Threads

Ch 9

Motivation

- Create GUI for program which finds primes
  - Using very slow algorithm:
    ~20 seconds to find a prime.
  - Want UI to be responsive while computing primes.

- Demo: ThreadDemoUI.java (ca.threads.primeui)
  1) Single threaded:..
  2) Background thread:..
  3) Many threads:..

Topics

1) How can our program do 2 things at once?
2) Does doing 2 things at once cause problems?

Thread Basics:
Runnable & Thread

Running Task

1) Create a Task:..

Must implement Runnable:

```
public interface Runnable {
    void run();
}
```

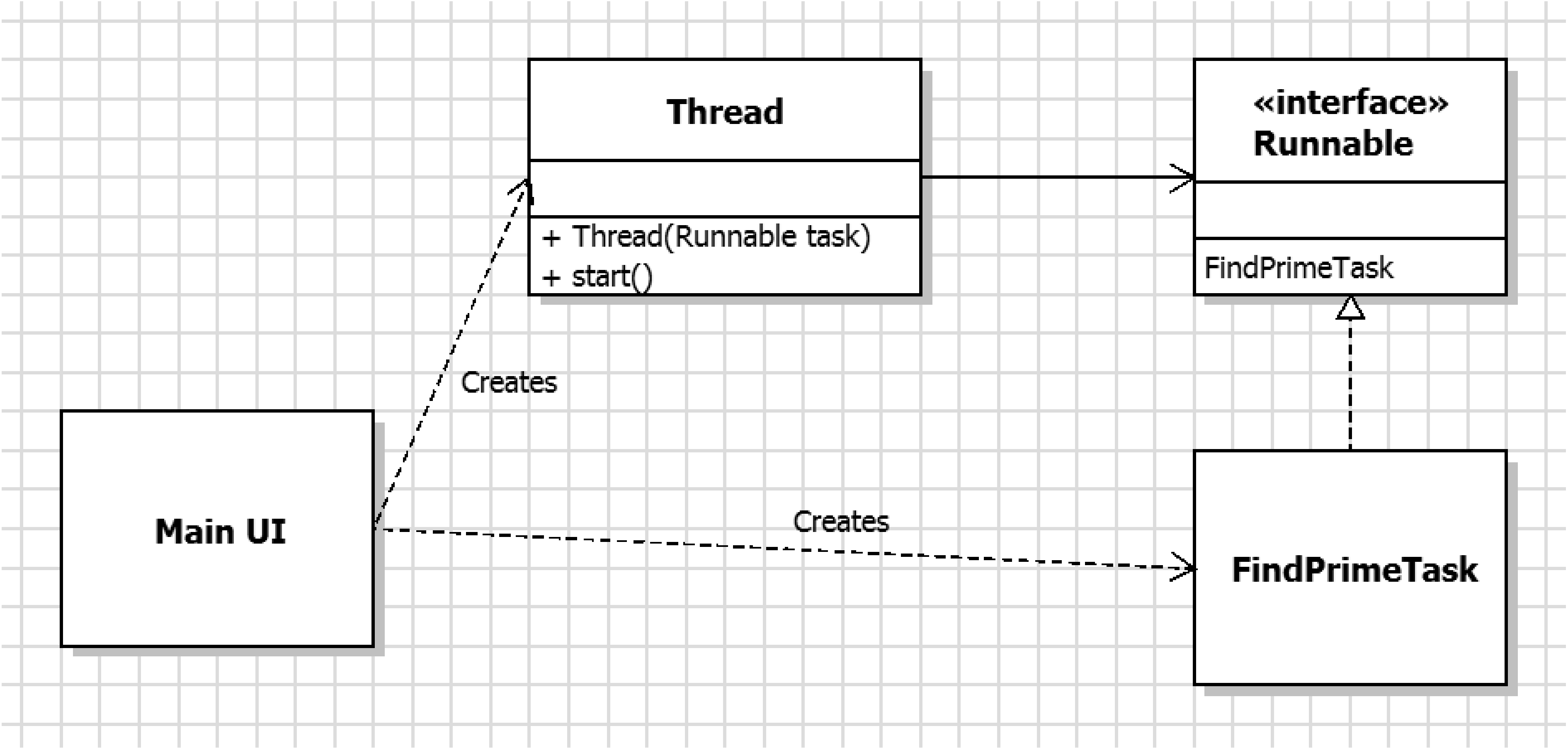
```
class MyAmazingTask implements Runnable {
    @Override
    public void run() {
        // Calculate something amazing here!
    }
}
```

2) Create a..

```
public void main(String[] args) {
    Runnable myTask = new MyAmazingTask();
    Thread myThread = new Thread(myTask);
    myThread.start();
```

! PrimeTest.java

UML for Prime Demo



Code: PrimeTest.java

Timing

- Time Slice:
  a block of time during which..
  - OS/JVM allocates time-slices to threads.
- Not always equal:
  - Starvation: a task given..
  - Fairness: Often use round-robin scheduling.
  - Priority: Some threads higher priority than others.
- UI Demo:
  - 10 threads computing if same number is prime.

