CSE 331
Software Design & Implementation

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Events, Listeners, and Callbacks

(slides by Mike Ernst and David Notkin)

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 parts with as little interaction as possible (coupling, cohesion)

A design exercise

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:

Write a method to display messages and offer exercises.

Write a loop to call that method from time to time.

(Let's ignore multi-threaded 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

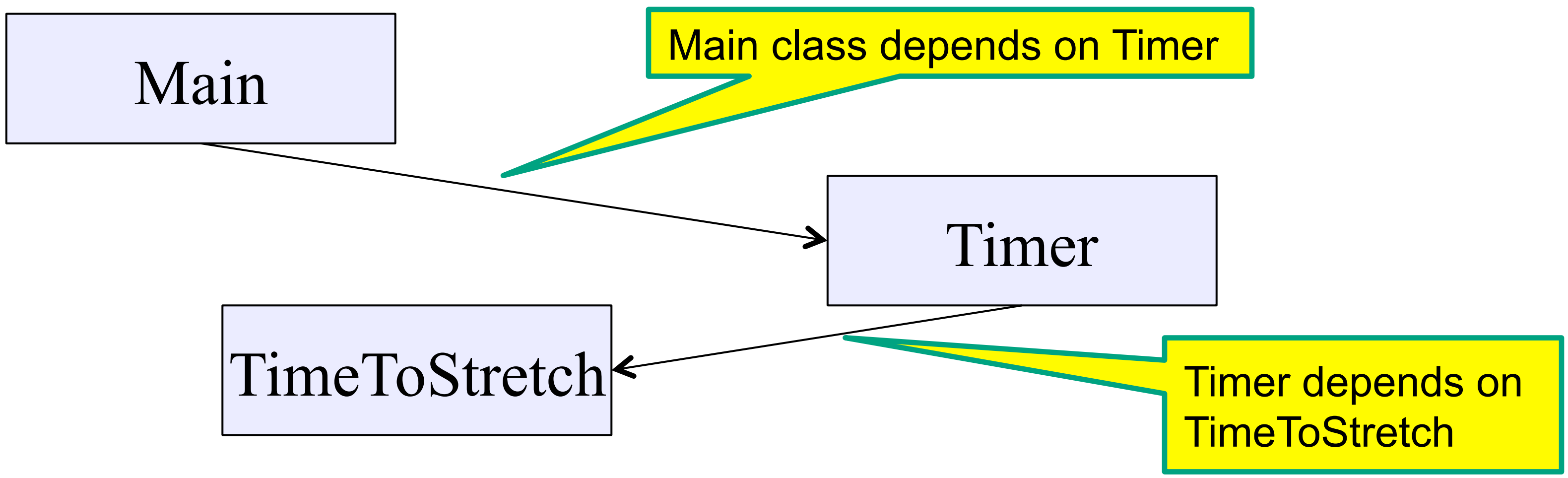
```
class Main {
  public static void main(String[] args) {
    Timer t = new Timer();
    t.start();
  }
}
```

This 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`** doesn't 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 the **`TimeToStretch`** object and passes it to **`Timer`**:

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

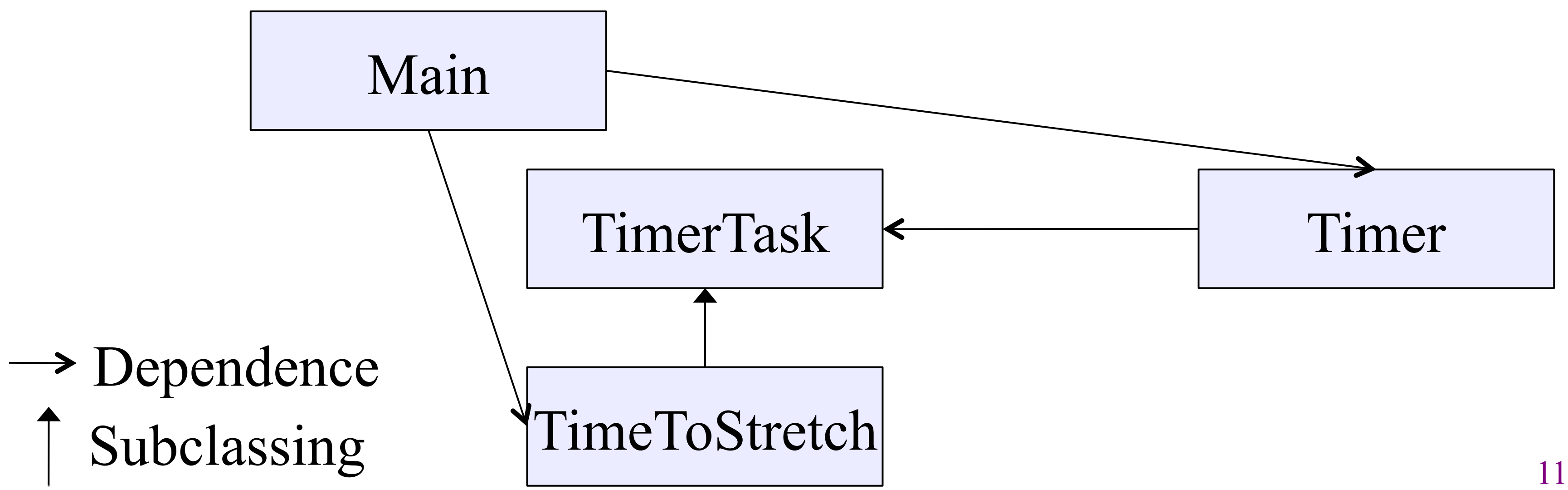
Module dependency diagram (version 2)

