COMP 322: Fundamentals of Parallel Programming

Lecture 25: Java Threads,Java synchronized statement

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Unit 7.1: Java Threads (Recap)

- Execution of a Java program begins with an instance of Thread created by the Java Virtual Machine (JVM) that executes the program's main() method.
- Parallelism can be introduced by creating additional instances of class Thread that execute as parallel threads.

```
public class Thread extends Object implements Runnable {
  Thread() { ... } // Creates a new Thread
  Thread(Runnable r) { ... } // Creates a new Thread with Runnable object r
  void  run() { ... } // Code to be executed by thr
   // Case 1: If this thread was c
   //         then that object's run method
   // Case 2: If this class is subclassed, t
   //         in the subclass is called
  void start() { ... } // Causes this thread to st
  void join() { ... } // Wait for this thread to die
  void  join(long m) // Wait at most m milliseconds for thread to die
  static Thread currentThread() // Returns currently executing thread
  . . .
}
```

A lambda can be passed as a Runnable

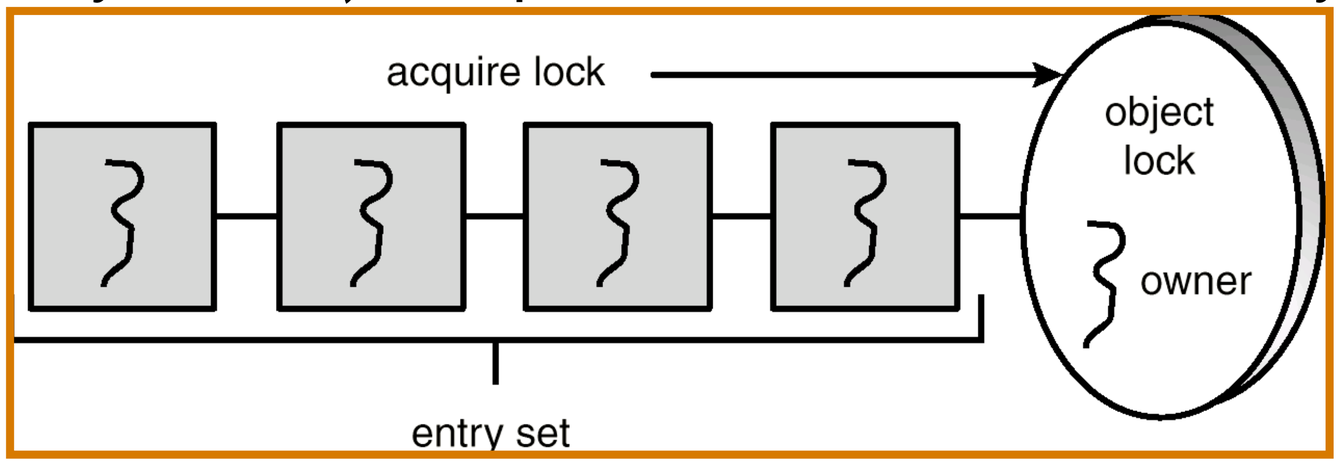
Listing 3: java.lang.Thread class

Unit 7.2: Objects and Locks in Java --- synchronized statements and methods (Recap)

- Every Java object has an associated *lock* acquired via:
  - `synchronized` statements
    - synchronized(foo) { // acquire foo's lock
      // execute code while holding foo's lock
      } // release foo's lock
  - `synchronized` methods
    - public synchronized void op1() { // acquire 'this' lock
      // execute method while holding 'this' lock
      } // release 'this' lock
- Java language does not enforce any relationship between object used for locking and objects accessed in isolated code
  - If same object is used for locking and data access, then the object behaves like a monitor
- Locking and unlocking are automatic
  - Locks are released when a synchronized block exits
    - By normal means: end of block reached, return, break
    - When an exception is thrown and not caught

Implementation of Java synchronized statements/methods

- Every object has an associated lock
- "synchronized" is translated to matching monitorenter and monitorexit bytecode instructions for the Java virtual machine
  - monitorenter requests "ownership" of the object's lock
  - monitorexit releases "ownership" of the object's lock
- If a thread performing monitorenter does not gain ownership of the lock (because another thread already owns it), it is placed in an unordered "entry set" for the object's lock



