Operating Systems

1DV512

Tutorial: “Java Programming with Threads”

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Introduction

- **The aim of this presentation is to introduce you to Java multi-threading**
  - Start, Interrupt and Sleep Threads
  - Thread Synchronisation
  - The Volatile and Synchronised keyword
  - Locks, Multiple locks
  - Thread Pools
  - Wait and Notify
  - Deadlocks
  - Semaphores

- **Code examples**
- **Questions**

Starting Threads in Java

- **Extend the Thread class**
  - Threads can be controlled using the Thread class
  - Start the thread using the start() method in order to run it in a separate thread

```
class ClassName extends Thread {
      public void run() {
         //your code here
      }
```

```
public static void main(String[] args) {
      ClassName t1 = new ClassName();
      t1.start();
}
```

- **Implement the Runnable interface**
  - Implement runnable class and pass it to the constructor of Thread

```
class ClassName implements Runnable {
      public void run() {
         //your code here
      }
```

```
public static void main(String[] args) {
      Thread t1 = new Thread(new ClassName());
      t1.start();
}
```

Starting Threads in Java - cont’d

❑ **Using Thread pools**

- ExecutorService - starting multiple threads at once

```
ExecutorService exec = Executors.newFixedThreadPool(2);
for (int i = 0; i < 5; i++) {
    exec.submit(new Runnable() {
        public void run() {
          //your code here
        }
    });
}
```

The volatile keyword and Interrupting Threads in Java

- **Stop thread using shared data**
  - It is possible that on some systems (or java implementation), when java optimises the code, the thread (in our example “Processor”) decides to cache a variable (in our example the “running” public variable).
  - To prevent caching variables we can use ***volatile*** keyword

- **Thread Interruption**
  - Using the interrupt() method, and handling the InterruptedException.
  - Interrupt thread pool using shutdownNow() method

Putting the threads to sleep

- ❑ **Using the sleep() method**
  - The thread pauses/sleeps for a certain amount of time.
  - Accepts an integer which indicates the milliseconds you want the thread to sleep for

```
try {
   Thread.sleep(100);
} catch (InterruptedException e) {
   e.printStackTrace();
}
```

The Synchronized keyword

- **Problem: Thread interleaving**
  - Two threads reading/writing the same data

```
private int count = 0;
//T1
for(int i=0; i<1000; i++) {
   count ++;
}
//T2
for(int i=0; i<1000; i++) {
   count ++;
}
```

- **Solution: Synchronized keyword**
  - Makes sure that when one thread is performing an action, no other thread is performing the same action at the same time
  - First thread acquires an intrinsic lock to the method, and the second thread has to wait until the intrinsic lock is released.

```
public synchronized void increment() {
   count ++;
}
```

Multiple Locks using Synchronized Code Blocks

- **The synchronised code blocks**
  - Allow you to lock a part of your code and assign different lock object to each synchronised code block

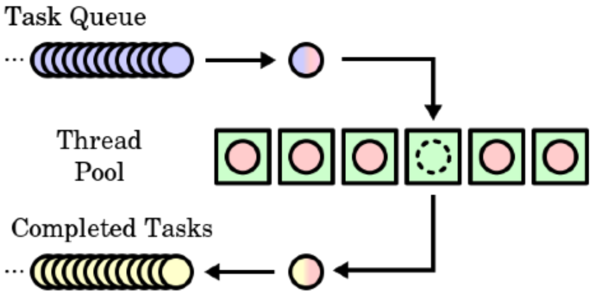
```
public synchronized void stageOne() {
        list1.add(random.nextInt(100));
}
public synchronized void stageTwo() {
        list2.add(random.nextInt(100));
}

public void process() {
        for (int i = 0; i < 1000; i++) {
                stageOne();
                stageTwo();
        }
}
```

```
private Object lock1 = new Object();
private Object lock2 = new Object();
public void stageOne() {
        synchronized (lock1) {
                list1.add(random.nextInt(100));
        }
}
public void stageTwo() {
        synchronized (lock2) {
                list2.add(random.nextInt(100));
        }
}
public void process() {
        for (int i = 0; i < 1000; i++) {
                stageOne();
                stageTwo();
        }
}
```

Thread Pools

- **Way of managing lots of threads at the same time**
  - Thread pool is a group of threads waiting for tasks to execute
  - The threads are always existing, which avoids the overhead of creating them every time
  - Using ExecutorService tasks are added in a queue, and assigned one at a time to each thread
  - You can think as having a number of workers in a factory, and having a larger number of tasks for these workers. When a worker completes a task, a new task will be assigned to him.



Wait and Notify

- ❑ **Wait()**
  - releases the lock of this object
  - tells the calling thread to give up the monitor and go to sleep until the other thread enters the same monitor and calls notify()

- ❑ **Notify()**
  - wakes up the first thread that called wait() on the same object

- ❑ **NotifyAll()**
  - wakes up the all the threads that are waiting on the same object

- ❑ **Can be used inside synchronised method or code blocks**

Low vs High Level synchronisation techniques

- ❑ **High level synchronisation using Java Concurrent package**
  - Contains set of classes that makes it easier to develop multithreaded applications in Java.
  - Avoids the low level synchronisation with the ***synchronized*** keyword
  - Available in ***java.util.concurrent*** package

- ❑ **Low level synchronisation**
  - Manually handling the thread synchronisation using ***synchronized***, ***wait***, ***notify*** …

Deadlocks

- **Deadlock is a situation where two or more threads are locked forever**
  - It can occur when locks are locked in different orders

- **Deadlock prevention**
  - Lock Ordering
    - Make sure the locks are always taken in the same order by any thread
  - Lock Timeout
    - Put a timeout on lock attempts, If not successful in taking the necessary locks, backup, free all the taken locks, wait for some time and retry.
  - Deadlock Detection
    - The heavier deadlock prevention. Every time a thread takes a lock or requests a lock it is noted in a data structure (map, graph) of threads and locks.
    - The detection is done by traversing the lock graph.

Semaphores

- **Semaphores ensure that only a given number of processes can access a certain resource at a given time.**
  - Useful for limiting connections
  - Limiting thread creation
  - Limiting concurrent access to the disk

- **Always release what you acquire (try - finally blocks)**
  - acquire() will block until permits are available
  - release() will always increment the number of permits

Literature

- **The Java Tutorials (Oracle)**
  https://docs.oracle.com/javase/tutorial/essential/concurrency/index.html
- **Steven Haines and Stephen Potts, “Java 2 Primer Plus”, Sams Publishing 2003**
- **Cave of Programming, http://www.caveofprogramming.com**