1.00 Lecture 28

Threads

Reading for next time: Big Java 20.4

Threads

- What if our Java program must do a lot of computation on the sensor inputs?
  - And listen for sensor input changes when they occur, possibly from many sensors
  - And respond to user requests through the Swing GUI, such as button clicks or other input
- How can it do multiple things "at the same time"?
  - If it's computing, will it delay processing or lose sensor events, or Swing events?
- Java (and other) programs run in their own processes, fully isolated from each other
  - Two programs running on your laptop don't interact
- We need to run "mini-programs" within the same program, but they must share data and logic
  - Threads are mini-processes within a process

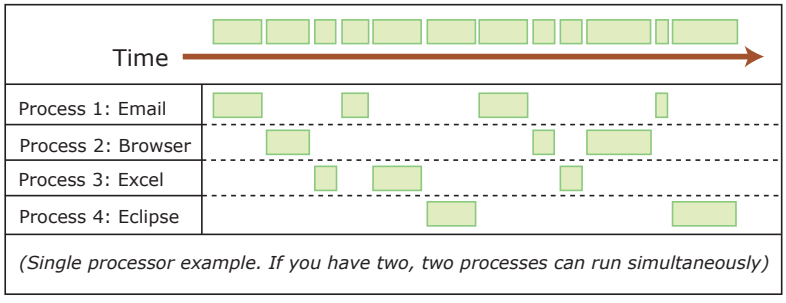
Threads

- **Most computers have multiple cores or processors that execute more than one piece of code or "thread " at a time**
  - **Even if they only have a single core/processor, they can implement threads by rapidly switching between tasks, giving each thread a small execution slice before switching to another task. All threads appear to proceed in parallel.**
- **Threads are different from processes**
  - ***Processes* are expensive but safe. Processes are so well insulated from each other that it is both complex and expensive to communicate between them.**
  - ***Threads* are cheap, but different threads running in the same process are not well-insulated from each other.**

Processes

Process –

- **Each program on your computer runs in its own process.**
- **Operating system's way of ensuring one program uses its own memory, and each program has a reasonable amount of processing time.**
- **Safe - the separation of memory spaces allow one program to continue running even if another program writes garbage into its own memory space (and crashes). It also provides a level of security.**



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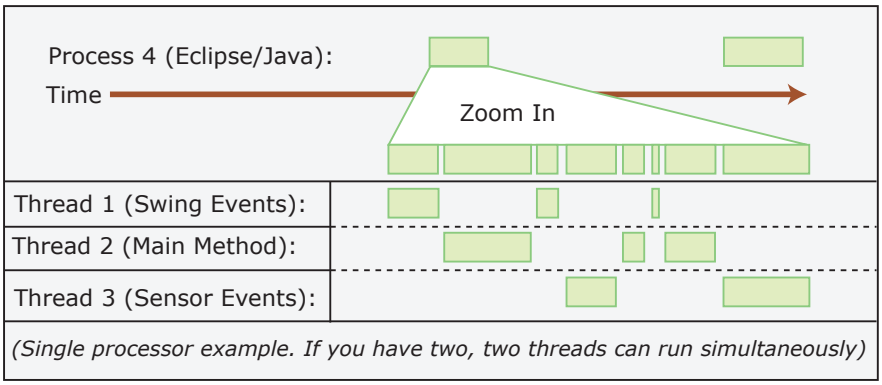
Threads

Threads –

- **If a process is an operating system's way of interleaving programs…**
- **A thread is a program's way of interleaving sections of code.**



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Writing a Thread, Option 1

- **Inherit from the Thread class and override its method `public void run()`:**

```
public class SensorManager extends Thread  {
      public void run() {
      // Code executed in the Thread goes here
      // run() is just like main(): Thread starts here
      }
  }
```

- **In main() or other method, create a Thread instance and start it:**

```
Thread t = new SensorManager();
t.start();
```

Writing a Thread, Option 2

- If the object you want to place in a thread already inherits from a superclass, use an interface

```
public interface Runnable {
      public void run();
}
```

