CSE 331
Software Design & Implementation

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Events, Listeners, and Callbacks

(slides by Mike Ernst and David Notkin)

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:

- 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)

`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

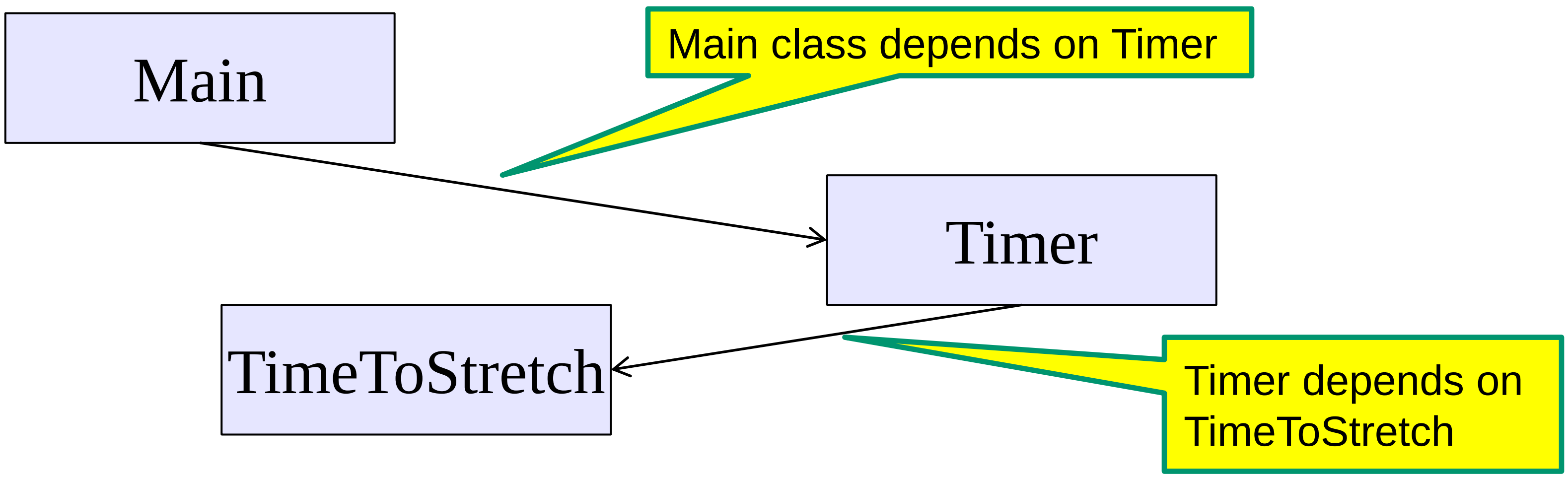
```
class Main {
  public static void main(String[] args) {
    Timer t = new Timer();
    t.start();
  }
}
```

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”



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)

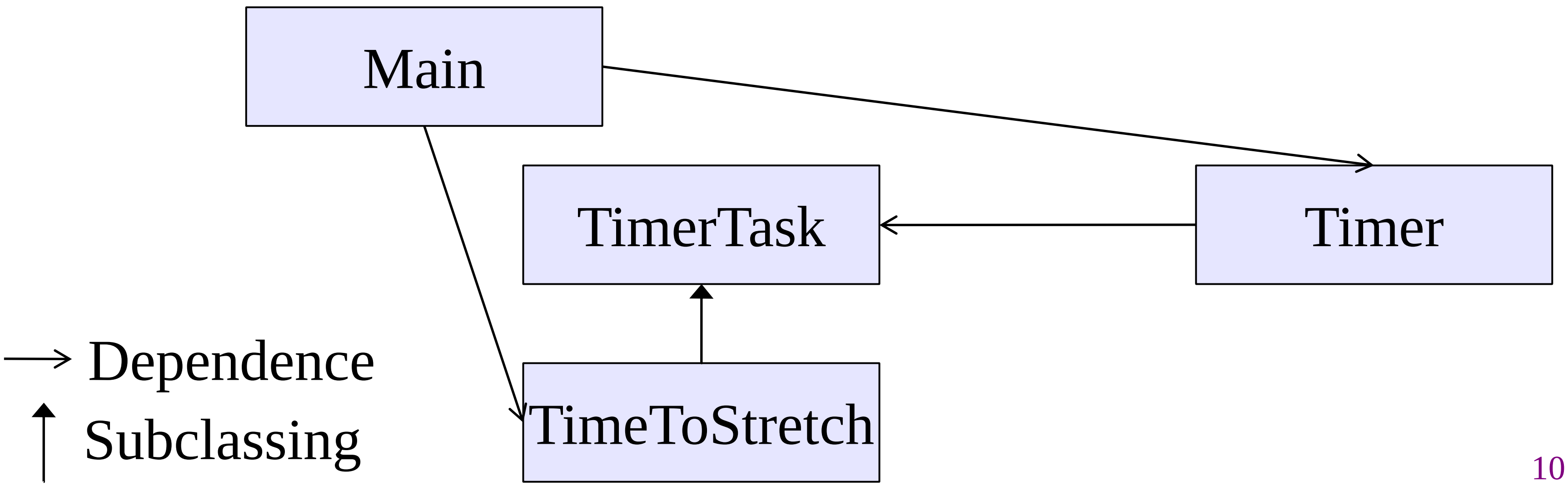
```
public class Timer {
  private TimerTask task;
  public Timer(TimerTask task) { this.task = task; }
  public void start() {
    while (true) {
      ...
      task.run();
    }
  }
}
```

