Recruiter: could you give me an example of deadlock situation?

Programmer: Hire me and then I'll tell you

Lab 10: Monitors

CS 2112 Fall 2020

November 30 / December 2, 2020

Threads

- Multiple threads may execute within the same program
- This is called called multithreading

Race Conditions

```
1  class TugOfWar {
2    int position = 0;
3    void pullLeft() {
4      position--;
5    }
6    void pullRight() {
7      position++;
8    }
9  }
```

If thread 1 runs `pullLeft()` a thousand times and thread 2 runs `pullRight()` a thousand times, where does the rope end up?

Locks

A lock, or a mutex (mutual exclusion object), is a mechanism that stops multiple threads from executing code at the same time.

Think of the lock as a physical object. Only one thread is allowed to "hold" the lock at any one point in time. Pass the lock object to the `synchronized` keyword to acquire it. Java automatically releases the lock at the end of the block.

```
1 public void run() {
2     synchronized(mutex) {
3         // Do unsafe mutable operation
4     }
5 }
```

Using Mutexes

Note that the existence of a lock does not inherently protect your data. It's the job of the programmer to make sure that any unsafe calls acquire the mutex first.

A common pattern is to keep unsafe variables as private instance variables inside a class, and then enforce all accesses to those variables through publicly exposed methods in the class.

Java Mutexes

Java allows any object to be used as a mutex.

Since the common use case involves keeping all lock acquisitions inside one object, it's customary to use `this` as the lock.

```
1 public void safeMethod() {
2     synchronized(this) {
3         // Do unsafe mutable operation
4     }
5 }
```

Since this is so common, using the `synchronized` keyword in the method header is syntactic sugar for the same.

```
1 public synchronized void safeMethod() {
2     // Do unsafe mutable operation
3 }
```

Busy-Waiting

What happens if your multi-threaded code needs to wait on some condition being true?

One Solution:

```
1 synchronized public void waitingMethod() {
2     while(!condition) {  }
3     // Do thing requiring condition
4 }
```

Do you see any problems with this?

Why Busy-Waiting Sucks

- Wastes CPU cycles
- Can cause deadlocks* if you hold a mutex

- It's bad

* Remember that a deadlock is when two threads both hold one lock and are both waiting on a lock held by each other

Condition Variables

High Level Overview:

Mechanism for a thread to release its lock and wait on a condition. Automatically reacquire the lock when the condition becomes true.

Theoretically, you can have one condition variable for every condition you want to wait on.

Condition Variables in Java

Java only allows one condition variable per object.

You can call the following methods from the Object API:

```
1 public void wait() // Makes this thread wait
2 public void notify() // Wake up one waiting thread
3 public void notifyAll() // Wake up all waiting threads
```

These methods can only be called by a thread that currently owns the object's lock.

Using Monitors

A couple of best practices:

- You should wrap your `wait` commands inside a `while` loop, since you might want to wait on multiple conditions.

```
1 while(!condition1 || !condition2) {
2     wait();
3 }
```

- Call `notifyAll()` instead of `notify()` unless you have a very good reason to only wake up one thread, since there's no guarantee which thread is woken up.

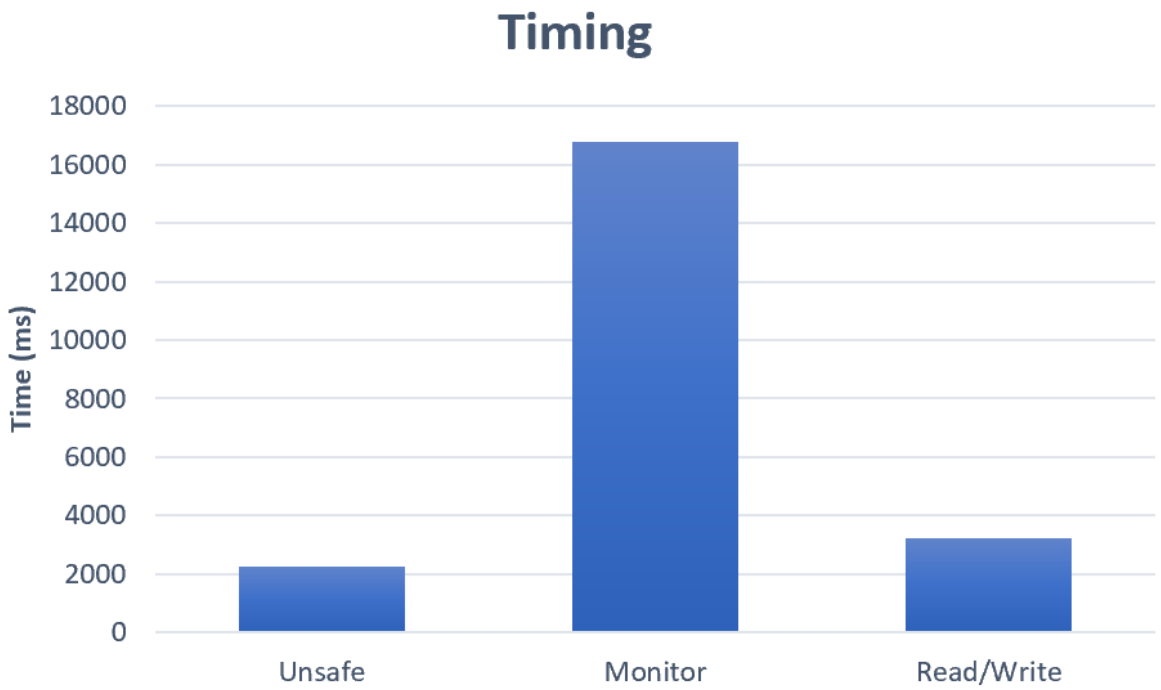
Reentrant Locks

- Reentrant locks allow a single thread to acquire the same lock multiple times
- This allows one synchronized method to call another on the same object without getting stuck
- Each mutex keeps track of the number of times the thread has acquired the mutex and is only released once the holding thread releases it the same number of times.

Read / Write Locks

- Any number of readers can hold the lock.
- Only one writer can hold it.
- Readers can starve out writers, so we need to stop new readers from joining when writers show up.

Performance



Exercise

Download the lab code and import it into Eclipse (no Gradle :D)
Run `MatrixTest.java` with the argument `unsafe`, `monitor`, or `rwlock` to run a bunch of threads without locks, with a normal lock, or with a read-write lock, respectively.
Your task is to implement all the `TODOs` in `RWLock.java`.

Variables:
`num_readers` - Number of readers currently with the lock
`num_writers_waiting` - Number of writers waiting for the lock
`held_count` - Number of times the writer has held this lock
`writer` - The writer with the lock, or null