- Modify the class to implement Runnable, e.g.,

```
public class SensorManager extends JFrame
  implements Runnable {
    // constructors and other methods go here
    public void run() {
      // code executed in the Thread goes here
    }
}
```

- In main() or other method:

```
Thread t = new Thread(new SensorManager());
t.start();
```

Find Status of Thread

- In main() or other method:

```
// Ask if thread is executing
if (t.isAlive())
  // code (can't use t's results yet)
else
  // code (assumes t has completed)
```

- You can also wait for a thread to finish:

```
// In a method of some thread other than t
t.join(); // waits until t completes
// code (assumes t has completed)
```

- To stop a thread, use:

```
t.interrupt();
// Thread t catches InterruptedException, returns
// We don't cover this in 1.00.
```

Computing with threads

- Program finds sum of set of numerical integrals of cylinder volumes
  - We cover numerical integration in lecture 32
  - In this lecture, we treat it as just an expensive computation
  - We scale the output, so we always get approximately π
- Reads radius of each cylinder
  - Must respond to input in timely fashion, even if integral takes a long time to compute
  - If program doesn't respond quickly, either the user will find the application unusable, or input events may be dropped
    - Maximum event queues are often short
  - We use Scanner and System.in for keyboard input
    - JOptionPane is a Swing object in its own thread, which would complicate the example
  - We use floats, not doubles, to simplify one ugly issue
    - We discuss it (synchronization) in the next lecture

Cylinder integral without threads

```
import java.util.*;

public class Cylinder {
   private static final int ITER = 20000000;
   private float radius;

   public Cylinder(float r) { radius= r; }

   public float circularIntegral() {
        float sum= 0.0F;
        for (int i= 0; i < ITER; i++) {
          // Math.random() returns double d: 0 <= d <= 1
          float x= 2*radius*(float)Math.random() - radius;
          float y= 2*radius*(float)Math.random() - radius;
          float f= 1.0F;              // f(x,y)=constant here
          if ((x*x + y*y) < radius*radius) // If in region
                sum += f;             // Increment integral sum
        }
        System.out.println("r "+ radius + " i " + 4.0F*sum/ITER);
        return 4.0F*sum/ITER;  // Integral value * 4 (pi)
   }
```

Cylinder without threads, p.2

```
   public static void main(String[] args) {
        Scanner in= new Scanner(System.in);     // Keyboard input
        float integral= 0.0;
        for (int i= 0; i < 6; i++) {
               System.out.println("Enter radius ");
               float radius= in.nextFloat(); // Keyboard input
               Cylinder t = new Cylinder(radius);
               integral += t.circularIntegral();
        }
        System.out.println("integral " + integral);
        System.out.println("Done");
   }
}

// Run this to see that it responds slowly. Enter r=1 each time
// Eclipse is flaky in not putting the cursor at end of prompt.
```

Exercise 1: Cylinder with threads

- CylinderThread uses threads
  - It splits the integration work across 6 threads
  - The threads each contribute their part of the integral to a static variable in CylinderThread
  - In main()
    - Each thread is created with a new keyword
    - Each thread is then started with start()
    - Each thread starts by executing its run() method
    - Which calls method circularIntegral()
    - Which increments a static variable that holds the sum
  - We enter the radius for each of the 6 parts
    - This could also come from a sensor or Swing event
  - We will complete CylinderThread

