Thread synchronization I

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V1.6

Introduction

In this exercise you will get some routine using thread synchronization mechanisms. First, you will revisit the *printout* exercise from Exercise *Posix Threads*, and ensure that the *printouts* work probably by using a mutex solution. Then, you will use the `vector` class and get a more indepth understanding of what you may or may not know using both *mutexes* and *semaphores*. Finally you are going to create the `ScopeLocker` class that utilizes the RAII idiom to ensure that locks are always relinquished.

Prerequisites

In order to complete this exercise, you must:

- have completed Exercise *Posix Threads*

The problem in Exercises *Sharing data between threads* and *Sharing a Vector class between threads* from *Posix Threads* is that all threads share and utilize a resource and that resource is not protected. This is illustrated in the fact that a thread could *not* necessarily complete its read or write operation uninterrupted. For write operations the consequence could be inconsistent data in the shared resource, whereas a reader operation could return inconsistent data due to either an "in-between update" or a write being interrupted as mentioned above resulting in an error.

This problem can be rectified using a `mutex`/`semaphore`.

Exercise 1 Precursor: Using the synchronization primitives

Exercise 1.1 Printout from two threads...

Write a program that creates two threads. When created, the threads must be passed an ID which they will print to `stdout` every second along with the number of times the thread has printed to `stdout`. When the threads have written to stdout 10 times each, they shall terminate. The `main()` function must wait for the two threads to terminate before continuing (hint: Look up `pthread_join()`).

Listing 1.1: A possible output from running the program is

```
$ ./lab
Main: Creating threads
Main: Waiting for threads to finish
Hello #0 from thread 0
Hello #0 from thread 1
Hello #1 from thread 0
Hello #1 from thread 1
...
Hello #9 from thread 0
Hello #9 from thread 1
Thread 0 terminates
Thread 1 terminates
Main: Exiting
$
```

You may know this program already :-), but if so, you have probably experienced that the printouts were some times done on top of each other.

1. Extend the program by creating a global `mutex`
2. Remember to initialise the `mutex`
3. Create a critical section *around* your printout.
   - What does it mean to create a *critical section* ?
   - Which methods are to be used and where exactly do you place them?

Exercise 1.2 Mutexes & Semaphores

What would you need to change in order to use `semaphores` instead? Would it matter?

For each of the two there are **2** main characteristics that hold true. Specify these **2** for both[1].

Exercise 2 Fixing vector

Fix the `Vector` problem twice, once using a `mutex` and secondly using a `semaphore`.

Questions to answer:

- Does it matter, which of the two you use in this scenario? Why, why not?
- Where have you placed the `mutex`/`semaphore` and why and ponder what the consequences are for your particular design solution (*do note that the answer to the below questions do actullay require some thought!*) ?
  - Inside the class - as a member variable?
  - Outside the class - as a global variable, but solely used within the class?
  - In your main cpp file used as a wrapper around calls to the `vector` class?

Exercise 3 Ensuring proper unlocking

The method for data protection in Exercise 2 has one problem namely that the programmer is not *forced* to release the `mutex`/`semaphore` after he updates the shared data. This scenario poses a risc since a `mutex` or a `semaphore` can unintentionally be left in a locked state. This can be rectified by using the *Scoped Locking idiom*.

The idea behind the *Scoped Locking idiom*[2] is that you create a class `ScopedLocker` which is passed a `mutex` (how is it passed a `mutex`? *by value* or *by reference* and why is this important?) on construction. The `ScopedLocker` *takes* the `mutex` object in its constructor and *holds* it until its destruction - thus, it holds the `mutex` as long as it is in scope.

Implement the class `ScopedLocker` and use it in class `Vector` to protect the resource. Verify that this improvement works. You only need to make it work with a `mutex`.

[1] Its **NOT** an explanation but merely a short statement where their properties are described. Whether this is a single statement or 2 points for each is up to you.

[2] This is a specialization of the *RAII - Resource Acquisition Is Initialization idiom*. This idiom is extremely simple but one of the most important you will learn, which is why it will be the focal point of a later lecture.

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Exercise 4 On target

Finally recompile your solution for Exercise 3 for target and verify that it actually works here as well.