    Will not all..

Suspending a Thread

- Can briefly suspend a thread with..
  - delay is in milliseconds (1/1000 second)
  - can throw InterruptedException

```
private static final long DELAY_MS = 1000;

@Override
public void run() {
    try {
        while (true) {
            System.out.println(“Hello!”);
            Thread.sleep(DELAY_MS);
        }
    } catch (InterruptedException e) {
        // Handle end of task here.
    }
}
```

Thread Synchronization

Image: http://www.shutterstock.com/portfolio/search.mhtml?gallery_landing=1&page=1&gallery_id=138331

Thread Interactions

- Race condition
  - Effect of multiple threads on shared data depends on..
  - Demo: MathDemo
- Cause
  - The execution of one thread is interrupted by another thread.
  - Second thread disturbs or corrupts operation of initial thread.
- Critical Section
  - A portion of a thread's execution where..

MathDemo Analysis

One possible scenario:

Thread 1:

Thread 2:

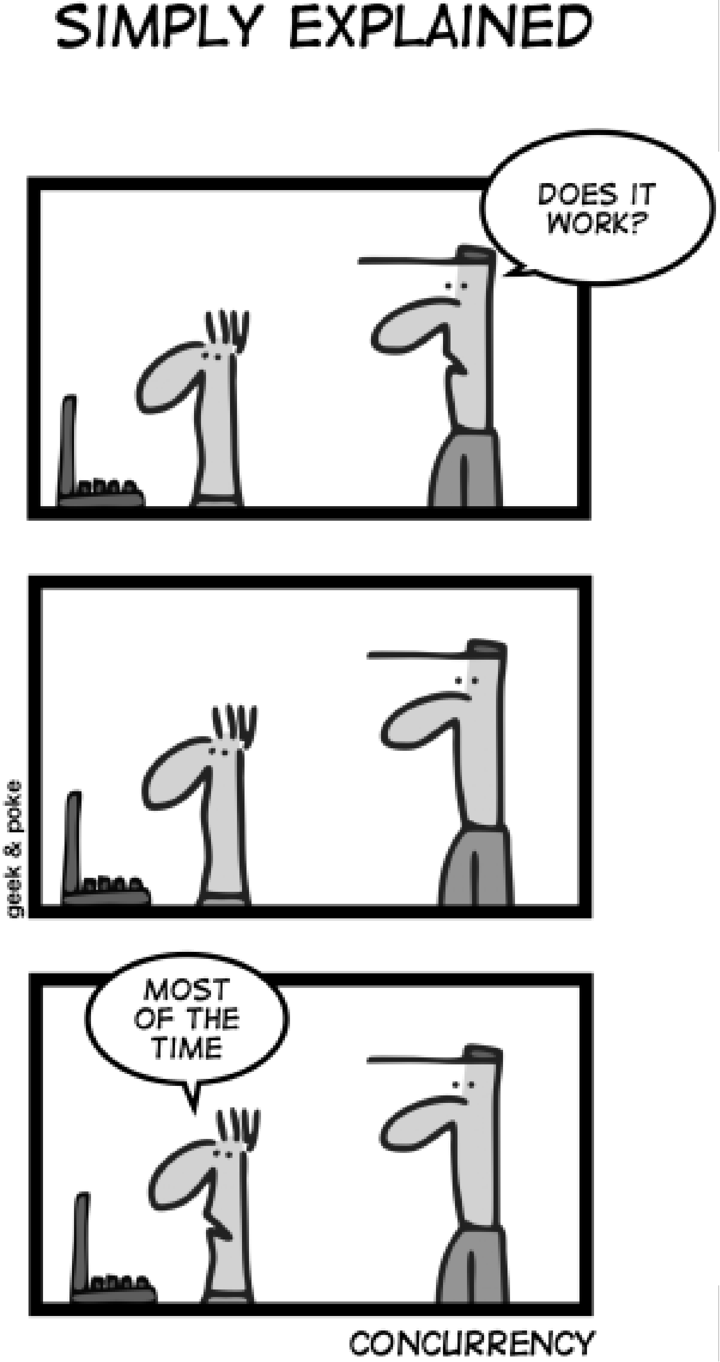
```
volatile private int number;

public int compute(int newValue) {
    number = newValue;

    int result = 0;
    for (int i = 0; i < NUM_STEPS; i++) {
        result += number;
    }
    for (int i = 0; i < NUM_STEPS; i++) {
        result -= number;
    }
    return result;
}
```

Heisenbug

- Race Condition Solution
  - Thread Safe: No race conditions.
  - How? Use locks.
- Aside: Non-reproducable bugs
  - Dependent on subtle timing events
  - Heisenbug: A bug who's behaviour is..
  - Debugging can change thread timing, changing the behaviour.
  - VERY tricky bugs to find!



