
CSE 331

Software Design & Implementation

Hal Perkins

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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 multithreaded solutions for this discussion)

TimeToStretch suggests exercises

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

Timer calls run () periodically

```
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();  
    }  
}
```

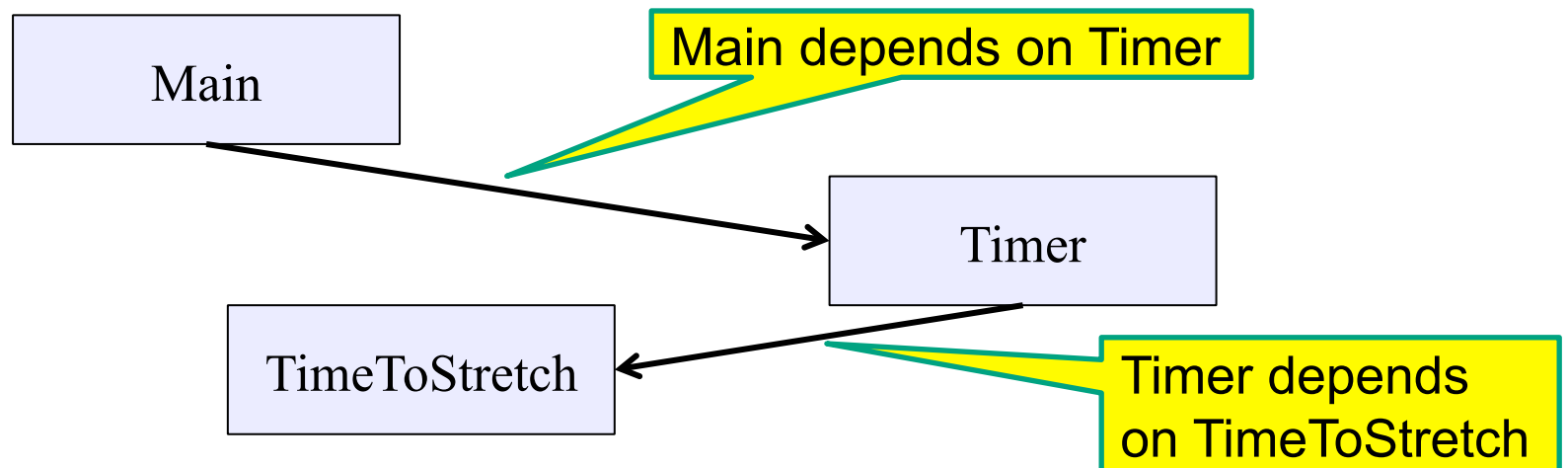
This program, as designed, will work...

