Distributed Systems

4. Programming with Threads

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Processes vs. Threads

Components of distributed systems have to do different things at the same time (concurrency)

Realization by processes is expensive

- processes have separate resources (e.g., memory space)

➔ switching between processes keeps the kernel busy

Threads are cheaper

- run in one process (each process has at least one)
- share memory space and other resources

(which gives rise to other difficulties)

Threads in Java

- Threads are first class objects
  - instances of the class **`Thread`** —
    or of a subclass of **`Thread`**, created by the programmer

- In every program, there is a thread “main”

- The class **`Thread`** implements the interface **`Runnable`**
  - Runnable has only one method: **`run()`**

- Threads can be constructed from implementations of **`Runnable`**, using constructors, like
  - **`new Thread(Runnable target)`**
  - **`new Thread(Runnable target, String name)`**

Threads in Java (cntd)

- Threads have the following methods
  - **`run()`**
  - **`start()`**
  - **`getPriority()`**
  - **`join()`** *(waits for the thread to die)*

- The class **`Thread`** has also static methods, e.g.,
  - **`yield()`** *(lets the current thread pause)*
  - **`sleep(long n)`** *(lets the current thread pause for n milliseconds)*

- Threads can be daemons and may belong to groups

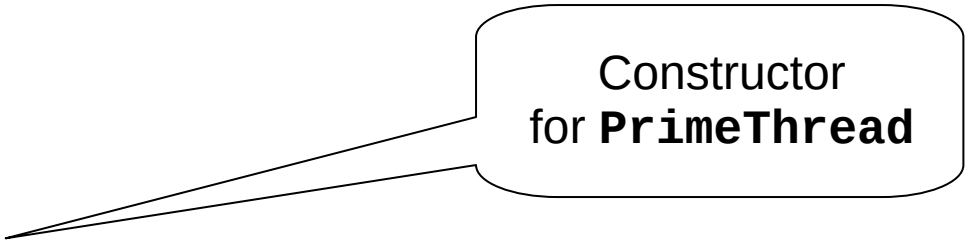
Extending the Class Thread (Example)

```
class PrimeThread extends Thread {

        long minPrime;

        PrimeThread(long minPrime) {
            this.minPrime = minPrime;
        }

        public void run() {
            // compute primes larger than minPrime
              . . .
        }}
```



Constructing a Thread from a “Runnable”

```
class PrimeGenerator implements Runnable {
        long minPrime;
        PrimeGenerator(long minPrime) {
            this.minPrime = minPrime;
        }

        public void run() {
            // compute primes larger than minPrime
              . . .
        }}


Thread primeThread =
            new Thread(new PrimeGenerator(1000));

primeThread.start();
```

Constructor for **`PrimeGenerator`**, fed into **`Thread`** constructor

Is this better? If so, why?

Putting a Thread Asleep

Static methods

```
Thread.sleep(ms)
Thread.sleep(ms,ns)
```

- Current thread pauses for (approx.) the indicated time

- Useful for
  - making processor time available for other threads
  - ensuring that thread proceeds with a defined rhythm

(“pacing” a thread)

Thread Interference

```
public class Counter {
    int c = 0;

    public void increment() { c++;  }

    public void decrement() { c--;  }

    public int value() { return c;  }
}
```

- In reality, **`increment()`** and **`decrement()`** are complex operations
- Two threads A, B may interfere when accessing the same counter
- Aim: B must see the effect of A's action (or vice versa)

  ➔ A "happens before" B

Synchronisation

Achieves “happens before” relationship

between threads accessing an object

Principles:

- Every object has an intrinsic lock (= “monitor”)
- A lock for on object is acquired e.g., by executing
  - a synchronised method of that object, or
  - a synchronized statement for that object *(see below)*
- Methods can be declared as synchronized
  - e.g., `public synchronized void updateBalance(..)` for class `Account`
  - `acc.updateBalance(...)` can only be executed by a thread if the thread has a lock for `acc`
  - when the method call is completed, the lock is released

Example: A Synchronized Counter

```
public class SynchronizedCounter {
    int c = 0;

    public synchronized void increment() {
       c++;
     }

    public synchronized void decrement() {
       c--;
     }

    public synchronized int value() {
       return c;
     }
}
```

Synchronization Wrappers for Collections

Collections (Set, List, Map, SortedSet, and SortedMap)
are typical data structures to be shared by several threads

➔ need for synchronization

- Factory methods of class Collections can make a collection object "thread safe"

```
List msgQueue =
     Collections.synchronizedList(new LinkedList());
```

- Iteration has to be synchronized by a synchronized statement

```
synchronized(msgQueue) {
    Iterator i = msgQueue.iterator();
                // must be in synchronized block
    while (i.hasNext())
        send(i.next());
}
```

Deadlocks

Scenario: two threads T_1, T_2

- T_1 has a lock for object O_1, T_2 has a lock for object O_2
- T_1 needs a lock for O_2 to complete work on O_1,

  T_2 needs a lock for O_1 to complete work on O_2

➔ Deadlock

References

In preparing the lectures I have used several sources.

The main one is the following:

Web:

- The Java tutorials, Lesson Concurrency

  http://java.sun.com/docs/books/tutorial/essential/concurrency/index.html