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[module lab 2.2]

GUI FRAMEWORKS & CONCURRENCY

GUI FRAMEWORKS & CONCURRENCY

- Once upon a time GUI applications were single-threaded...
  - GUI events processed by a “main event loop”
- ..modern GUI Frameworks are not so different
  - creating a dedicated *event dispatch thread* (EDT) for handling GUI events
  - the thread fetches events off a queue and dispatches them to application-defined event handlers
- Most of the modern GUI Frameworks are single-threaded
  - Java, QT, NextStep, Mac OS Cocoa, XWindow...
- Multithreaded GUI as a “failed dream” [*]
  - many attempts, failed due to the generation of problems with race conditions and deadlock

[*] referred in this way by Sun VP Graham Hamilton in his blog
http://weblogs.java.net/blog/kgh/archive/2004/10

MULTITHREADED GUI FRAMEWORKS: THE PROBLEM

- Clash between input event processing and OO modelling of GUI components
  - that can easily lead to *deadlocks* and *race conditions*
- Inconsistent lock ordering
  - in managing user-initiated actions and application-initiated actions
    - user actions “bubble up” from OS to the application
      - OS mouse click ->mouse click event of the GUI toolkit -> high-level event of the application listener...
    - application-actions “bubble down” from application to action
      - changing background color of a component at the application level -> disptached to component class -> dispatched to OS for rendering,,,
    - most of the actions need to lock objects
  - model-view-control (MVC) pattern
    - the control calls into the model, which notifies the view that something has changed...
    - ...but the controller calls also the view, which may in turn call back into the model to query the model state

SINGLE-THREADED GUI

- Achieving thread-safety via thread-confinement
  – all GUI objects are accessed exclusively by the event thread
    - including visual components and data models
  – the application developer must make sure that these objects are properly confined
- Sequential event processing
  – events like kind of task to be processed sequentially by the event thread
- Problems and challenges
  – if one task takes long time to execute, other task must wait
    - blocking the overall GUI
  > ...so tasks that execute in the event-thread must return quickly
  – to initiate a long-term task a separate thread must be used
    - es: spell-checking a document, searching the file system
  > ...but typically a long-term task must provide a visual feedback for indicating progress or when it completes
    - and this code need to be executed by the event thread...

THREAD CONFINEMENT IN SWING

- All Swing components (such as JButton and JTable) and data models (e.g. Table Model and Tree Model) are confined to the event thread
  - any code that access these objects must run in the event thread
- Exceptions
  - Swing methods that can be safely called from any thread
    - clearly identified in the Javadoc as thread-safe

THREAD-SAFE SWING METHODS

- Thread-Safe methods
  - **`SwingUtilities.isEventDispatchThread`**
    - to check if the current thread is the event thread
  - **`SwingUtilities.invokeLater`**
    - to schedule a `Runnable` for execution on the event thread
  - **`SwingUtilities.invokeAndWait`**
    - to schedule a `Runnable` task for execution on the event thread, blocking the current thread until it completes
    - cannot be called by the event thread
  - methods to enqueue and repaint or revalidation request on the event queue
  - methods for adding or removing listeners
    - can be called from any thread, but listeners will always be invoked in the event thread
- The swing event thread can be thought as a single-thread Executor that processes tasks from the event queue
  - `invokeLater` and `invokeAndWait` used to submit new tasks to execute

A SIMPLE GUI EXECUTOR

- Executor delegating tasks to `SwingUtilities` for executions

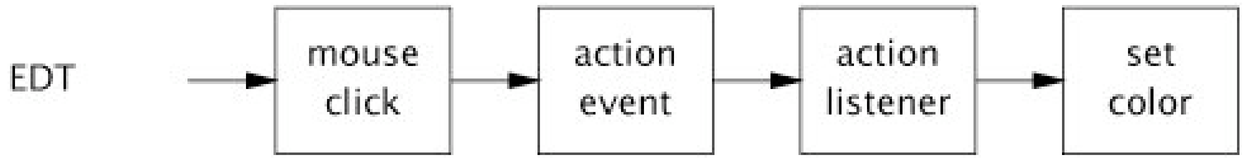
```
public class GuiExecutor extends AbstractExecutorService {
    // Singletons have a private constructor and a public factory
    private static final GuiExecutor instance = new GuiExecutor();

    private GuiExecutor() { }

    public static GuiExecutor instance() { return instance; }

    public void execute(Runnable r) {
        if (SwingUtilities.isEventDispatchThread())
            r.run();
        else
            SwingUtilities.invokeLater(r);
    }

    // Plus trivial implementations of lifecycle methods
}
```

SHORT-RUNNING GUI TASKS

- Can be executed directly by the event thread
- Simple example

```
final Random random = new Random();
final JButton button = new JButton("Change Color");
...
button.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        button.setBackground(new Color(random.nextInt()));
    }
});
```

