

Java Threads in a Nutshell

Chris Kauffman

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Logistics

Schedule

| | | |
|-------|------------|------------------------------------|
| 11/15 | Mon | OpenMP Wrap Java Threads |
| 11/17 | Wed | CUDA / GPUs Mini-Exam 3 |
| 11/22 | Mon | CUDA / GPUs |
| 11/24 | Wed Thu | CUDA / GPUs Thanksgiving |
| 11/29 | Mon | CUDA / GPUs Applications |
| 12/01 | Wed | Guest Lecture |

Threads Reading

Java Concurrency Tutorial

GPU Reading

GPU parallel program
development using CUDA by
Tolga Soyata

- ▶ Ch 6 start GPU Coverage
- ▶ [UMN Library Link](#)

Logistics

A2

- ▶ Release Later this week
- ▶ 30% of grade
- ▶ 3 Problems: 2 MPI + 1 OpenMP
- ▶ Makeup Credit Available
- ▶ Due at End of Semester

A3

- ▶ 10% CUDA Programming, Short
- ▶ Release after Thanksgiving
- ▶ Due at End of Semester

Mini-Exam 3

- ▶ Focus on Threads, OpenMP, Java Threads
- ▶ Contrast approaches in each
- ▶ Short code optimizations similar to lecture examples

Later Exams

- ▶ Mini-Exam 4: CUDA + Applications
- ▶ Final Exam: Cumulative
- ▶ Separately worth 10%
- ▶ Merge to 20% last-day-of-class exam?

Threads in Java

- ▶ Java was built with concurrency in mind
- ▶ `java.lang.Thread` is a core part of the language
- ▶ Represents a runnable unit
- ▶ `java.lang.Runnable` does so similarly as an interface

Typical Parallel Setup

- ▶ Create a class which extends `Thread`
- ▶ Override the `run()` method to do real work
- ▶ In a `main()` method, instantiate the thread class and invoke the `thread.start()`, thread begins execution asynchronously
- ▶ Eventually call `thread.join()` to wait for thread to finish

Picalc example (again)

Three variants

1. Reduction version: no thread synchronization required
2. Synchronized methods: only one thread executes a method at a time
3. Synchronized statements: any java object can be a lock

Highlights of PicalcReduction.java

- ▶ Create a nested subclass

```
static class CalcThread extends Thread
```

- ▶ Fields and constructor allows initialization information to be communicated

```
    public CalcThread(int threadNum, int nPoints){  
        this.threadNum = threadNum;  
        this.nPoints = nPoints;  
    }
```

- ▶ Override the public void run() to initialize a Random number generator, perform hit computations, update this.hits
- ▶ Accessor public int getHits() allows retrieval of hits computed
- ▶ main() method creates an array of CalcThreads, starts them running
- ▶ join() each thread to wait for it to finish, sum up hits with
 threads[i].join();
 totalHits += threads[i].getHits();
- ▶ Must be aware of an irritating InterruptedException

Highlights of PicalcSynchMethod.java

- ▶ Class field to track total hits

```
static int totalHits;
```

- ▶ Class method to control updates: **synchronized**

```
static synchronized void incrTotal(){  
    totalHits++;  
}
```

- ▶ Only one thread in the method at a time
- ▶ Nested class CalcThread calls incrTotal() to update totalHits
- ▶ main() spins up threads and waits to join
- ▶ No need to perform any reductions

Highlights of PicalcSynchStatement.java

- ▶ Class field to track total hits
`static int totalHits;`
- ▶ Class field to serve as a lock to control access
`static Object lock = new Object();`
- ▶ Nested class CalcThread directly updates by acquiring/releasing lock

```
synchronized(lock){  
    totalHits++;  
}
```
- ▶ Only one thread in the critical section at time
- ▶ `main()` spins up threads and waits to join
- ▶ No need to perform any reductions

Timings of Java Variants

```
>> cd 13-java-threads-code
>> time java PicalcReduction
npoints: 75000000
threads: 4
hits:    58909237
pi_est:  3.141826

real    0m0.982s
user    0m3.401s
sys     0m0.071s
```

| | 75M | 75M | 75M |
|----------------------|-------|-------|--------|
| samples | | | |
| threads | 1 | 2 | 4 |
| JAVA | | | |
| PicalcReduction | 3.378 | 1.803 | 0.988 |
| PicalcSynchMethod | 4.272 | 7.755 | 10.623 |
| PicalcSynchStatement | 3.366 | 7.753 | 10.866 |
| PTHEADS | | | |
| mutex_fast | 1.032 | 0.521 | 0.268 |