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

```
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)

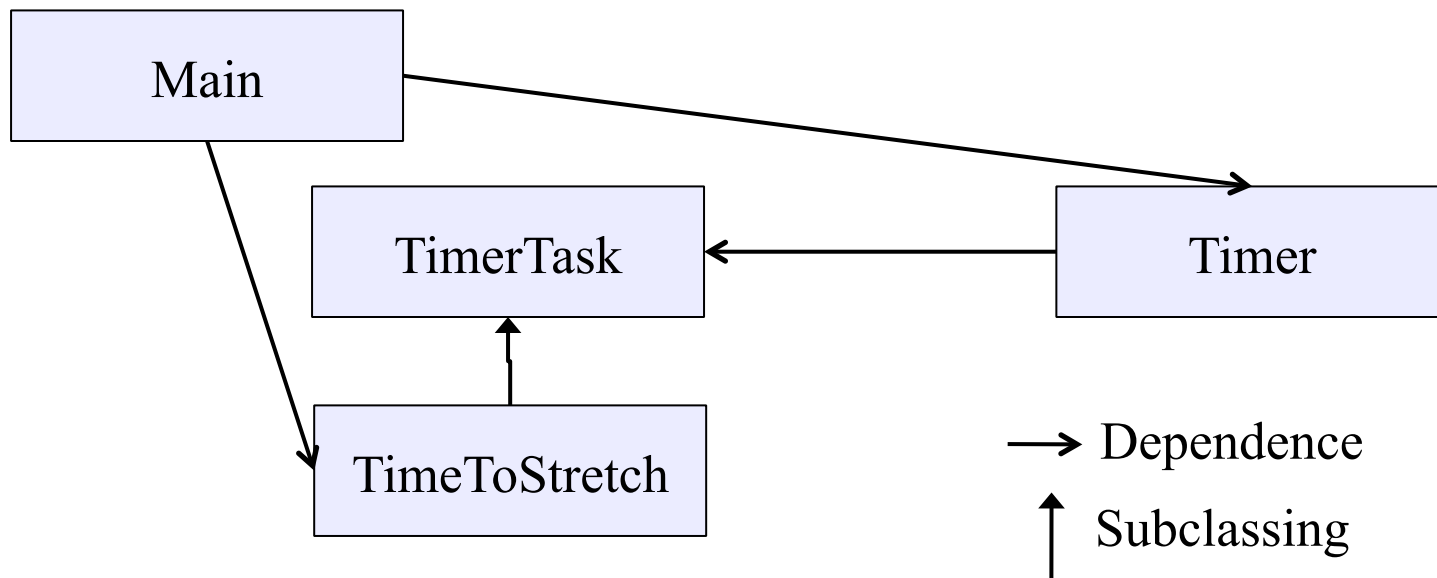
```
public class Timer {
    private TimerTask task;
    public Timer(TimerTask task) {
        this.task = task;
    }
    public void start() {
        while (true) {
            ...
            task.run();
        }
    }
}
```

Main creates a `TimeToStretch` object and passes it to `Timer`:

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

