Lecture 16
Events, Listeners, Callbacks
The limits of scaling

What prevents us from building huge, intricate structures that work perfectly and indefinitely?

– Not just friction
– Not just gravity
– Not just wear-and-tear

… it’s the difficulty of managing complexity!

So we split designs into sensible parts and reduce interaction among the parts

– More *cohesion* within parts
– Less *coupling* across parts
Design exercise #1

Write a typing-break reminder program

*Offer the hard-working user occasional reminders of the perils of Repetitive Strain Injury, and encourage the user to take a break from typing.*
Design exercise #1

Write a typing-break reminder program

Offer the hard-working user occasional reminders of the perils of Repetitive Strain Injury, and encourage the user to take a break from typing.

Naive design:
– Make a method to display messages and offer exercises
– Make a loop to call that method from time to time

(Let's ignore multithreaded solutions for this discussion)
public class TimeToStretch {
    public void run() {
        System.out.println("Stop typing!");
        suggestExercise();
    }
    public void suggestExercise() {
        ...
    }
}
public class Timer {
    private TimeToStretch tts = new TimeToStretch();
    public void start() {
        while (true) {
            ...
            if (enoughTimeHasPassed) {
                tts.run();
            }
            ...
        }
    }
}
**Main class puts it together**

class *Main* {
    public static void *main*(String[] *args*) {
        Timer *t* = new Timer();
        *t*.start();
    }
}

This program, as designed, will work...

But we can do better
Module dependency diagram (MDD)

An arrow in a module dependency diagram (MDD) indicates “depends on” or “knows about”
– Simplistically: “any name mentioned in the source code”

What’s wrong with this diagram?
– Does Timer really need to depend on TimeToStretch?
– Is Timer re-usable in a new context?
Decoupling

Timer needs to call the run method

- Timer does *not* need to know what the run method does

Weaken the dependency of Timer on TimeToStretch

- Introduce a weaker specification, in the form of an interface or abstract class

```java
class TimerTask {
    public abstract void run();
}
```

Timer only needs to know that something (e.g., TimeToStretch) meets the TimerTask specification
public class TimeToStretch extends TimerTask {
    public void run() {
        System.out.println("Stop typing!");
        suggestExercise();
    }

    public void suggestExercise() {
        ...
    }
}
public class Timer {
    private TimerTask task;
    public Timer(TimerTask task) {
        this.task = task;
    }
    public void start() {
        while (true) {
            ...
            task.run();
        }
    }
}

Main creates a TimeToStretch object and passes it to Timer:
    Timer t = new Timer(new TimeToStretch());
    t.start();
Module dependency diagram (version 2)

- Timer depends on TimerTask, not TimeToStretch
  - Unaffected by implementation details of TimeToStretch
  - Now Timer is much easier to reuse
    - Main depends on the constructor for TimeToStretch
- Main still depends on Timer (is this necessary?)
The callback design pattern

An alternative: use a callback to *invert the dependency*

**TimeToStretch** creates a **Timer**, and passes in a reference to *itself* so the **Timer** can *call it back*

- This is a *callback* – a method call from a module to a client that it notifies about some condition

The callback *inverts a dependency*

- Inverted dependency: **TimeToStretch** depends on **Timer** (not vice versa)
  - Less obvious coding style, but more “natural” dependency
- Side benefit: **Main** does not depend on **Timer**
Callbacks

Callback: “Code” provided by client to be used by library
  • In Java, pass an object with the “code” in a method

Synchronous callbacks:
  • Examples: HashMap calls its client’s hashCode, equals
  • Useful when library needs the callback result immediately

Asynchronous callbacks:
  • Examples: GUI listeners
  • Register to indicate interest and where to call back
  • Useful when the callback should be performed later, when some interesting event occurs
public class TimeToStretch extends TimerTask {
    private Timer timer;
    public TimeToStretch() {
        timer = new Timer(this);
    }
    public void start() {
        timer.start();
    }
    public void run() {
        System.out.println("Stop typing!");
        suggestExercise();
    }
    ...
}
Main (version 3)

```java
TimeToStretch tts = new TimeToStretch();
tts.start();
```

