CS 111 assign5 YEAH Hours:
Thread Dispatcher / Locks / CVs

Overall Task

- **The threads you've been using so far are implemented by Linux ("system threads")**
- **This project: use one system thread to implement any number of simulated threads**
- **Also implement your own mutex and condition variable types**

Assignment Overview

- Part 1: Dispatcher
- Part 2: Mutex
- Part 3: Condition

Thread Class

`Thread(std::function<void()> main)`

- Constructor: runs `main` as the top-level function in the thread

`void schedule()`

- Add the associated thread to the back of the ready queue

`void Thread::redispatch()`

- Run a different thread; current thread will block if it hasn't been scheduled.

`void Thread::exit()`

- Terminate current thread

`void Thread::yield()`

- Invoke `schedule()` followed by `redispatch()`; allows other threads to run

`Thread* Thread::current()`

Class Static Variables

```
class Foo {
    int x;
    int y;
    static int z;
}
```

z: 87

Foo
```
x: 24
y: 13
```

Foo
```
x: 18
y: 7
```

Foo
```
x: 199
y: 62
```

Instance variables: one in each instance of object

Static variable: one variable, shared across all instances

Class Static Methods

```
class Foo {
public:
    method1(int x);
    static method2(char *s);
}

Foo f1;

f1.method1(14);

Foo::method2("xyzzy");
```

Normal method:

- Invoked on object instance
- Can access instance variables

Static method:

- Not associated with a particular instance
- No `this` variable accessible in method
- Can access static variables

Example: static.cc

```
class Demo {
public:
    Demo();
    ~Demo();
    static int num_live();
private:
    static int live_objects;
};

int Demo::live_objects = 0;

Demo::Demo() {
    live_objects++;
}

Demo::~Demo() {
    live_objects--;
}

int Demo::num_live() {
    return live_objects;
}
```

```
int main(int argc, char **argv)
{
    std::cout << "Initial number of live objects: “
                << Demo::num_live() << std::endl;

    Demo *d1 = new Demo();
    Demo *d2 = new Demo();
    Demo *d3 = new Demo();

    std::cout << "New number of live objects: “
                << Demo::num_live() << std::endl;

    delete d2;
    delete d3;

    std::cout << "Live objects after deleting 2: “
                << Demo::num_live() << std::endl;

    delete d1;
}
```

Managing Stacks

- **Stack class created for you to use:**

```
Stack(void(*start)(Thread *), Thread *t);
void stack_switch(Stack *current, Stack *next);
```

- **Stack object holds:**
  - Space for call stack
  - Place to save stack pointer when stack isn't active
- **Constructor takes a function as argument**
  - This function will be invoked the first time the stack is activated via `stack_switch`
  - Passed the specified thread as a parameter when it is called
- **`stack_switch` does a context switch**
  - Save registers on current stack
  - Save sp in `current`
  - Load sp from `next`
  - Restore registers from new stack
  - Return in new context

Preemption

```
void timer_init(uint64_t usec, std::function<void()> handler);
void intr_enable(bool on);
class IntrGuard;
```

- **Preemption requires interrupts**
- **`timer_init` causes timer handler to be called periodically**
- **For safety, need to disable interrupts when touching data shared by multiple threads**
- **`IntrGuard` makes it easy to disable interrupts**
  - Creating an `IntrGuard` object saves current state, disables interrupts
  - Destroying the `IntrGuard` restores interrupts to original state
  - Similar to `std::unique_lock`

Timer lecture example: interrupt.cc

```
void timer_interrupt_handler() {
    cout << "Timer interrupt occurred“ << endl;
}

int main(int argc, char *argv[]) {
    timer_init(500000, timer_interrupt_handler);
    while (true) {}
}
```

Disabling interrupts: interrupt2.cc

```
/* Atomic is a quick short cut here to make counter atomic for operations like
 * incrementing without having to worry about race conditions.
 */
atomic<size_t> counter(0);

void timer_interrupt_handler() {
    cout << "Timer interrupt occurred with counter “ << counter << endl;
}

int main(int argc, char *argv[]) {
    int toggle_interval = 1'000'000'000;
    size_t next_toggle = toggle_interval;

    timer_init(500000, timer_interrupt);
    while (true) {
        counter++;

        if (counter >= next_toggle) {
            intr_enable(!intr_enabled());
            next_toggle += toggle_interval;
        }
    }
}
```

