References


Concurrent Programming in Java: Design Principles and Patterns, Doug Lea, Addison-Wesley, 1997

The Java Programming Language, 2nd Ed. Arnold & Gosling, Addison-Wesley, 1998


Java 1.5.0 on-line documentation

Java Network Programming 2nd Ed., Harold, O'Reilly, Chapter 5

Programming Ruby, 2nd Ed, Thomas

Interrupt

The following program does not end
The interrupt just sets the interrupt flag!

```java
public class NoInterruptThread extends Thread {
    public void run() {
        while (true) {
            System.out.println("From: " + getName());
        }
    }
}

public static void main(String args[]) throws InterruptedException{
    NoInterruptThread focused = new NoInterruptThread();
    focused.setPriority(2);
    focused.start();
    Thread.currentThread().sleep(5); // Let other thread run
    focused.interrupt();
    System.out.println("End of main");
}
```

Output

From: Thread-0  (repeated many times)
End of main
From: Thread-0  (repeated until program is killed)
Using Thread.interrupted

```java
public class RepeatableNiceThread extends Thread {
    public void run() {
        while ( true ) {
            while ( !Thread.interrupted() )
                System.out.println( "From: " + getName() );

            System.out.println( "Clean up operations" );
        }
    }

    public static void main(String args[]) throws InterruptedException{
        RepeatableNiceThread missManners =
            new RepeatableNiceThread();
        missManners.setPriority( 2 );
        missManners.start();
        Thread.currentThread().sleep( 5 );
        missManners.interrupt();
    }
}
```

Output

```
From: Thread-0
Clean up operations
From: Thread-0
From: Thread-0 (repeated)
```
public class NiceThread extends Thread {
    public void run() {
        try {
            System.out.println("Thread started");
            while (!isInterrupted()) {
                sleep(5);
                System.out.println("From: " + getName());
            }
            System.out.println("Clean up operations");
        } catch (InterruptedException interrupted) {
            System.out.println("In catch");
        }
    }

    public static void main(String args[]) {
        NiceThread missManners = new NiceThread();
        missManners.setPriority(6);
        missManners.start();
        missManners.interrupt();
    }
}
Java interrupt ()

Sent to a thread to interrupt it

If thread is blocked on a call to wait, join or sleep
   InterruptedException is thrown &
   The interrupted status flag is cleared

if the thread is blocked on I/O operation on an interruptible channel (NIO)
   ClosedByInterruptException is thrown
   The interrupted status flag is set

If the thread is blocked by a selector (NIO)
   Interrupt status is set
   The thread returns from the selector call as normal

If none of the other conditions hold then the thread’s interrupt status is set
Details

If thread is blocked on a call to wait, join or sleep
   InterruptedException is thrown &
   The interrupted status flag is cleared

if the thread is blocked on I/O operation on an interruptible channel (NIO)
   ClosedByInterruptException is thrown
   The interrupted status flag is set

If the thread is blocked by a selector (NIO)
   Interrupt status is set
   The thread returns from the selector call as normal

If none of the other conditions hold then the thread’s interrupt status is set
Interrupt and Pre JDK 1.4 NIO operations

If a thread is blocked on a read/write to a:
   Stream
   Reader/Writer
   Pre-JDK 1.4 style socket read/write

The interrupt does not interrupt the read/write operation!

The threads interrupt flag is set

Until the IO is complete the interrupt has no effect

This is one motivation for the NIO package
Safety - Mutual Access
A call to a synchronized method locks the object
    Object remains locked until synchronized method is done

Any other thread's call to any synchronized method on the same object
    will block until the object is unlocked
class SynchronizeExample {
    int[] data;

    public String toString() {
        return "array length " + data.length + " array values " + data[0];
    }

    public synchronized void initialize(int size, int startValue) {
        data = new int[size];
        for (int index = 0; index < size; index++)
            data[index] = (int) Math.sin(index * startValue);
    }

    public void unSafeSetValue(int newValue) {
        for (int index = 0; index < data.length; index++)
            data[index] = (int) Math.sin(index * newValue);
    }

    public synchronized void safeSetValue(int newValue) {
        for (int index = 0; index < data.length; index++)
            data[index] = (int) Math.sin(index * newValue);
    }
}
Synchronized Static Methods

class SynchronizeExample {
    int[] data;

    public String toString() {
        return "array length " + data.length + " array values " + data[0];
    }

    public synchronized void initialize( int size, int startValue) {
        data = new int[size];
        for (int index = 0; index < size; index++)
            data[index] = (int) Math.sin(index * startValue);
    }

    public void unSafeSetValue( int newValue) {
        for (int index = 0; index < data.length; index++)
            data[index] = (int) Math.sin(index * newValue);
    }

    public synchronized void safeSetValue( int newValue) {
        for (int index = 0; index < data.length; index++)
            data[index] = (int) Math.sin(index * newValue);
    }
}

