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)

Timer calls run() periodically

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

TimeToStretch suggests exercises

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

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
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?

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?)

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

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) {
      ...  
      task.run();
    }
  }
}

Main creates a TimeToStretch object and passes it to Timer:

Timer t = new Timer(new TimeToStretch());
t.start();

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

dependence
Subclassing
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

TimeToStretch (version 3)

```java
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)

```
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

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
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.
}
```

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

```java
Create viewers and get observers
Main
Stocks
StockTicker
Spreadsheet
StockGraph
Create (or be) observers
```

• 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()
```

An Observer

```
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
Part of the JDK
```
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