CSE 331
Software Design & Implementation

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Events, Listeners, and Callbacks
The limits of scaling

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

– No friction
– No gravity
– No wear-and-tear

… it’s the difficulty of understanding them

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 multi-threaded solutions for this discussion)
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

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
public abstract 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() {
            ...
        }
    }
Timer (version 2)

```java
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?)

```
Main
  ↓
TimerTask
  ↓
TimeToStretch
  ↑
Timer
```

→ Dependence
↑ Subclassing
The callback design pattern

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

Use a callback to invert 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 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);
    }
    ...
}
```

Register a callback

Do the callbacks
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

// 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();
    }
    ...}

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());
    }
}
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