Today’s Topics

- Introduction to Java threads
- Swing and threading
- Lab 5 Hints
Java Threads

- A “thread of execution” is a single, sequential flow of execution through your program
  - Threads have a beginning and an end
  - A thread does only one thing at a time

- All programs have at least one thread of execution
  - The “main thread” runs your `main()` method

- Multi-threaded programs have several threads of execution
  - They can do multiple things “at the same time”
Standard Java Threads

- The Java VM uses multiple threads
  - The main thread runs your program
  - The garbage-collector may use a thread
  - Java AWT/Swing starts its own thread
    - For event-dispatching
  - Some Java library classes use threads internally

- You can start your own threads too
  - This week’s lab doesn’t need them (phew!)
A thread can have local resources; only used by the thread
Threads can also share resources between each other
  - This can lead to many problems
One big problem: interleaved access
  - Example: count is a shared variable. Assume count = 15.
  - Two threads executing count = count + 1;
Locking Shared Resources

- Shared resources must be manipulated **atomically**
  - Only allow one thread to access shared resource at a time
  - Shared resources can be locked by a thread

- If threads can lock multiple shared resources, **deadlock** can occur
  - Thread A locks resource R1
  - Thread B locks resource R2
  - Thread A tries to lock resource R2…
  - Thread B tries to lock resource R1…
  - **Locking order** is the issue here.
Swing and Thread-Safety

- Swing has its own thread for event handling
  - the event dispatcher thread
- ...but, Swing components aren’t thread-safe!
- To be thread-safe in Swing:
  - Once a Swing component has been made visible, only interact with it from event dispatcher thread.
- Initializing a Swing UI from another thread is fine (it hasn’t been made visible yet)
  - e.g. usually done from the main thread
Long-Running Tasks and Swing

- Very common to have UIs performing long-running tasks
  - e.g. web browsers frequently have large files to download when displaying a web page, etc.

- Problem:
  - If long-running operation is performed on the event-dispatch thread, can’t process events!
  - There is only one event-dispatch thread. If it’s tied up with work, the UI will freeze until work is done.
Swing provides a solution to this issue:
- `javax.swing.SwingWorker`

Can dispatch a long-running task on a worker thread, in the background
- Task won’t tie up the event-dispatch thread
- Can still interact with the user interface while task is being completed

When task is finished, SwingWorker’s results are made available on event-dispatch thread
- Can update user interface with results of task
SwingWorker Details

- SwingWorker is an abstract class
  - Must be subclassed to perform specific tasks

- Several important methods:
  - protected Object doInBackground()
    - Implement this method to perform the long-running task
    - This method is never called on the event-dispatch thread
    - (uses a small thread-pool of worker threads)
  - protected void done()
    - This method is always called on event-dispatch thread!
    - Implement this method to update your Swing GUI with results of long-running task
SwingWorker<T,V> Details

- **SwingWorker** is also a generic class
  - Can (and should) specify type parameters

- Type **T** specifies what `doInBackground()` returns
  - `protected T doInBackground()`

- If your `doInBackground()` implementation doesn’t return anything:
  - Just set **T** to `Object`, and return `null`
SwingWorker<T,V> Details (2)

- Type V represents *intermediate state*
  - Some tasks generate intermediate results that need to be represented in the user interface
    - (Many tasks do not, so not every SwingWorker subclass uses this functionality)
  - In these cases, task’s `doInBackground()` calls:
    - `protected void publish(V[] chunks)`
    - Whenever intermediate state must be published, this can be called
  - Causes this method to be called on the event-dispatcher thread:
    - `protected void process(List<V> chunks)`
SwingWorker<T, V> Details (3)

- As before, if your `SwingWorker` task doesn’t publish intermediate state:
  - Just set `V` to `Object`, and don’t use `publish()` method
Shutting Down a GUI Application

- In Java AWT, closing a `Frame` just hides the window
  - If you don’t do something special, application keeps running
  - Have to register a `WindowListener` impl to exit application when window closes

- In Swing, `JFrame` gives you options
  ```java
  JFrame f = new JFrame("My App!");
  f.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
  ```
  - Default is `HIDE_ON_CLOSE`; like AWT Frame
Arrays in Java

- In Java, arrays are also objects
  - Some different syntax though!

- Example:
  ```java
  int[] myInts = new int[10]; // Allocate the array.
  for (int i = 0; i < myInts.length; i++) {
    myInts[i] = 100 * i; // Store stuff in it.
  }
  ```
  - In Java, *all* arrays are dynamically allocated
  - Elements are accessed with brackets (like C/C++)
  - Arrays expose a length field, indicating their size
  - length is read-only (of course)
Array Variables

- Array-types have brackets after type, not after variable name
  - `String[] names;` vs. `String names[];`
  - Latter form is supported, but is discouraged.

- Can declare array-variables without assigning
  - `boolean[] flags;` // Array of boolean values
  - `float[] weights;` // Array of floats

- Must initialize them before using
  - Can allocate new array with `new type[size];`
    - `size` can be zero! Called an “empty array.”
  - Can assign an existing array to the variable
    - (Java arrays are basically objects with additional syntax)
  - Can set to `null` too!
More Array Initialization

- Can also assign specific values to arrays
  
  ```java
  String[] colorNames = {
      "puce", "mauve", "fuchsia", "chartreuse", "umber"
  };
  // colorNames.length == 5
  ```

- Syntactic sugar for the initialization operations
- Can still reassign and reinitialize such arrays
  - `colorNames` is a reference to an array of `String` objects
Arrays of Objects

- Arrays of objects initially contain null values
  - Array initialization does not initialize object-references
  - Must do that in a separate step

Example:

```java
// Allocate an array of 20 point-references
Point2d[] points = new Point2d[20];

// Make a new Point2d object for each elem
for (int i = 0; i < points.length; i++)
    points[i] = new Point2d();
```
Arrays of Arrays

- Arrays can contain other arrays
  
  ```java
  int[][] nums2d; // Array of arrays of ints.
  ```

- First the array-of-arrays is allocated:
  
  ```java
  nums2d = new int[20][];
  ```

  - Each element of `nums2d` is of type `int[]`.

- Next, each inner array is allocated
  
  ```java
  for (int i = 0; i < nums2d.length; i++)
      nums2d[i] = new int[50];
  ```

- When size is fixed, Java provides a shortcut
  
  ```java
  int[][] nums2d = new int[20][50]; // Same thing!
  ```
More Arrays of Arrays

- Inner arrays can be different sizes, if need be
  ```java
  int[][] reducedMatrix;
  reducedMatrix = new int[20][];
  for (int i = 1; i <= 20; i++)
      reducedMatrix[i] = new int[i];
  ```
  - Can’t do this with the shortcut syntax

- Can also specify nested initial values
  ```java
  double[][] weights = {
      {3.1,2.6}, {1.5,4.4,-3.6}, null, {6.2}
  };
  ```
Copy Arrays

- Use `System.arraycopy()` to copy one array to another efficiently

- Can use `clone()` method to duplicate array
  - Result’s type is `Object`; must cast to proper type
    ```java
    int[] nums = new int[35];
    ...
    int[] numsCopy = (int[]) nums.clone();
    ```
  - Copy is **shallow** – only top-level array is copied!
    - If array of objects, the objects are not cloned
    - If array of arrays, subarrays are not cloned either
Next Week

- Java Sockets API
- String processing