- The control never leaves the event thread
  - the event originates in the GUI toolkit, is delivered to the application, the application modifies the GUI in response to user's action



LONG-RUNNING TASKS

- Some of the processing must be *offloaded* to another thread
  - exploiting executors
- Two main cases
  - long-term task without visual feedbacks
    - simple case, quite unfrequent
  - long-term task with visual feedbacks
    - complex case, most frequent

BINDING A TASK WITHOUT VISUAL FEEDBACKS

- Exploiting a simple separated executor (or thread)
- Example:

```
ExecutorService backgroundExec = Executors.newCachedThreadPool();
...
button.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        backgroundExec.execute(new Runnable() {
            public void run() { doBigComputation(); }
        });
}});
```

LONG-RUNNING TASK WITH USER FEEDBACKS

- The long-running task must submit another task to run in the event thread whenever the user interface must be updated
- Example:

```
button.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        button.setEnabled(false);
        label.setText("busy");
        backgroundExec.execute(new Runnable() {
            public void run() {
                try {
                    doBigComputation();
                } finally {
                    GuiExecutor.instance().execute(new Runnable() {
                        public void run() {
                            button.setEnabled(true);
                            label.setText("idle");
                        }
                    });
                }
            }
        });
    }
});
```

SwingWorker

- Java 6.0 provides auxiliary classes for making it easier to program complex long-term tasks that can interact with the GUI
- `SwingWorker` class
  - provide a direct support for task cancellation, completion notification and progress indication

```
class SwingWorker<T,V> implements RunnableFuture<T> {
  ...
  // to be overridden
  protected abstract  T doInBackground();
  protected  void     done()

  protected final void publish(V... chunks)
  protected void process(List<V> chunks);
  ...
  // to be directly used
  boolean cancel(boolean mayInterruptIfRunning);
  protected  void setProgress(int progress);
  ...
}
```

TASK EXECUTION AND INTERFACE UPDATE

- Support for asynchronous task execution & consequent interface update
  - `doInBackground`
    - encapsulate the computational body of the task to be executed asynchronously w.r.t. GUI activity, computing a result or throwing an exception if unable to do so
    - executed by some thread, not by the Swing EDT
  - `done`
    - encapsulate the action to do on the GUI when the task completed
    - executed by the Swing EDT
- Support for asynchonous update of interfaces
  - `publish(V... chunks)`
    - used from inside doInBackground to deliver intermediate results for processing on the Event Dispatch Thread inside the process method
  - `process(List<V> chunks);`
    - receives data chunks from the publish method asynchronously on the EDT

AN EXAMPLE: SWING WORKER TEST

```
class CounterTask extends SwingWorker<Integer, Integer> {

  protected Integer doInBackground() throws Exception {
    int i = 0;
    int sum = 0;
    int maxCount = 10;
    while (!isCancelled() && i < maxCount) {
      sum+=i;
      i++;
      publish(new Integer[] { i });
      setProgress(100 * i / maxCount);
      Thread.sleep(1000);
    }
    return sum;
  }

  protected void process(List<Integer> chunks) {
    for (int i : chunks)
      System.out.println("Step "+i);
  }

  protected void done() {
    if (isCancelled()){
      System.out.println("Task cancelled.");
    } else {
      System.out.println("Task completed.");
    }
  }
}
```

```java
public class SwingWorkerTest {
  public static void main(String[] args) {
    JTextArea textArea = new JTextArea(10, 20);
    JProgressBar progressBar = new JProgressBar(0, 100);
    CounterTask task = new CounterTask();

    JButton startButton = new JButton("Start");
    startButton.addActionListener(new ActionListener() {
       public void actionPerformed(ActionEvent e) { task.execute();}});

    JButton cancelButton = new JButton("Cancel");
    cancelButton.addActionListener(new ActionListener() {
       public void actionPerformed(ActionEvent e) { task.cancel(true); }});

    task.addPropertyChangeListener(new PropertyChangeListener() {
       public void propertyChange(PropertyChangeEvent evt) {
           if ("progress".equals(evt.getPropertyName())) {
             progressBar.setValue((Integer) evt.getNewValue());
           }
       }
    });

    JPanel buttonPanel = new JPanel();
    buttonPanel.add(startButton);
    buttonPanel.add(cancelButton);
    JPanel cp = new JPanel();
    LayoutManager layout = new BoxLayout(cp, BoxLayout.Y_AXIS);
    cp.setLayout(layout);
    cp.add(buttonPanel);
    cp.add(new JScrollPane(textArea));
    cp.add(progressBar);
    JFrame frame = new JFrame("SwingWorker Test");
    frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
    frame.setContentPane(cp);
    frame.pack();
    frame.setVisible(true);
  }
}
```