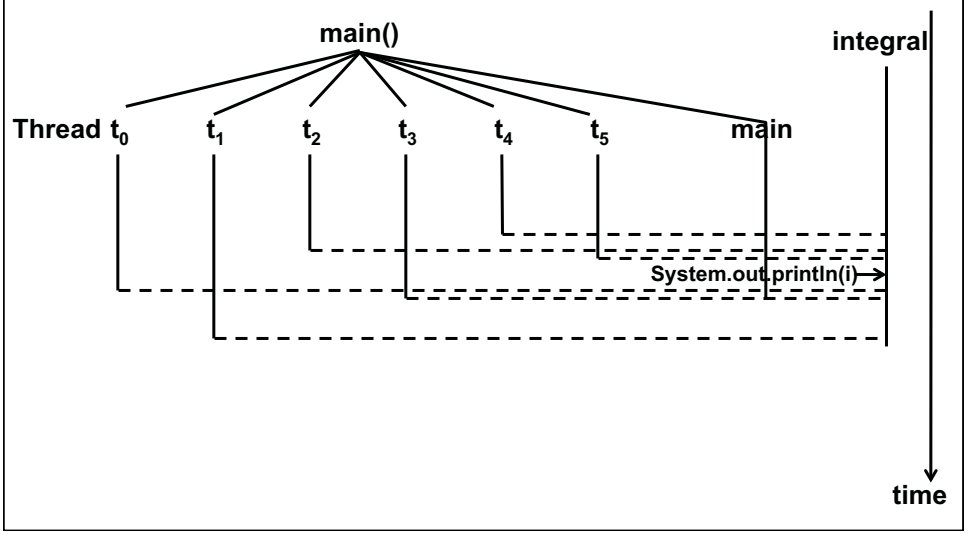
Exercise 1a: Cylinder with threads

```
import java.util.*;

public class CylinderThread _____________ { // Complete this line
   private static final int ITER = 20000000;
   private float radius;
   private static float integral;            // New; holds sum
   public CylinderThread(float r) { super(); radius= r;} // Diff

   public float circularIntegral() {
        float sum= 0.0F;
        for (int i= 0; i < ITER; i++) {
          float x= 2*radius*(float)Math.random() - radius;
          float y= 2*radius*(float)Math.random() - radius;
          float f= 1.0F;             // f(x,y)=constant here
          if ((x*x + y*y) < radius*radius) // If in region
            sum += f;                // Increment integral sum
        }
        System.out.println("r "+ radius + " i " + 4.0F*sum/ITER);
        integral += 4.0*sum/ITER;            // New, adds to sum
         return 4.0F*sum/ITER; // Integral value * 4 (pi)
    }
```

Exercise 1b: Cylinder with threads

```
   // Write the run() method. It's like a main() method.


   public static void main(String[] args) {
        Scanner in= new Scanner(System.in);
        for (int i= 0; i < 6; i++) {
                System.out.println("Enter radius ");
                float radius= in.nextFloat();
                CylinderThread t = new CylinderThread(radius); //New
                t.start();   // Uncomment this                 //New
        }
        System.out.println("integral: " + CylinderThread.integral);
        System.out.println("Done");
   }
}
// When you are done, compile and run this.
// It prompts for keyboard input quickly, unlike Cylinder
// But… it does not give the correct answer.
```

What happens?



Exercise 2

- Correct CylinderThread, which has an error:
  - It splits the integration work across 6 threads
  - The threads each contribute their part of the integral to a static variable in CylinderThread
  - However, the threads may not have all completed when main() outputs the answer
- Use isAlive() or join() to wait until all parts of the integral have been computed
  - You will need to keep track of all the thread objects you created, perhaps in an array or ArrayList
  - join() and isAlive() throw InterruptedException
  - You must put calls to them in a try-catch block
- Your changes are all in main()

Interface Runnable

- Suppose Cylinder extends another class
  - It still contains the integration method that takes a long time to compute
  - So we still want to put each computation in a separate thread
- We use the following class definition:

```
public class Cylinder2 extends EngrComponent
  implements Runnable {
```

  - Instead of: `extends Thread`
- We use the following constructor:

```
Thread t = new Thread(new Cylinder2(radius));
```

  - Instead of:

```
CylinderThread2 t = new CylinderThread2(radius);
```

Exercise 3

- Modify the solution to exercise 2 to implement Runnable instead of extending Thread. The changes are minor:
  - Copy and rename the exercise 2 solution to a different class name (e.g., CylinderRunnable)
  - Inherit from EngrComponent and Runnable
    - Change class definition, as on previous slide
    - Modify constructor to also call superclass constructor
  - main(): change use of constructor, as on previous slide

```
public class EngrComponent {          // In download
  private int ID;
  private static int nextID= 0;
  public EngrComponent() {ID= nextID++; }
  public final int getID() { return ID;}
}
```

1.00 / 1.001 / 1.002 Introduction to Computers and Engineering Problem Solving
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