

## 333 Section 9 - Concurrency and pthreads

Welcome back to section, we're glad you're here :)

### Boost Library

- Very useful for dealing with strings (HW4!), such as trimming, pattern matching, splitting, replacing, etc.
- `#include <boost/algorithm/string.hpp>`.
- Boost is template madness, so we have some handy reference information here :)

```
// Trim the whitespace off the left and right of to_modify
// to_modify is input and output parameter
void boost::trim(string& to_modify);

// Replace all instances of to_find with to_replace.
// to_modify is input and output parameter
void boost::replace_all(string& to_modify,
                       const string& to_find,
                       const string& to_replace);

// Returns a predicate that matches on any of the characters in tokens
boost::PredicateT boost::is_any_of(const string& tokens);

// Split the string by the characters in match_on
void boost::split(vector<string>& output,
                 const string& input,
                 boost::PredicateT match_on,
                 boost::token_compress_mode_type compress);
```

#### Examples:

```
TRIM: string s(" \t HI \n ");
      boost::algorithm::trim(s); // s == "HI"
```

#### REPLACE\_ALL:

```
string s1("ynrnrt");
boost::algorithm::replace_all(s1, "nr", "e"); // s1 == "yeet"

string s2("queue?");
boost::algorithm::replace_all(s2, "que", "q"); // s2 == "que?"
```

```
SPLIT: string str1("hello abc-*--ABC-*--aBc goodbye");
        vector<string> SplitVec; // #2: Search for tokens
        split(SplitVec, str1, is_any_of("-*"), token_compress_on );
        // SplitVec == { "hello abc", "ABC", "aBc goodbye" }
```

## POSIX threads (pthreads) API

- Part of the standard C/C++ libraries and declared in `pthread.h`.
- **Must compile and link with** `-pthread`.

```
int pthread_create(pthread_t *thread, const pthread_attr_t *attr,  
                  void *(*start_routine) (void *), void *arg);
```

- `thread`: Output parameter for thread identifier
- `attr`: Used to set thread attributes. Use `NULL` for defaults.
- `start_routine`: Pointer to a function that the thread will execute upon creation.
- `arg`: A single argument that may be passed to `start_routine`. `NULL` may be used if no argument is to be passed.
- ★ Creates a new thread and calls `start_routine(arg)`.
- ★ Returns 0 if successful and an error number otherwise.

```
int pthread_join(pthread_t thread, void **retval);
```

- ★ Called by parent thread to wait for the termination of the thread specified by `thread`. If `retval` is non-`NULL`, then `retval` acts as an output parameter and the address passed to `pthread_exit` by the finished thread is stored in it.
- ★ Returns 0 if successful and an error number otherwise.

```
void pthread_exit(void *retval);
```

- ★ Terminates the calling thread with an optional termination status parameter, `retval`, which can just be set to `NULL`.

## POSIX mutual exclusion (mutex) API

- Restrict access to sections of code in order to protect shared data from being simultaneously accessed by multiple threads.

```
int pthread_mutex_init(pthread_mutex_t *mutex,  
                       const pthread_mutexattr_t *attr);
```

- ★ Initializes the mutex referenced by `mutex` with attributes specified by `attr` (use `NULL` for a default attributes).

```
int pthread_mutex_destroy(pthread_mutex_t *mutex);
```

- ★ Destroys (*i.e.* uninitialized) the mutex object referenced by `mutex`.

```
int pthread_mutex_lock(pthread_mutex_t *mutex);
```

- ★ Attempts to acquire the mutex object referenced by `mutex` and blocks if it's currently held by another thread. Should be placed at the start of your critical section of code.

```
int pthread_mutex_unlock(pthread_mutex_t *mutex);
```

- ★ Releases the mutex object referenced by `mutex`. Should be placed at the end of your critical section of code.

**Exercise 1) Consider the following multithreaded C program:**

```
int g = 0;
void *worker(void *ignore) {
    for (int k = 1; k <= 3; k++) {
        g = g + k;
    }
    printf("g = %d\n", g);
    return NULL;
}

int main() {
    pthread_t t1, t2;
    int ignore;
    ignore = pthread_create(&t1, NULL, &worker, NULL);
    ignore = pthread_create(&t2, NULL, &worker, NULL);
    pthread_join(t1, NULL);
    pthread_join(t2, NULL);
    return EXIT_SUCCESS;
}
```

**Give three different possible outputs (there are many)**

**What are the possible final values of the global variable 'g'? (circle all possible)**

0   1   2   3   4   5   6   7   8   9   10   11   12   13   14   15+

**Exercise 2) It's the payday! It's time for UW to pay each of the 333 TAs their monthly salary. Each of the TA's bank accounts is inside the bank\_accounts[] array and the person who is in charge of paying the TAs is a 333 student and decided to use pthreads to pay the TAs by adding 1000 into each bank account. Here is the program the student wrote:**

```
// Assume all necessary libraries and header files are included
const int NUM_TAS = 10;

static int bank_accounts[NUM_TAS];
static pthread_mutex_t sum_lock;

void *thread_main(void *arg) {
    int *TA_index = reinterpret_cast<int*>(arg);

    pthread_mutex_lock(&sum_lock);
    bank_accounts[*TA_index] += 1000;
    pthread_mutex_unlock(&sum_lock);

    delete TA_index;
    return NULL;
}

int main(int argc, char** argv) {
    pthread_t thds[NUM_TAS];
    pthread_mutex_init(&sum_lock, NULL);

    for (int i = 0; i < NUM_TAS; i++) {
        int *num = new int(i);
        if (pthread_create(&thds[i], NULL, &thread_main, num) != 0) {
            /*report error*/
        }
    }

    for (int i = 0; i < NUM_TAS; i++) {
        cout << bank_accounts[i] << endl;
    }

    pthread_mutex_destroy(&sum_lock);
    return 0;
}
```

**(see next page for discussion questions)**

**a) Does the program increase the TAs' bank accounts correctly? Why or why not?**

**b) Could we implement this program using processes instead of threads? Why would or why wouldn't we want to do this?**

**c) Assume that all the problems, if any, are now fixed. The student discovers that the program they wrote is kinda slow even though it's a multithreaded program. Why might it be the case? And how would you fix that?**

### Exercise 3 (Bonus!)

Write a function called `ExtractRequestLine` that takes in a well-formatted HTTP request as a string and returns a map with the keys as `method`, `uri`, `version` and the values from the corresponding request. For example,

#### Example Input:

```
"GET /index.html HTTP/1.1\r\nHost: www.mywebsite.com\r\nConnection: keep-alive\r\nUpgrade-Insecure-Requests: 1\r\n\r\n"
```

#### Map Returned:

```
{  
  "method" : "GET"  
  "uri"    : "/index.html"  
  "version" : "HTTP/1.1"  
}
```

```
map<string, string> ExtractRequestLine(const string& request) {
```

```
}
```