`Main` still depends on **`Timer`** (is this necessary?)

`Main` depends on the constructor for **`TimeToStretch`**

`Timer` depends on **`TimerTask`**, not **`TimeToStretch`**

- Unaffected by implementation details of **`TimeToStretch`**
- Now **`Timer`** is much easier to reuse



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

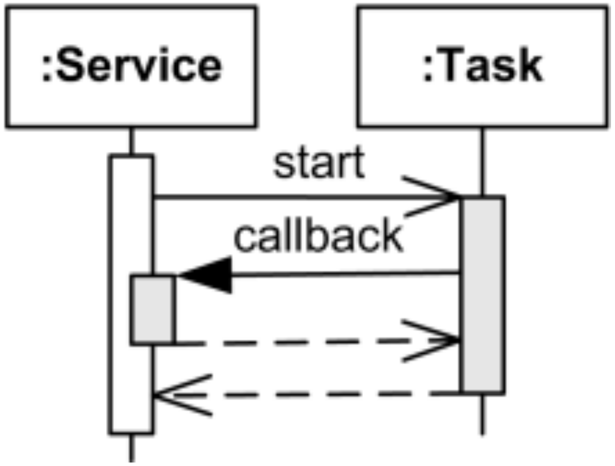
- Inverted dependency: **`TimeToStretch`** depends on **`Timer`** (not vice versa).
- Side benefit: **`Main`** does not depend on **`Timer`**

Callbacks

Synchronous callbacks:

Examples: **`HashMap`** calls its client's **`hashCode`**, **`equals`**

Useful when the callback result is needed immediately by the library



A synchronous callback.
Time increases downward.
Solid lines: calls
Dotted lines: returns