Locks class
Blocks other synchronized class methods
Synchronized Statements

synchronized ( expression ) {
    statements
}

eexpression must evaluate to an object
That object is locked

class LockTest {
    public synchronized void enter() {
        System.out.println( "In enter");
    }
}

class LockTest {
    public void enter() {
        synchronized ( this ) {
            System.out.println( "In enter");
        }
    }
}
public class LockExample extends Thread {
    private Lock myLock;

    public LockExample( Lock aLock ) {
        myLock = aLock;
    }

    public void run() {
        System.out.println( "Start run" );
        myLock.enter();
        System.out.println( "End run" );
    }

    public static void main( String args[] ) throws Exception {
        Lock aLock = new Lock();
        LockExample tester = new LockExample( aLock );

        synchronized ( aLock ) {
            System.out.println( "In Block" );
            tester.start();
            System.out.println( "Before sleep" );
            Thread.currentThread().sleep( 5000 );
            System.out.println( "End Block" );
        }
    }
}

class Lock {
    public synchronized void enter() {
        System.out.println( "In enter" );
    }
}

Output
In Block
Start run
Before sleep
End Block
In enter
End run  (why is this at the end?)
Synchronized and Inheritance

class Top {
    public void synchronized left() {
        // do stuff
    }

    public void synchronized right() {
        // do stuff
    }
}

class Bottom extends Top {
    public void left() {
        // not synchronized
    }

    public void right() {
        // do stuff not synchronized
        super.right(); // synchronized here
        // do stuff not synchronized
    }
}

methods do not inherit synchronized
class Counter
  attr_reader :count
  def initialize
    @count = 0
    super
  end

  def tick
    @count += 1
  end
end

counter = Counter.new
tickA = Thread.new { 10000.times { counter.tick}}
tickB = Thread.new { 10000.times { counter.tick}}
tickA.join
tickB.join
puts counter.count -> **14451**

require 'monitor'
class Counter < Monitor
  attr_reader :count
  def initialize
    @count = 0
    super
  end

  def tick
    synchronize do
      @count += 1
    end
  end
end
counter = Counter.new
tickA = Thread.new { 10000.times { counter.tick}}
tickB = Thread.new { 10000.times { counter.tick}}
tickA.join
tickB.join
puts counter.count -> **20000**
require 'monitor'

class Counter
  include MonitorMixin
  attr_reader :count
  def initialize
    @count = 0
    super
  end
  def tick
    synchronize do
      @count += 1
    end
  end
end

Ruby Synchronize examples from Programming Ruby, 2nd Ed, Thomas, pp 142-144
Using Monitor directly

require 'monitor'

class Counter
  attr_reader :count
  def initialize
    @count = 0
    super
  end

def tick
  @count += 1
end
end

counter = Counter.new
lock = Monitor.new
tickA = Thread.new { 10000.times { lock.synchronize {counter.tick}}}
tickB = Thread.new { 10000.times { lock.synchronize {counter.tick}}}
tickA.join
tickB.join
puts counter.count -> 20000
wait and notify

public final void wait(timeout) throws InterruptedException
public final void wait(timeout, nanos) throws InterruptedException
public final void wait() throws InterruptedException
    Causes a thread to wait until it is notified or the specified timeout expires.

    Throws: IllegalMonitorStateException
    If the current thread is not the owner of the Object's monitor.

    Throws: InterruptedException
    Another thread has interrupted this thread.

public final void notify()
public final void notifyAll()
    Notifies threads waiting for a condition to change.
The thread waiting for a condition should look like:

```java
synchronized void waitingMethod()
{
    while ( ! condition )
        wait();

    Now do what you need to do when condition is true
}
```

Everything is executed in a synchronized method

The test condition is in loop not in an if statement

The wait suspends the thread it atomically releases the lock on the object
synchronized void changeMethod() {
    Change some value used in a condition test
    notify();
}

When can Consumer read from queue?
import java.util.concurrent.*;

public class Producer extends Thread {
    BlockingQueue<String> factory;
    int workSpeed;

    public Producer( String name, BlockingQueue<String> output, int speed ) {
        setName(name);
        factory = output;
        workSpeed = speed;
    }

    public void run() {
        try {
            int product = 0;
            while (true) {
                System.out.println( getName() + " produced " + product);
                factory.add( getName() + String.valueOf( product) );
                product++;
                sleep( workSpeed);
            }
        } catch ( InterruptedException workedToDeath ) {
            return;
        }
    }
}
import java.util.concurrent.*;

class Consumer extends Thread {
    BlockingQueue<String> localMall;
    int sleepDuration;

    public Consumer(String name, BlockingQueue<String> input, int speed) {
        setName(name);
        localMall = input;
        sleepDuration = speed;
    }

    public void run() {
        try {
            while (true) {
                System.out.println(getName() + " got " + localMall.take());
                sleep(sleepDuration);
            }
        }
        catch (InterruptedException endOfCreditCard) {
            return;
        }
    }
}
wait and notify - Driver Program