Monitors – a Diagrammatic summary

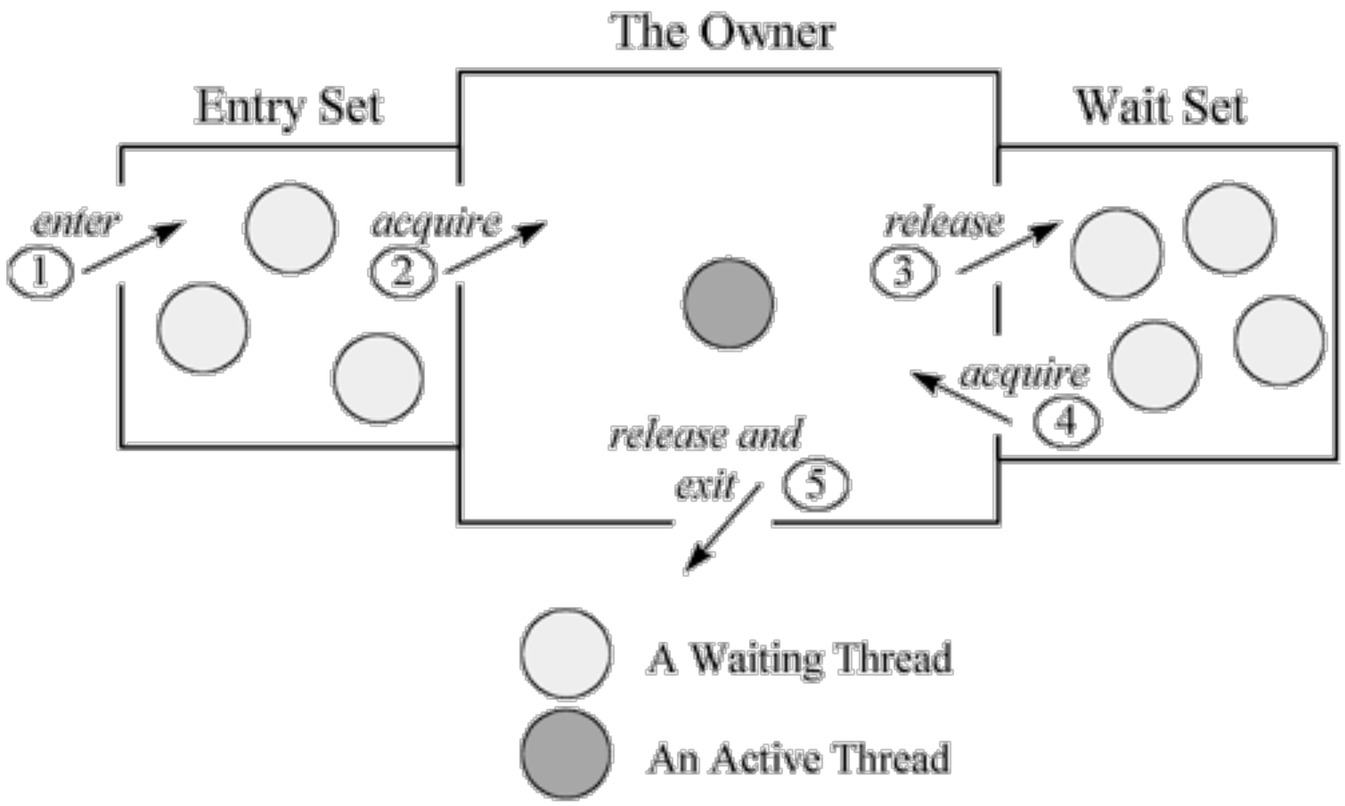


Figure 20-1. A Java monitor.

Figure source: http://www.artima.com/insidejvm/ed2/images/fig20-1.gif

What if you want to wait for shared state to satisfy a desired property? (Bounded Buffer Example)

```
public synchronized void insert(Object item) { // producer
    // TODO: wait till count < BUFFER SIZE
    ++count;
    buffer[in] = item;
    in = (in + 1) % BUFFER SIZE;
    // TODO: notify consumers that an insert has been performed
}

public synchronized Object remove() { // consumer
    Object item;
    // TODO: wait till count > 0
    --count;
    item = buffer[out];
    out = (out + 1) % BUFFER SIZE;
    // TODO: notify producers that a remove() has been performed
    return item;
}
```