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

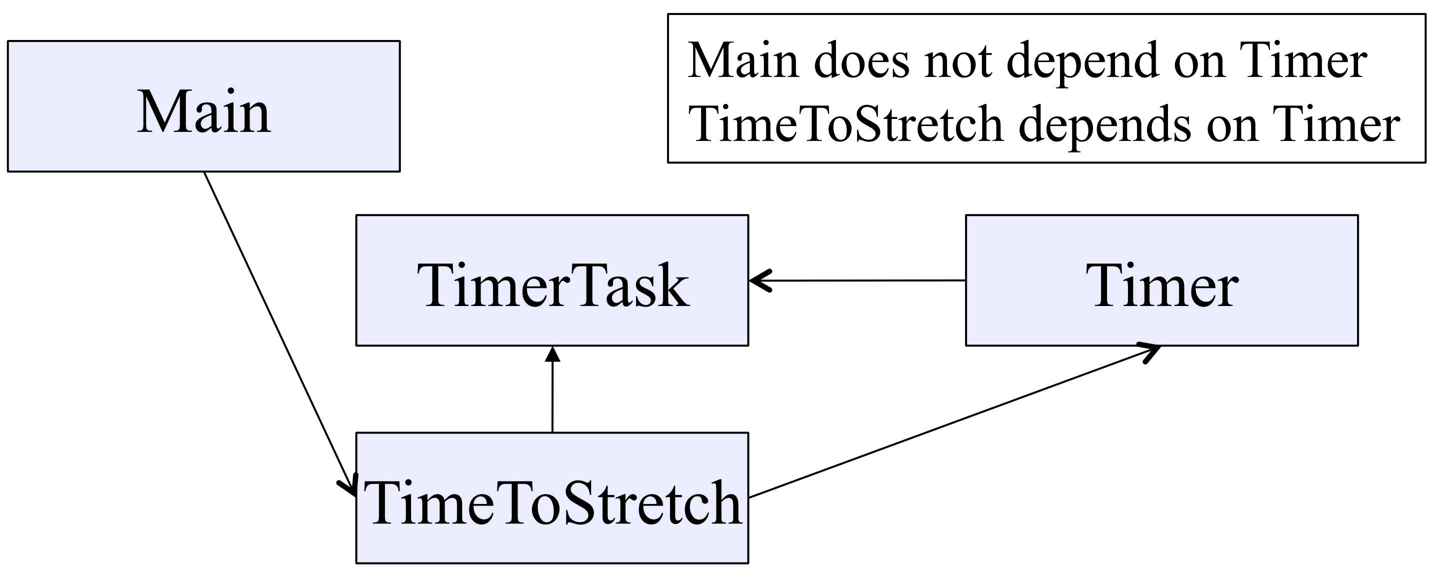
Callback entry point

Main (version 3)

```
TimeToStretch tts = new TimeToStretch();
tts.start();
```

Use a callback to invert a dependency

This diagram shows the inversion of the dependency between **`Timer`** and **`TimeToStretch`** (compared to ver. 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

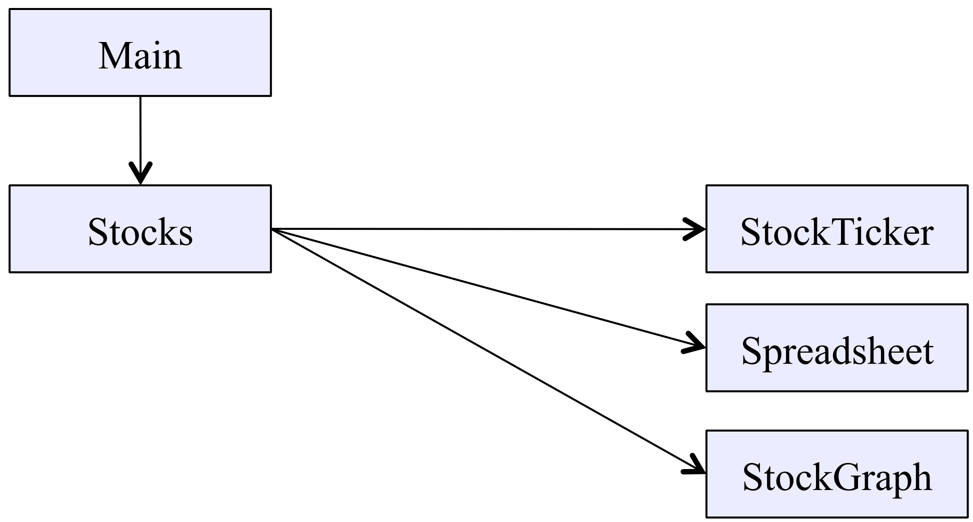
Naive design:

- 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 when things change

Old:

```
void updateViewers() {
    ticker.update(newPrice);
    spreadsheet.update(newPrice);
    graph.update(newPrice);
    // Edit this method whenever
    // different viewers are desired. ☹
}
```

New (uses “observer pattern”):

```
List<Observer> observers;

void notifyObserver() {
    for (Observer obs : observers) {
        obs.update(newPrice);
    }
}

interface Observer {
    void update(...);
}
```

