MP4 Overview Session

CS 240 - The University of Illinois

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Goals

In this MP, you will:

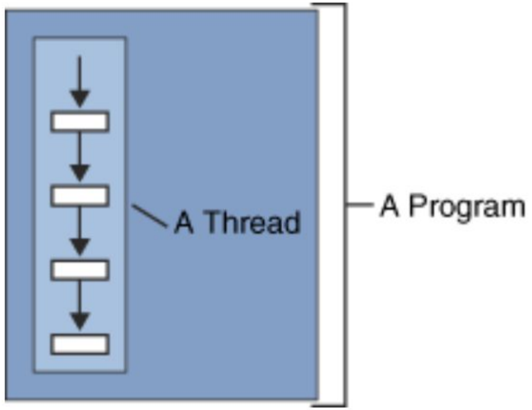
- learn about multithreaded programming in C
- create thread-safe data structure using mutex, condition variable, etc.
- implement a wallet structure that holds resources

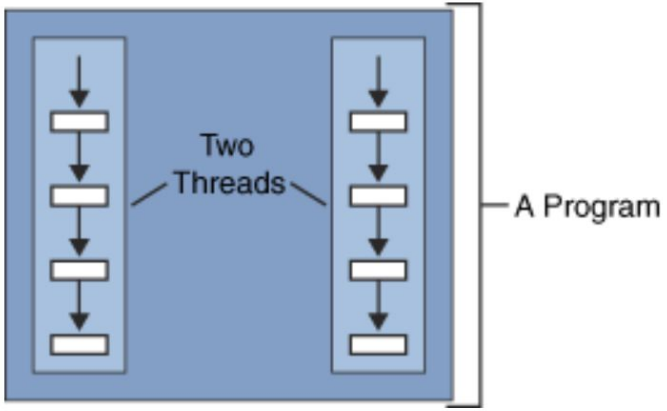
Multithreading

Thread

A thread is a single sequential flow of control within a program

A program can have multiple threads running concurrently



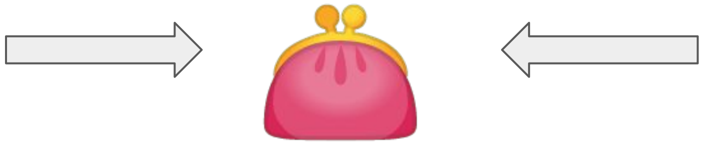


Implement wallet

In this MP, you will create a wallet data structure that will be accessed by multiple threads at the same time

Thread 1:

1. Add 10 🍎
2. Sub 5 ☘️
3. Sub 2 💫



Thread 2:

1. Add 7 ☘️
2. Sub 10 💫
3. Add 1 ✨

Synchronization

Threads should be synchronized to avoid critical resource use conflicts

Race conditions happen when an operation touches a piece of shared memory at the same time as another thread

Critical section: a section of code that can only be executed by one thread at a time if the program is to function correctly.

Race Condition

A wallet 👛 contains 10 ☘️	
Thread 1	Thread 2
access ☘️ (= 10)	access ☘️ (= 10)
☘️ += 5 (10 + 5 = 15)	
	☘️ += 10 (10 + 10 = 20)
☘️ = 20	
☘️ should be 25! (10 + 10 + 5)	

Mutex

Ensure only one thread is inside the critical section at one time

- `pthread_mutex_init` - create a new mutex in the “unlocked” state
- `pthread_mutex_lock` - lock the mutex; if the mutex is already locked by another thread, block execution until the mutex is unlocked
- `pthread_mutex_unlock` - unlock the mutex
- `pthread_mutex_destroy` - destroy the mutex

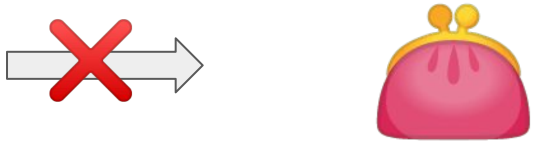
Wallet resource

A user will interact with your wallet by adding/subtracting resources to/from it

You must not allow the wallet to ever go negative. The function must wait until there are enough resources to subtract from

Thread 1:

Sub 50 ✨



(contain 10 ✨)

Wallet resource

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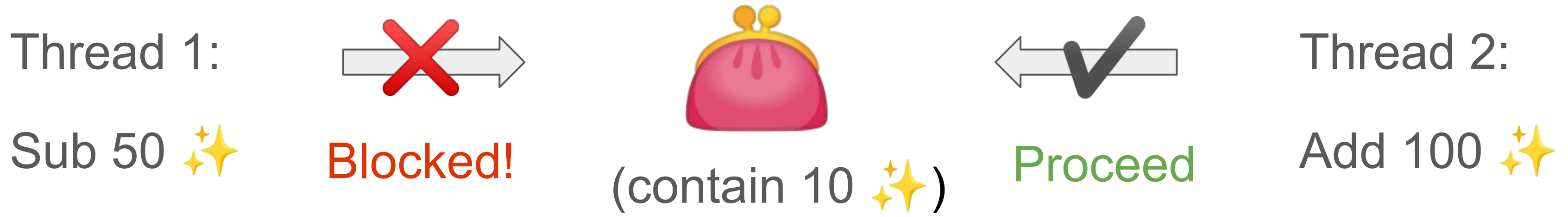

Wallet resource

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You must not allow the wallet to ever go negative. The function must wait until there are enough resources to subtract from

Thread 1: ✓ 👛

Sub 50 ✨ Proceed (contain 110 ✨)

Avoid Busy Waiting

A naive approach: repeatedly check if the condition is satisfied in a loop before proceeding with its execution

It is considered bad practice because

1. errors may occur due to race conditions
2. system resources are wasted

```
// DON'T DO THIS!
while (condition not met) {
    sleep for a little
    wake up and check again
}
```

Condition Variable

Condition variables allow a set of threads to sleep until woken up

- `pthread_cond_init` - create a new condition variable
- `pthread_cond_wait` - release mutex and cause the calling thread to block on the condition variable
- `pthread_cond_signal` - unblock at least one thread that is blocked on the condition variable

Condition Variable

Condition variables allow a set of threads to sleep until woken up

- `pthread_cond_broadcast` - unblock all threads that are blocked on the condition variable
- `pthread_cond_destroy` - destroy the condition variable

Spurious Wakeup

Occasionally, a waiting thread may appear to wake up for no reason. This is called a spurious wakeup.

It usually happens due to race condition, where another thread changes the condition before the waiting thread finally runs

You want to call `pthread_cond_wait` on the thread again if that happens

```
// mutex is locked
...
while(condition not met)
{
    pthread_cond_wait();
}
// condition is met
```

Resource Manager

structs in wallet

In your *lib/wallet.h*:

- *wallet_t* - maintain the state of a wallet
- *wallet_resource* - represent the resource in a wallet

Add any additional variable you may need

Example 👛: 10 ☘️ → 2 💎 → 1 🧰

functions in wallet

Implement these functions in *lib/wallet.c*:

- *wallet_init* - initialize the wallet
  - the wallet starts out empty, with 0 of all resources
- *wallet_get* - return the amount of a given resource
  - ensure accesses to your wallet are properly synchronized

functions in wallet

Implement these functions in *lib/wallet.c*:

- *wallet_change_resource* - change the amount of a resource by a certain *delta*
  - the resource amount cannot go negative
  - must wait until the request can be satisfied (e.g. another thread add to the resource)
- *wallet_destroy* - destroy a wallet and free any memory associated with it

Question