CSE 331
Software Design & Implementation

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Events, Listeners, and Callbacks

(Based on slides by Mike Ernst, Dan Grossman, David Notkin, Hal Perkins)

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();
  }
}
```

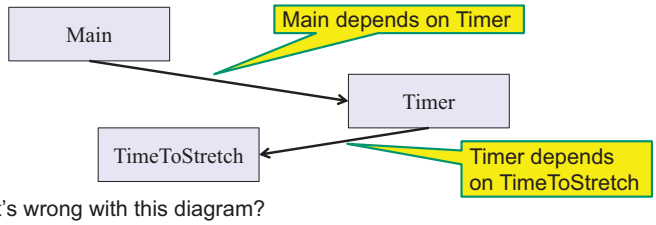
This program, as designed, will work...

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)

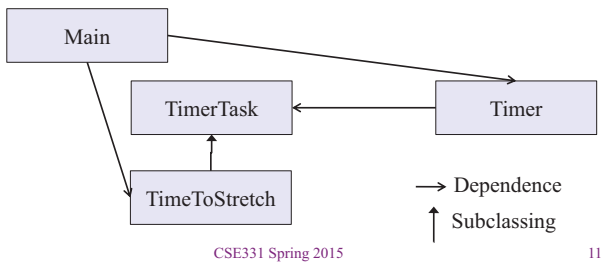
```
public class Timer {
  private TimerTask task;
  public Timer(TimerTask task) {
     this.task = task;
  }
  public void start() {
    while (true) {
      ...
      task.run();
    }
  }
}
```

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();
    }
    ...
}
```

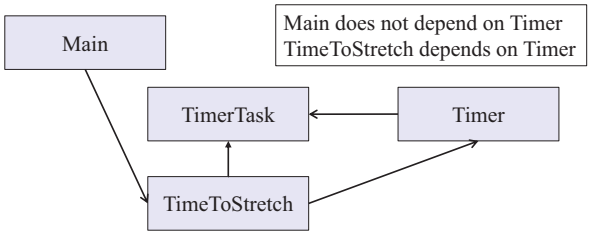
Register interest with the timer

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

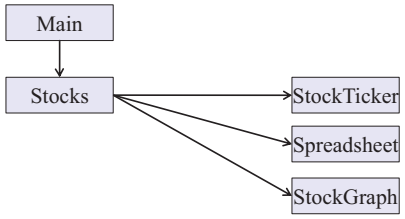
Design exercise #2

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"

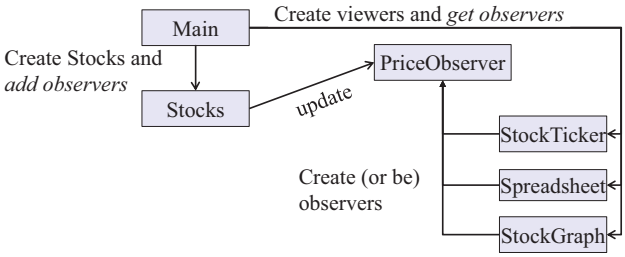
```
interface PriceObserver {
  void update(PriceInfo pi);
}

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

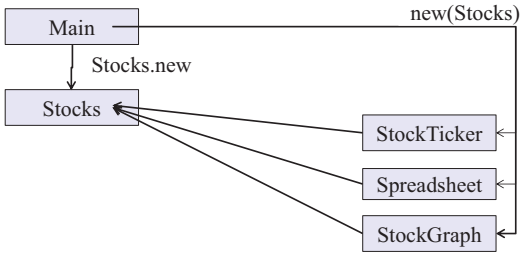
- **Stocks** not responsible for viewer creation
- **Main** passes viewers to **Stocks** as *observers*
- **Stocks** keeps list of **PriceObservers**, notifies them of changes



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

A different design: pull versus push

- The Observer pattern 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();
  }
  …
}
```

Part of the JDK

SignupSheet *inherits* many methods including:
void addObserver(Observer o)
protected void setChanged()
void notifyObservers()

An Observer

Part of the JDK

```
public class SignupObserver implements Observer {
  // called whenever observed object cha
  // and observers are notified
  public void update(Observable o, Object arg) {
    System.out.println("Signup count: "
                       + ((SignupSheet)o).size());
  }
}
```

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