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

TimeToStretch (version 3)

```
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();
    }
    ...
}
```

Register interest
with the timer

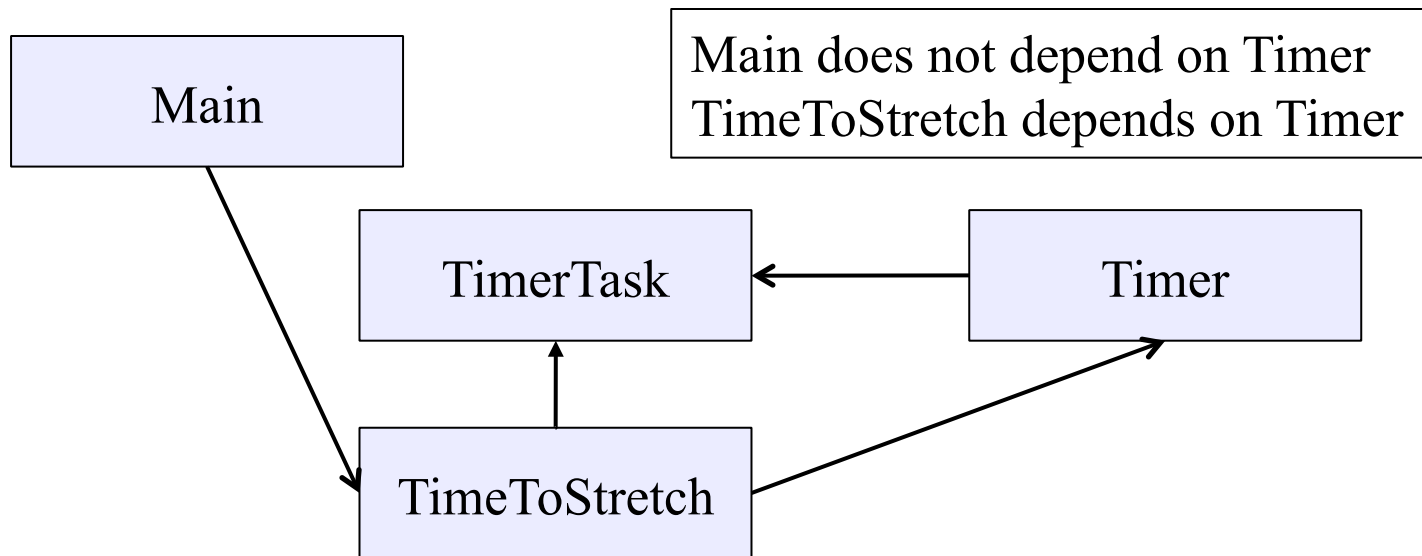
Callback entry point

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

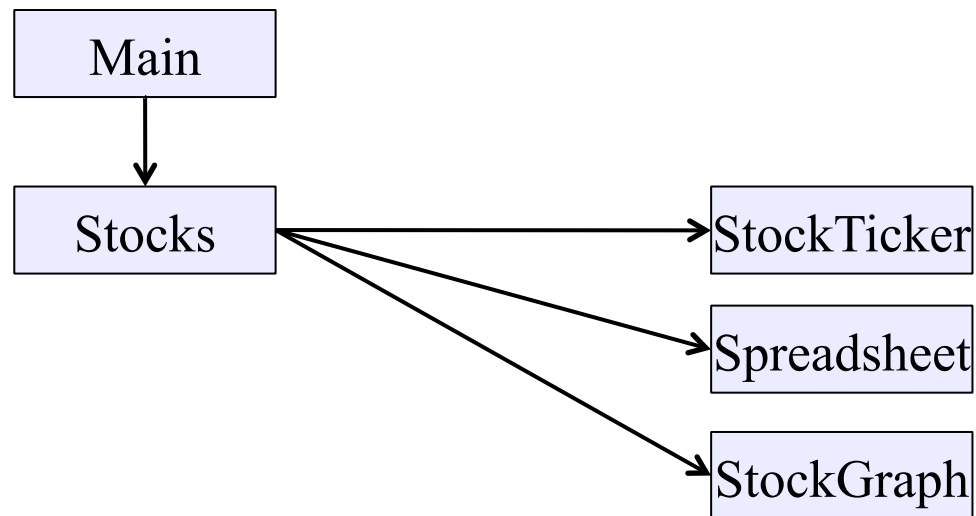
- Stock tickers
- Spreadsheets
- Graphs

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:

