Lecture 17
Events, Listeners, Callbacks

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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.

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)

TimeToStretch suggests exercises

```java
public class TimeToStretch {
    public void run() {
        System.out.println("Stop typing!");
        suggestExercise();
    }

    public void suggestExercise() {
        ...
    }
}
```
**Timer calls run() periodically**

```java
public class Timer {
    private TimeToStretch tts = new TimeToStretch();
    public void start() {
        while (true) {
            ... 
            if (enoughTimeHasPassed) {
                tts.run();
            }
            ... 
        }
    }
}
```

**Main class puts it together**

```java
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

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

Timer only needs to know that something (e.g., TimeToStretch) meets the TimerTask specification
**TimeToStretch (version 2)**

public class TimeToStretch extends TimerTask {
    public void run() {
        System.out.println("Stop typing!");
        suggestExercise();
    }

    public void suggestExercise() {
        ...
    }
}

**Timer (version 2)**

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

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

Weaken the coupling

What should Stocks class know about viewers?
- Only needs an 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);
    }
    ...
}
```

Module dependency diagram

- 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
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

Another example of Observer pattern

```java
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();
    }
}
```

An Observer

```java
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());
    }
}
```

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.)
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