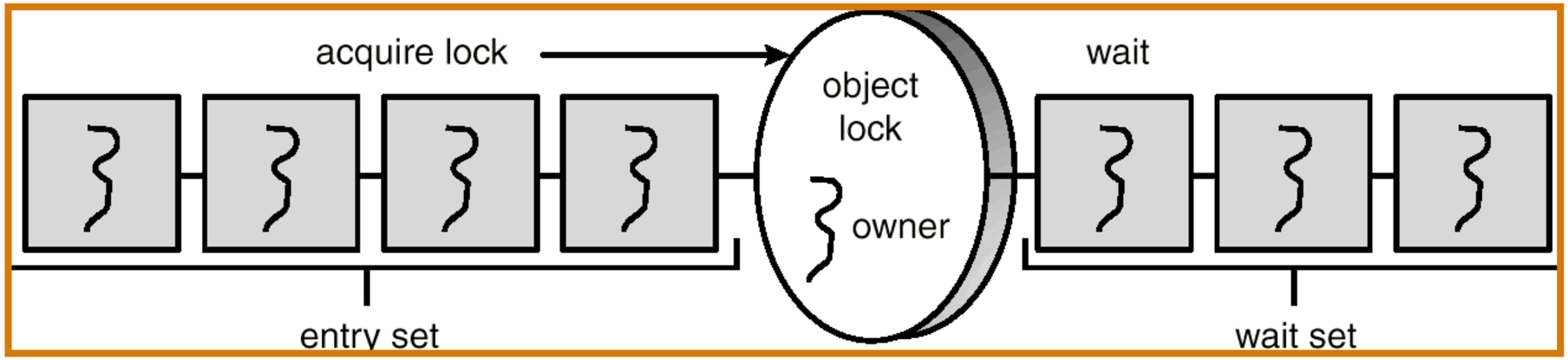
The Java wait() Method

- A thread can perform a wait() method on an object that it owns:
  1. the thread releases the object lock
  2. thread state is set to blocked
  3. thread is placed in the wait set
- Causes thread to wait until another thread invokes the notify() method or the notifyAll() method for this object.
- Since interrupts and spurious wake-ups are possible, this method should always be used in a loop e.g.,

```
synchronized (obj) {
    while (<condition does not hold>)
        obj.wait();
    ... // Perform action appropriate to condition
}
```

- Java's wait-notify is related to "condition variables" in POSIX threads

Entry and Wait Sets



The notify() Method

When a thread calls notify(), the following occurs:

1. selects an arbitrary thread T from the wait set
2. moves T to the entry set
3. sets T to Runnable

T can now compete for the object's lock again

Multiple Notifications

- notify() selects an arbitrary thread from the wait set.
  - This may not be the thread that you want to be selected.
  - Java does not allow you to specify the thread to be selected
- notifyAll() removes ALL threads from the wait set and places them in the entry set. This allows the threads to decide among themselves who should proceed next.
- notifyAll() is a conservative strategy that works best when multiple threads may be in the wait set

insert() with wait/notify Methods

```
public synchronized void insert(Object item) {
    while (count == BUFFER SIZE) {
                try {
                        wait();
                }
                catch (InterruptedException e) { }
    }
    ++count;
    buffer[in] = item;
    in = (in + 1) % BUFFER SIZE;
    notify();
}
```

remove() with wait/notify Methods

```
public synchronized Object remove() {
    Object item;
    while (count == 0) {
                try {
                        wait();
                }
                catch (InterruptedException e) { }
    }
    --count;
    item = buffer[out];
    out = (out + 1) % BUFFER SIZE;
    notify();
    return item;
}
```

Complete Bounded Buffer using Java Synchronization

```
public class BoundedBuffer implements Buffer
{
    private static final int BUFFER SIZE = 5;
    private int count, in, out;
    private Object[] buffer;
    public BoundedBuffer() { // buffer is initially empty
                count = 0;
                in = 0;
                out = 0;
                buffer = new Object[BUFFER SIZE];
    }
    public synchronized void insert(Object item) { // See previous slides
    }
    public synchronized Object remove() { // See previous slides
    }
}
```

Announcements

- The entire written + programming (Checkpoint #2) is due by Monday, April 5th at 11:59pm
- Lab 6 is due Tuesday, April 6th at 12pm (noon)

Worksheet #25: Bounded Buffer

Consider the case when multiple threads call insert() and remove() methods concurrently for a single BoundedBuffer instance with SIZE >= 1.

1) Can you provide an example in which the wait set includes a thread waiting at line 2 in insert() and a thread waiting at line 11 in remove(), in slide 8? If not, why not?

2) How would the code behave if all wait/notify calls (lines 2, 6, 11, 15) were removed from the insert() and remove() methods in slide 8?