Locks

- Process:
    1. Create a lock for access to some resource
       (such as a variable, file, printer, ...)
    2. Lock the lock before accessing resource.
    3. Use resource
    4...

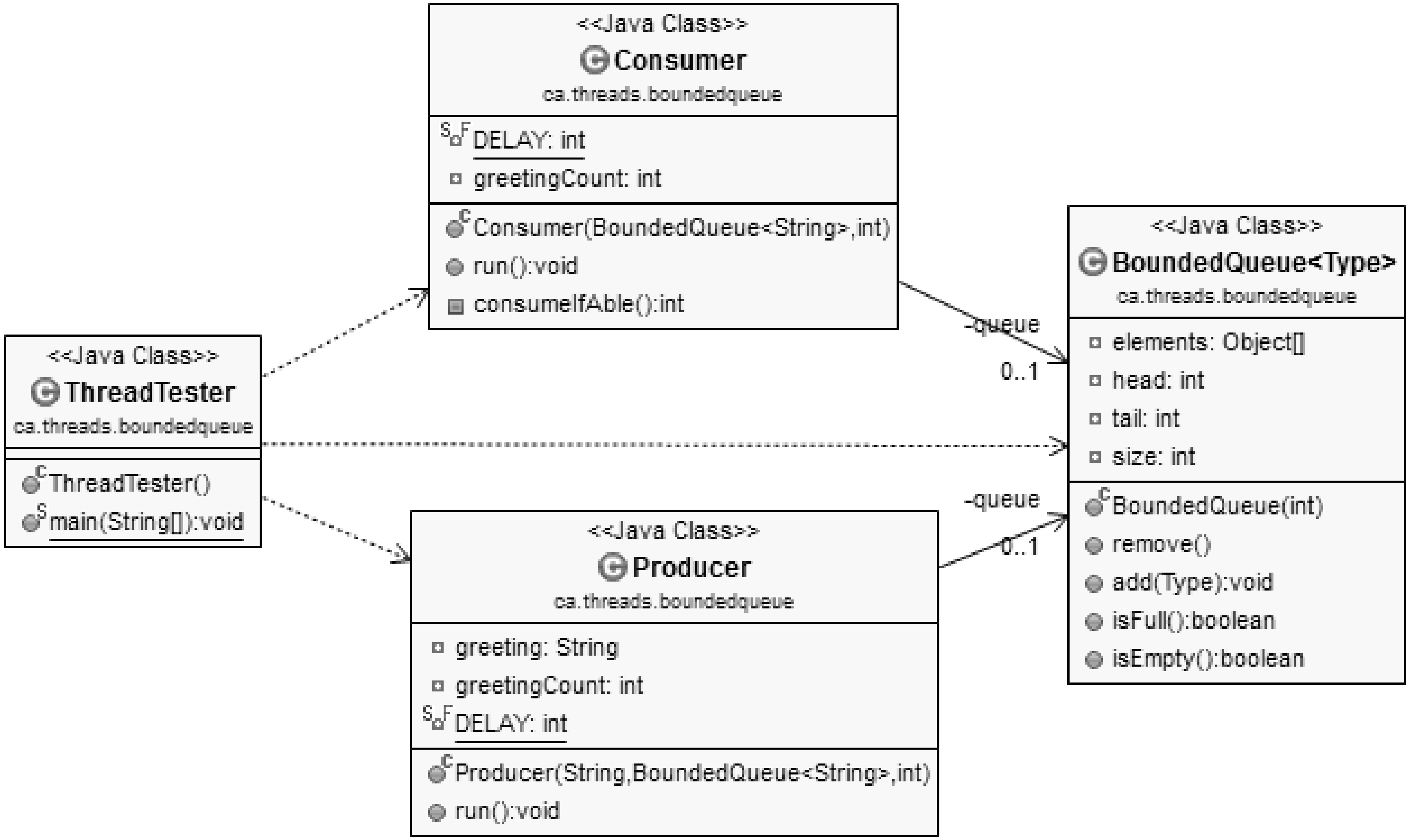
```
class LockExample {
    private ReentrantLock myLock = new ReentrantLock()
    public void foo() {
        myLock.lock();
        try {
            // Protected critical section
            // ... do stuff here
        } finally {
            myLock.unlock();
        }
    }
}
```

No other thread can execute this code while this thread has it locked.