Java

Keep in mind the slower times might be improved with tweaks to compilation + runtime invocation, perhaps with [ahead of time compilation via jaotc](#). The JVM does a LOT of stuff favoring flexibility over performance

Exercise: Java Collisions

- ▶ `Collisions.java` gives a serial collision detector
- ▶ Discuss with a neighbor how to parallelize this in Java
- ▶ Will require a `Thread` subclass
- ▶ Discuss using reductions or synchronized methods/statements
- ▶ Be fairly **specific** with your design: sketch subclasses, fields, methods

Note on Synchronized Sections

- ▶ Synchronized methods are synced on the associated object
- ▶ Only one thread is in ANY method at a time
- ▶ Maintain consistency of object state
- ▶ static methods sync on class, can only be in one at a time

```
class C {  
    int total;  
    public C(){ this.total = 0; }  
  
    synchronized void incrTotal(){  
        total++;  
    }  
    synchronized void decrTotal(){  
        total++;  
    }  
}
```

```
class D {  
    static int total;  
  
    synchronized static void incrTotal(){  
        total++;  
    }  
    synchronized static void decrTotal(){  
        total++;  
    }  
}
```

Contrast

- ▶ Unlike the new collection implementations, Vector is synchronized.
- ▶ ArrayList: Note that this implementation is not synchronized.

Example of Easy Creation of a Synchronized Instance

From ArrayList [Java Docs](#)

Note that this implementation is not synchronized. If multiple threads access an ArrayList instance concurrently, and at least one of the threads modifies the list structurally, it must be synchronized externally. (A structural modification is any operation that adds or deletes one or more elements, or explicitly resizes the backing array; merely setting the value of an element is not a structural modification.) This is typically accomplished by synchronizing on some object that naturally encapsulates the list. If no such object exists, the list should be “wrapped” using the Collections.synchronizedList method. This is best done at creation time, to prevent accidental unsynchronized access to the list:

```
List list = Collections.synchronizedList(new ArrayList(...));
```

Question

What does the code for `synchronizedList(..)` look like?

Iterators are Inherently Serial

Manual synchronization on iterators is still required.

```
synchronized (list) {  
    Iterator i = list.iterator();  
    while (i.hasNext())  
        foo(i.next());  
}
```

- ▶ Required if another thread is performing `list.add(x)`
- ▶ Prevents `ConcurrentModificationException`

Wait, Notify, Volatility

```
class C {  
    public volatile boolean joy = false;  
    public void guardedJoy() {  
        while(!joy) {}           // Busy polling  
        System.out.println("Joy has been achieved!");  
    }  
  
    public synchronized void guardedJoy() {  
        while(!joy) {  
            try {  
                this.wait();      // Blocking wait  
            } catch (InterruptedException e) {}  
        }  
        System.out.println("Joy and efficiency have been achieved!");  
    }  
    public synchronized notifyJoy() {  
        this.joy = true;  
        this.notifyAll();  
    }  
}
```

See: WaitNotify.java for timings

Java's Memory Model

At the bottom of this issue lies the need for aggressive optimization in the face of concurrency: any mechanism which ensures memory coherency between threads is expensive, and much (most) of the data is not shared between threads. Therefore the data not explicitly marked volatile, or protected by locks, is treated as thread-local by default (without strict guarantees, of course).

– [Marko Topolnik, Stack Overflow](#)

Other Capabilities in Java

- ▶ Concurrent collections (ConcurrentMap rather than HashMap and TreeMap)
- ▶ Runnable interface - class provides a run() method

```
Runnable r = new Something();  
Thread t = new Thread(r);
```
- ▶ Executor interface and associates for more complex scheduling
- ▶ Use of ThreadPools to farm out work
- ▶ New-ish ForkJoinPool

Generally concurrency is a prime part of Java and one of its strengths.

We may discuss a few alternative JVM languages which build up higher structures on these capabilities.