Monitors in Java

Model and Examples

Threads

A “thread”

- represents an independent activity
  - •animations (one thread is performing the animation while another thread is responding to the user)
  - •servers (separate threads are created for each client)
- is separately scheduled by the system
- can manipulated by the program
- coexists with other threads in the same address space

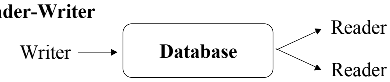
Motivations for Using Threads

- performance (on multiprocessor machines)
- simplicity (direct modeling of autonomous events)
- availability(unblocked threads can make progress)
- controllability (start/stop threads as needed)
- asynchrony (thread can block without halting program)
- required (by some Java services)

Classical Problems

Producer - Consumer

Reader-Writer



Java as a Concurrency Programming Language

- •Language features:
  - threads class and synchronization constructs
  - platform independent
- Libraries for basic network programming
  - sockets/URL
  - Remote Method Invocation (RMI)
- •Used to implement distributed agent systems
  - Aglets
  - Voyager
  - Odyssey

Java Threads

Thread class:

- •extends Object class
- •implements Runnable interface

Attributes of a thread:

- •target - in what object it will begin execution
- •name - for identification by program
- •group - of which it is a member
- •priority - for scheduling

Thread Basics

Operations performed on a thread:

- •start - begin execution
- •stop - end execution (deprecated)
- •suspend - await resumption (deprecated)
- •resume - awake suspended thread (deprecated)
- •interrupt - cause exception to be thrown

Operations performed by a thread:

- •sleep - dormant for specified time period
- •yield - allow scheduler to select among ready threads
- •join - await completion of another thread
- •wait - delay until notified
- •notify/notifyAll - awaken one/all waiting threads

Application-Specific Threads

There are two ways of defining a thread to perform application specific activities by creating a class that:

- extends the Thread class using inheritance
- implements the Runnable interface

In each case, the application specific class defines a run() method where execution of the thread begins.

Extending the Thread Class

```
public class Worker extends Thread
{ …
   public void run()      //defines where thread will begin
   { // code for worker
   }
}


public class Boss
{  private worker Worker;
   …
   public startWorker()
   { worker = new Worker();
     worker.start();
   }
}
```


Implementing the Runnable Interface

```
public class Worker implements Runnable
{ …
   public void run()      //defines where thread will begin
   { // code for worker
   }
}


public class Boss
{  private thread workerThread;
   …
   public startWorker()
   { Worker worker = new Worker();
     workerThread = new Thread(worker);
     workerThread.start();
   }
}
```


Forms of Synchronization

- mutual exclusion - preventing concurrent access to shared objects to preserve the consistency of the object
- condition synchronization - blocking attempted operations on a shared object until that object is in a state where the operation will preserve the consistency of the object (Monitor model)

Mutual Exclusion

The synchronized keyword can be used to:

- provide mutual exclusion among methods of the same object
- provide mutually exclusive ownership of an object

Mutual exclusion is needed to insure the consistency of the state of objects that can be accessed by multiple threads.

Synchronized Methods

```
public class Value
{ private int current;

  synchronized public void increment()
  { current = current + 1;
  }

  synchronized public void decrement()
  { current = current - 1;
  }
  public int current()
  { return current
  }
}
```


Mutually Exclusive Ownership

Employee worker; // shared object

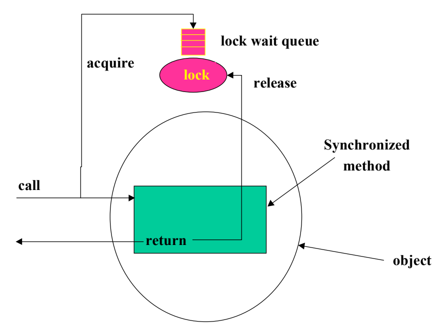
synchronized(worker)
{ // access and output
// worker information
}