- Uses a callback in `TimeToStretch` to invert a dependency
- This MDD shows the inversion of the dependency between `Timer` and `TimeToStretch` (compare to version 1)
Decoupling and design

• A good design has dependences (coupling) only where it makes sense

• While you design (*before* you code), examine dependences

• Don’t introduce unnecessary coupling

• Coupling is an easy temptation if you code first
  – Suppose a method needs information from another object:
  – If you hack in a way to get it:
    • The hack might be easy to write
    • It will damage the code’s modularity and reusability
    • More complex code is harder to understand
Design exercise #2

A program to display information about stocks
  – Stock tickers
  – Spreadsheets
  – Graphs

Naive design:
  – Make a class to represent stock information
  – That class updates all views of that information (tickers, graphs, etc.) when it changes
• Main class gathers information and stores in Stocks
• Stocks class updates viewers when necessary

Problem: To add/change a viewer, must change Stocks
Better: insulate Stocks from the vagaries of the viewers
Weaken the coupling

What should \textbf{Stocks} class know about viewers?
  – Only needs an \texttt{update} method to call with changed data
  – Old way:

```java
void updateViewers() {
    ticker.update(newPrice);
    spreadsheet.update(newPrice);
    graph.update(newPrice);
    // Edit this method to
    // add a new viewer. 😞
}
```
Weaken the coupling

What should Stocks class know about viewers?

- Only needs an **update** method to call with changed data
- New way: The “observer pattern”

```java
interface PriceObserver {
    void update(PriceInfo pi);
}

class Stocks {
    private List<PriceObserver> observers;
    void addObserver(PriceObserver pi) {
        observers.add(pi);
    }
    void notifyObserver(PriceInfo i) {
        for (PriceObserver obs : observers)
            obs.update(i);
    }
    ...
}
```
The observer pattern

- **Stocks** not responsible for viewer creation
- **Main** passes viewers to **Stocks** as *observers*
- **Stocks** keeps list of **PriceObservers**, notifies them of changes

- **Issue:** *update* method must pass enough information to (unknown) viewers
A different design: pull versus push

- The Observer pattern implements *push* functionality
- A *pull* model: give viewers access to *Stocks*, let them extract the data they need

“Push” versus “pull” efficiency can depend on frequency of operations (Also possible to use both patterns simultaneously.)
Another example of Observer pattern

```java
// Represents a sign-up sheet of students
public class SignupSheet extends Observable {
    private List<String> students
        = new ArrayList<String>();

    public void addStudent(String student) {
        students.add(student);
        setChanged();
        notifyObservers();
    }

    public int size() {
        return students.size();
    }

    // Part of the JDK
    SignupSheet inherits many methods including:
    void addObserver(Observer o)
    protected void setChanged()
    void notifyObservers()
}
```
public class SignupObserver implements Observer {
    // called whenever observed object changes
    // and observers are notified
    public void update(Observable o, Object arg) {
        System.out.println("Signup count: "+((SignupSheet)o).size());
    }
}

Part of the JDK

Not relevant to us

cast because Observable is not generic 😞
Registering an observer

```java
SignupSheet s = new SignupSheet();
s.addStudent("billg");
  // nothing visible happens
s.addObserver(new SignupObserver());
s.addStudent("torvalds");
  // now text appears: "Signup count: 2"
```

Java's “Listeners” (particularly in GUI classes) are examples of the Observer pattern

(Feel free to use the Java observer classes in your designs – if they are a good fit – but you don’t have to use them)
User interfaces: appearance vs. content

It is easy to tangle up *appearance* and *content*
- Particularly when supporting direct manipulation (e.g., dragging line endpoints in a drawing program)
- Another example: program state stored in widgets in dialog boxes

Neither can be understood easily or changed easily

This destroys modularity and reusability
- Over time, it leads to bizarre hacks and huge complexity
- Code must be discarded

Callbacks, listeners, and other patterns can help