```
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”

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

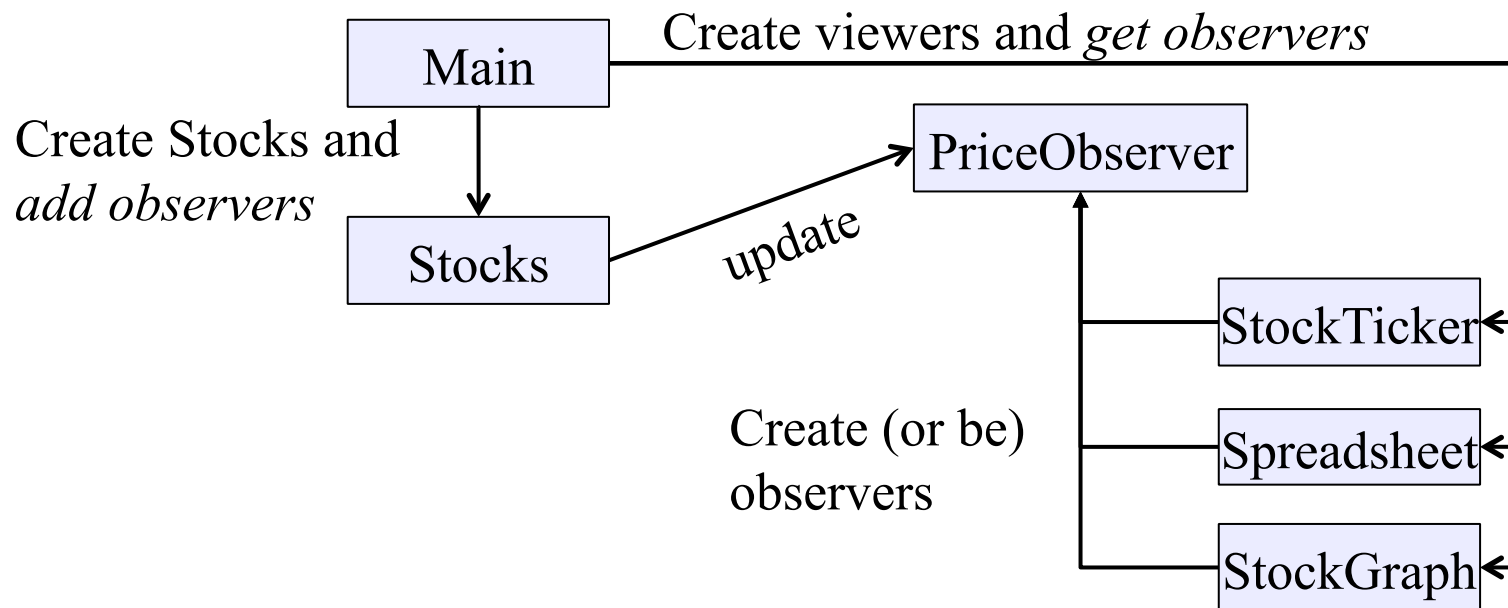
class Stocks {
    private List<PriceObserver> observers;
    void addObserver(PriceObserver pi) {
        observers.add(pi);
    }
    void notifyObserver(PriceInfo i) {
        for (PriceObserver obs : observers)
            obs.update(i);
    }
    ...
}
```

Register a
callback

Do the callbacks

The observer pattern

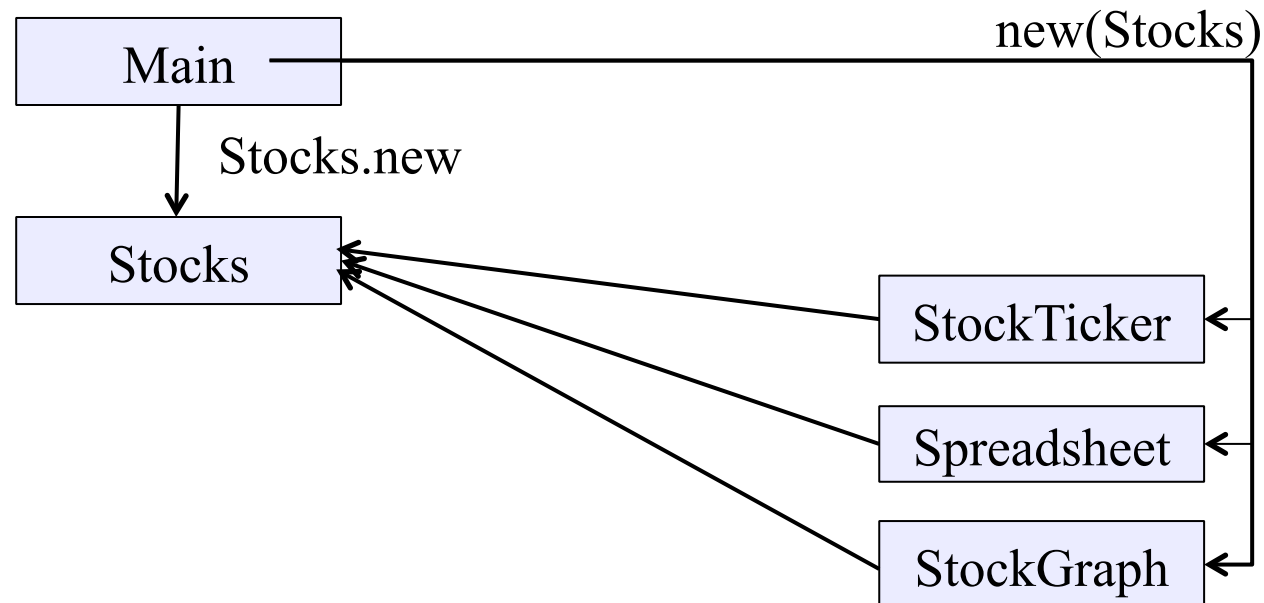
- **Stocks** not responsible for viewer creation
- **Main** passes viewers to **Stocks** as *observers*
- **Stocks** keeps list of **PriceObservers**, notifies them of changes



- Issue: **update** method must pass enough information to (unknown) viewers

A different design: pull versus push

- The Observer pattern (last slide) implements *push* functionality
- Alternative: 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();
    }
    ...
}
```

Part of the
JDK

`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

cast because
Observable is
not generic ☹

Registering an observer

```
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