import java.util.concurrent.*;
public class ProducerConsumerExample {
    public static void main( String[] args ) throws Exception {
        BlockingQueue<String> wallmart = new ArrayBlockingQueue(100, true);
        Producer nike = new Producer( "Nike", wallmart, 500 );
        Producer honda = new Producer( "Honda", wallmart, 1200 );
        Consumer valleyGirl = new Consumer( "Sue", wallmart, 400);
        Consumer valleyBoy = new Consumer( "Bob", wallmart, 900);
        Consumer dink = new Consumer( "Sam", wallmart, 2200);
        nike.start();
        honda.start();
        valleyGirl.start();
        valleyBoy.start();
        dink.start();
    }
}

<table>
<thead>
<tr>
<th>Nike produced 0</th>
<th>Nike produced 2</th>
<th>Nike produced 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honda produced 0</td>
<td>Sue got Nike2</td>
<td>Sue got Nike4</td>
</tr>
<tr>
<td>Sue got Nike0</td>
<td>Honda produced 1</td>
<td>Honda produced</td>
</tr>
<tr>
<td>Bob got Honda0</td>
<td>Bob got Honda1</td>
<td>Bob got Honda2</td>
</tr>
<tr>
<td>Nike produced 1</td>
<td>Nike produced 3</td>
<td>Nike produced 5</td>
</tr>
<tr>
<td>Sam got Nike1</td>
<td>Sue got Nike3</td>
<td>Sue got Nike5</td>
</tr>
</tbody>
</table>
Java Blocking Queues

ArrayBlockingQueue
DelayQueue
LinkedBlockingQueue
PriorityBlockingQueue
SynchronousQueue
require 'thread'

queue = Queue.new
consumers = (1..3).collect do |each|
  Thread.new("Consumer #{each}") do |name|
    begin
      product = queue.deq
      puts "#{name}: consumed #{product}"
      sleep(rand(0.05))
    end until product == :END_OF_WORK
  end
end

producers = (1..2).collect do |each|
  Thread.new("Producer #{each}") do |name|
    3.times do |k|
      sleep(0.1)
      queue.enq("Item #{k} from #{name}")
    end
  end
end

producers.each { |each| each.join }
consumers.size.times { queue.enq(:END_OF_WORK)}
consumers.each { |each| each.join }

Example from Programming Ruby, 2nd Ed, Thomas, pp 743
Java ThreadPoolExecutor

```java
import java.util.concurrent.*;

public class ThreadPoolExample extends Object {
    public static void main(String[] args) {
        int corePoolSize = 2;
        int maximumPoolSize = 5;
        long keepAliveTime = 60 * 10;
        TimeUnit keepAliveUnit = TimeUnit.SECONDS;
        BlockingQueue<Runnable> surplusJobs = new LinkedBlockingQueue<Runnable>();
        ThreadPoolExecutor workers = new ThreadPoolExecutor(corePoolSize,
                                                          maximumPoolSize,
                                                          keepAliveTime,
                                                          keepAliveUnit,
                                                          surplusJobs);

        for (int k = 0; k < 5; k++)
            workers.execute(new SimpleThread(k + 5));
    }
}
```
Types of Servers

Connectionless (UDP) verse Connection-Oriented (TCP)

Iterative verses Concurrent

Stateless verse stateful
Iterative verses Concurrent Server

Iterative

Single process

Handles requests one at a time

Good for low volume & requests that are answered quickly
Iterative verses Concurrent Server

Concurrent

Handle multiple requests concurrently

Normally uses thread/processes

Needed for high volume & complex requests

Harder to implement than iterative

Must deal with currency
require 'socket'
class DateServer
  def initialize(port)
    @port = port
  end

  def run()
    server = TCPServer.new( @port)
    puts("start " + @port.to_s)
    while (session = server.accept)
      Thread.new(session) do |connection|
        process_request_on(connection)
        connection.close
      end
    end
  end
end

def process_request_on(socket)
  request = canonical_form( socket.gets("\n") )
  now = Time.now
  answer = case request
           when 'time'
             now.strftime("%X")
           when 'date'
             now.strftime("%x")
           else
             "Invalid request"
           end
  socket.send(answer + "\n",0)
end

def canonical_form(string)
  string.lstrip.rstrip.downcase
end
Single Thread Concurrent Server

One can implement a concurrent server using one thread/process

while (true) {
    check if any new connects (non-block accept)
    if new connection accept
    process a little on each current request
}
Stateless verses Stateful Servers

State information

Information maintained by server about ongoing interactions with clients

Consumes server resources

How long does one maintain the state?
Modes of Operation

Stateful servers sometimes have different modes of operation.

Each mode has a set of legal commands.

In Login mode only the commands password & username are acceptable.

After successful login client-server connection in transaction mode.

In transaction mode command X, Y Z are legal.

These modes are also called server states or just states.