Callback

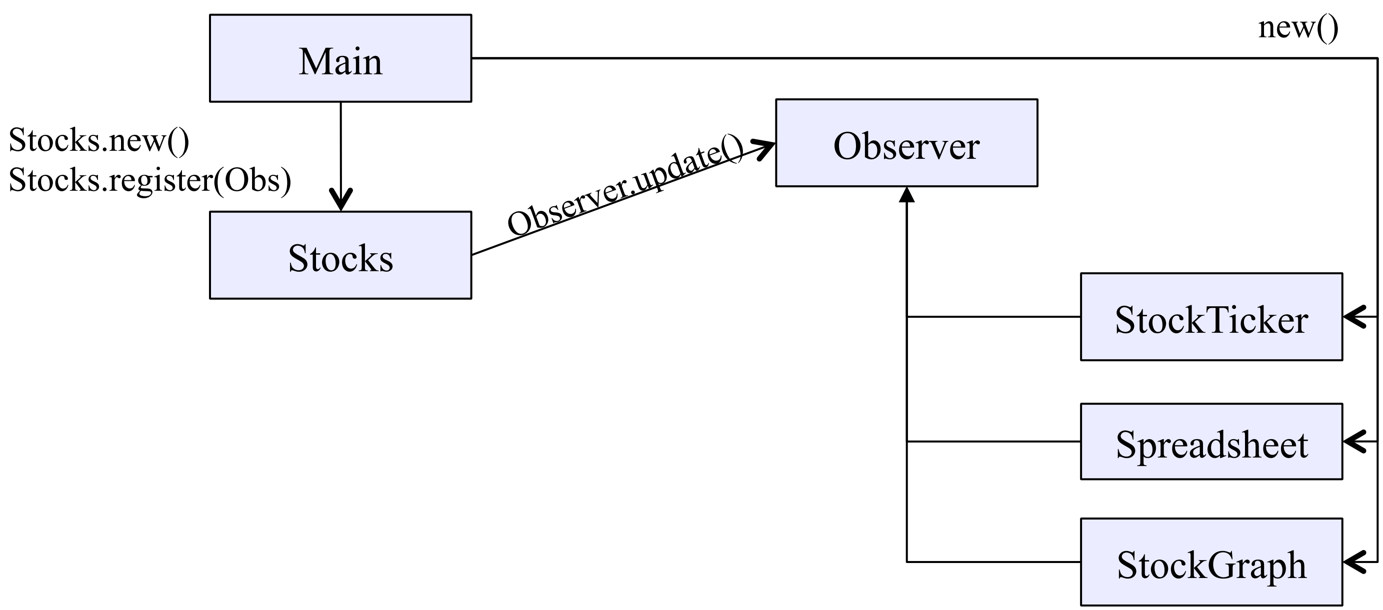
How are observers created?

The observer pattern

`Stocks` not responsible for viewer creation

`Main` passes viewers to `Stocks` as Observers

`Stocks` keeps list of Observers, notifies them of changes



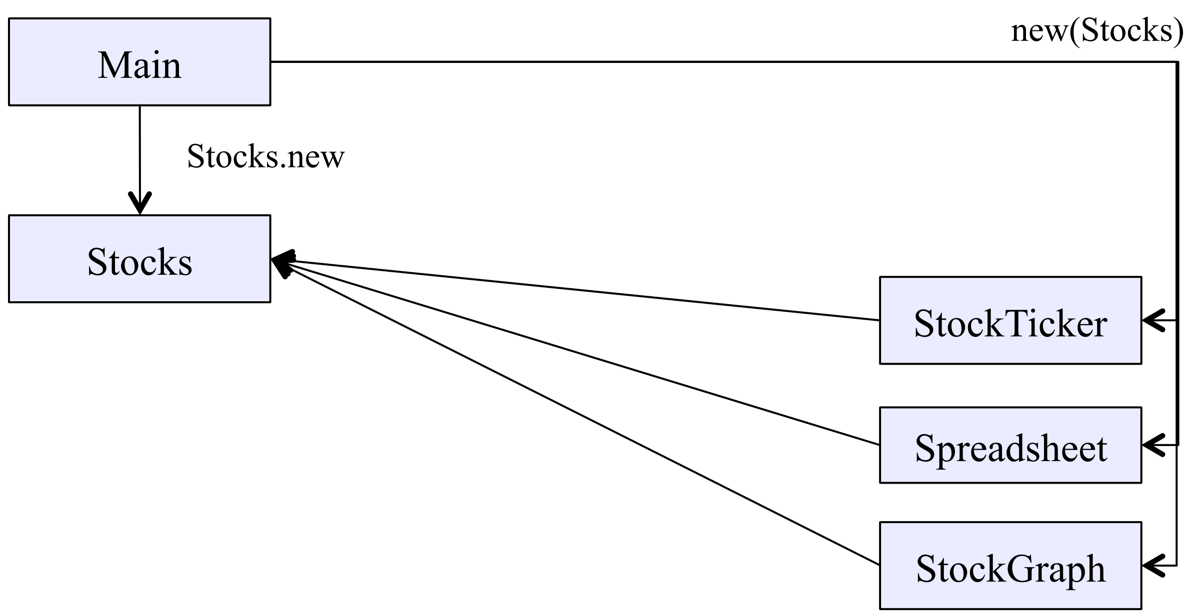
Problem: doesn't know what info each Observer needs

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

Usually need way for **`Stocks`** to tell viewers when changes happen



The best design depends on frequency of operations

(It's also possible to use both patterns simultaneously.)

Another example of Observer pattern

Part of the JDK

// 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);
    notifyObservers();
  }
  public int size() {
    return students.size();
  }
}
```

An Observer

Part of the JDK

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

Not relevant to us

cast because Observable is non-generic ☹

Using the 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