synchronized(worker)
{ // update worker
// information
}

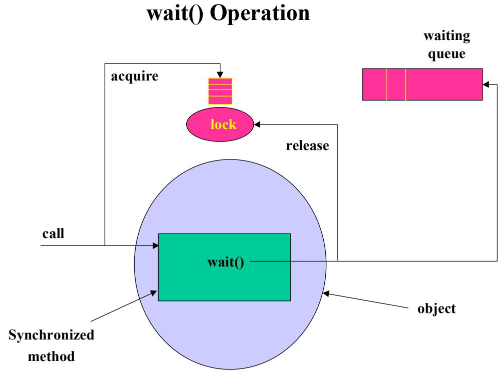
Monitors in Java

- every object has a single lock and a waiting queue
- synchronized methods acquire the lock before executing
- the wait() operation suspends the executing thread on the object's waiting queue and releases the object's lock
- the notify() operation awakens exactly one thread suspended on the object's waiting queue but does not release the lock
- the notifyAll() operation awakens all threads suspended on the object's waiting queue but does not release the lock
- wait, notify, and notifyAll must be in synchronized methods
- awakened threads must reacquire the lock before continuing

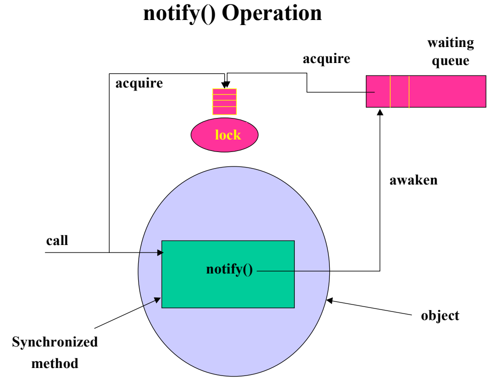
Structure of a Java Monitor



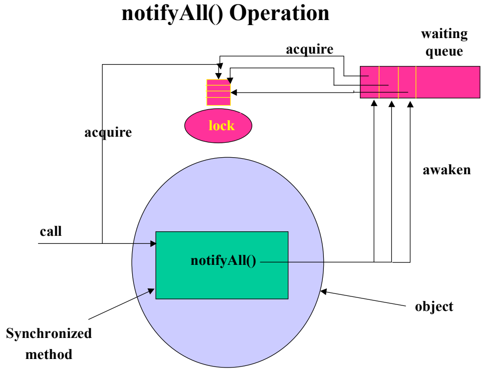
wait() Operation



notify() Operation



notifyAll() Operation



Generic Monitor Code

```
public class MonitorClass
{
   ... // private data
   public synchronized void enter(…)
   {  ...
      while ( ! condition )  // test for desired condition
      { wait();              // block execution
         ...                 // continue here when notified
      }
   }

   public synchronized void change(…)
   {  ...        // change the object’s state
      notify();   // unblock any single waiter
      ...
      notifyAll(); // unblock all waiters
   }
}
```


Semaphore Example

```
// file Semaphore.java
// note: some details missing
public class Semaphore
{
     private int count;
     public Semaphore(int initial)
     {
          count = initial;
     }
     synchronized public void P()
     {
          count = count - 1;
          if(count < 0) wait();
     }
     synchronized public void V()
     {
          count = count + 1;
          if (count <= 0) notify();
     }
}
```


Readers-Writers Example

```
public class ReadersWriters                          //some details missing
{                                                    //see Wait Exceptions
    private boolean writing;
    private int readers;
    public ReadersWriters()
    {
        writing = false;
        readers = 0;
    }
    public synchronized void startRead()
    {
        while (writing) wait();
        readers = readers + 1;
    }
    public synchronized void endRead()
    {
        readers = readers - 1;
        if (readers == 0) notify();
    }
    public synchronized void startWrite()
    {
        while (writing || readers > 0) wait(); }
        writing = true;
    }
    public synchronized void endWrite()
    {
        writing = false;
        notifyAll();
    }
}
```


Wait Exceptions

The wait operation is defined to return an exception if the wait is terminated abnormally. So the wait must be written as follows.

```
public class MonitorClass
{
   public synchronized void enter(…)
   {  ...
      while ( ! condition )  // test for desired condition
      { try { wait(); }      // block execution
        catch(InterruptedException(ie)
        { ... }             // handle wait exception
        ...                 // continue here when notified
      }
   }
   ...
}
```


Timed Waits

The time to wait for a synchronization condition can be bounded.

```
public class Resource
{ private boolean available = true;

  ...

  public synchronized boolean timedAcquire(int maxTime)
  {  if (! available)
     {  try { wait(maxTime); }
        catch(InterruptedException ex)
        { return false;
        }
     }
     available = false;
     return true;
  }
  ...
}
```