Locking Example

- Dealing with a shared queue.
  - threads adding data to a bounded queue
    - Ex: calculating prime numbers.
  - thread removing data from a bounded queue
    - Ex: printing out the prime numbers.
- Thread Synchronization Problem
  - Two producers may interfere with each other.
  - Consumer and producer may interfere.
- Thread safe:..

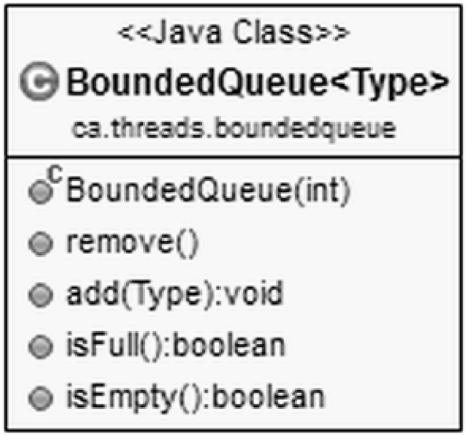
Producer / Consumer UML



Producer / Consumer

```
public class Producer implements Runnable {
    // Passed the queue from main()
    private BoundedQueue<String> queue;

    public void run() {
        while (..) {
            if (!queue.isFull()) {
                queue.add("Hello");
            }
            Thread.sleep(...);
        }
    }
}
```



```
public class Consumer implements Runnable {
    // Passed the queue from main()
    private BoundedQueue<String> queue;

    public void run() {
        while (...) {
            if (!queue.isEmpty()) {
                String msg = queue.remove();
                System.out.println(msg);
            }
            Thread.sleep(...);
        }
    }
}
```

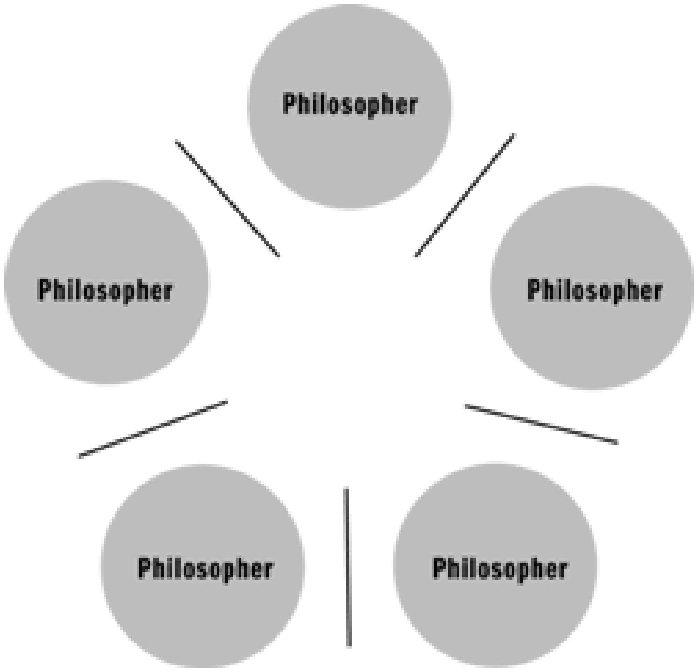
Note: Exception handling removed.

Demo: ...boundedqueue.ThreadTester.java

Deadlock

- Deadlock:
  if no thread can proceed because..

- Ex: Dining Philosophers
  - Philosophers are either:
    - Thinking or
    - Eating
  - To eat, a philosopher needs..
  - How can deadlock happen?
  - How to resolve?



Stopping a Thread

- Thread normally ends when..
- Can end a running thread (vs letting it finish):
  - *Notify* thread of interruption with:

    ```
    Runnable myTask = new MyAmazingTask();
    Thread myThread = new Thread(myTask);
    myThread.start();

    // ... Later, when thread not needed:
    myThread.interrupt();
    ```

  - Interrupted thread knows it's interrupted by:
    - If in a Thread.sleep(), it throws exception.
    - Manually check the interrupted flag:
      `if (Thread.currentThread().isInterrupted()) {...}`

Summary

- Process
  - Create a task: Implement Runnable
  - Create a thread: pass it a runnable, call start()
  - Interrupt with myThread.interrupt()
- Race Condition: Threads may interfere
  - Solution: locks
- Common Examples
  - Produce/Consumer
  - Dining Philosophers
    - Deadlocks: Threads waiting on each-other.