Assignment Overview

- **Part 1: Dispatcher**
- **Part 2: Mutex**
- **Part 3: Condition**

Classes to Implement

```
class Mutex {
public:
    void lock();
    void unlock();
    bool mine();
};
```

```
class Condition {
public:
    void wait(Mutex &m);
    void notify_one();
    bool notify_all();
};
```

- **Similar to `std::mutex` except:**
  - Additional method `mine`: indicates whether caller owns Mutex
- **Similar to `std::condition_variable_any` except:**
  - Argument to `wait` is `Mutex`, not `std::unique_lock` or `std::mutex`

Uniprocessor Locks from Lecture

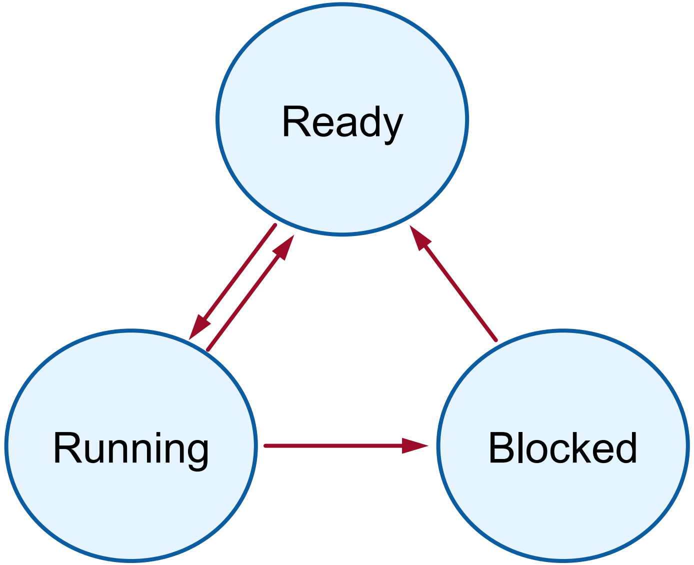
```
class Lock {
    Lock() {}
    int locked = 0;
    ThreadQueue q;
};

void Lock::lock() {
    IntrGuard guard;
    if (!locked) {
        locked = 1;
    } else {
        q.add(currentThread);
        blockThread();
    }
}
```

```
void Lock::unlock() {
    IntrGuard guard;
    if (q.empty() {
        locked = 0;
    } else {
        unblockThread(q.remove());
    }
}
```

Blocking Threads

- When new thread created, which state is it in?
- How do we know if thread is ready?
- How can we tell if thread is running?
- How does running thread block itself? Call `Thread::yield()`?
- Once thread blocks, how to find it to wake it up?
- What if `thread->schedule()` is never called for blocked thread?



Project Notes

- Implementation of `Condition` is similar to `Mutex`
- Use `IntrGuard` objects to disable interrupts
- Use only public methods of `Thread` class
- The `Condition` class should use only public methods of `Mutex`

Sample Test: mutex_basic

```
Mutex m;

void basic_thread1()
{
    m.lock();
    std::cout << "thread 1 yielding while holding lock" << std::endl;
    Thread::yield();
    std::cout << "thread 1 yielding again while holding lock" << std::endl;
    Thread::yield();
    std::cout << "thread 1 releasing lock then trying to reacquire" << std::endl;
    m.unlock();
    m.lock();
    std::cout << "thread 1 reacquired lock" << std::endl;
}

void basic_thread2()
{
    std::cout << "thread 2 attempting to lock" << std::endl;
    m.lock();
    std::cout << "thread 2 acquired lock; now unlocking" << std::endl;
    m.unlock();
}
```

Sample Test: mutex_basic

```
void
mutex_basic_test()
{
    new Thread(basic_thread1);
    new Thread(basic_thread2);
    intr_enable(false);
    Thread::redispatch();
}
```