>

6. Self assessment

- ☐ How can I produce an executable file out of a C program?
- ☐ I wrote a program in Eclipse. Now how can I execute it?
- ☐ What does the "sample fork program" print out at LINE A? and at LINE B?
- ☐ Is it possible to predict which line is printed out first (A or B)?
- ☐ What Pthreads function call is used to wait for a thread to finish?
- ☐ Does splitting the program into multiple threads make the execution faster?