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

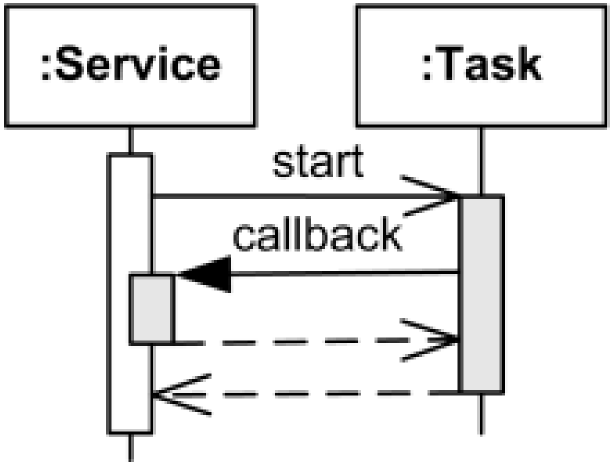


Callbacks

- **`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
- 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



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

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

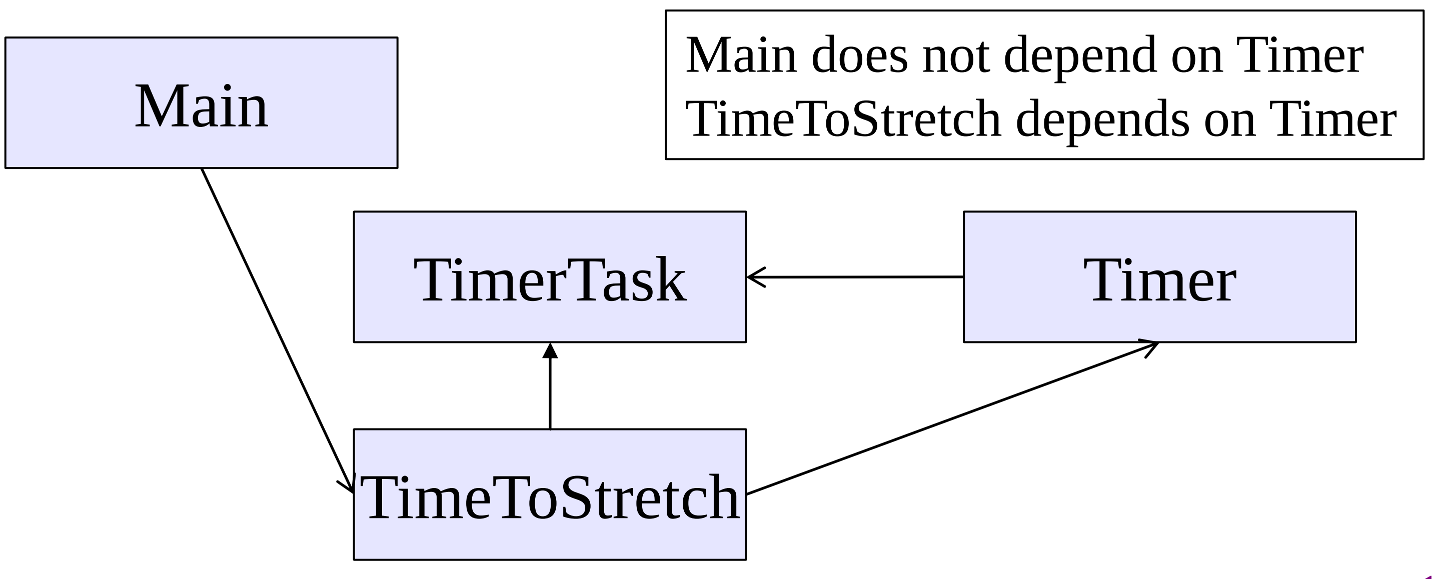
Callback entry point

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

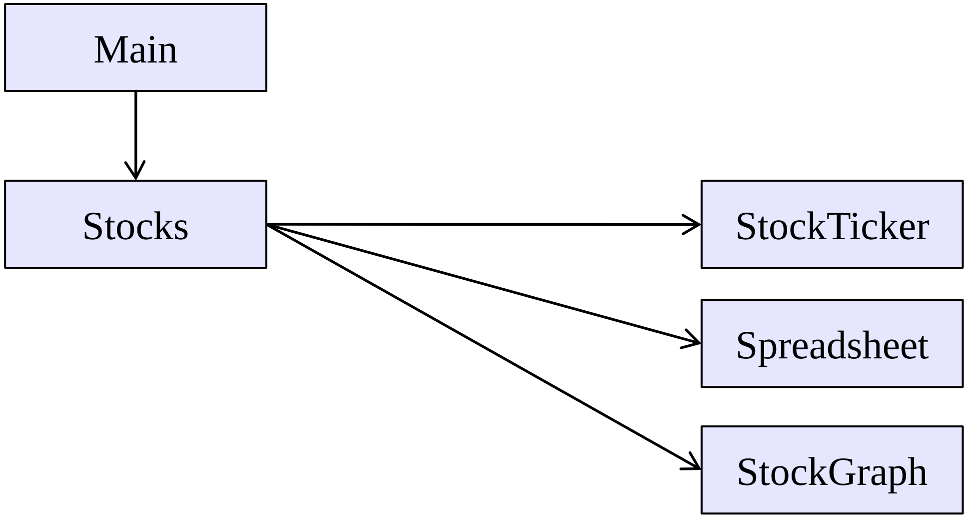
Design exercise #2

- 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

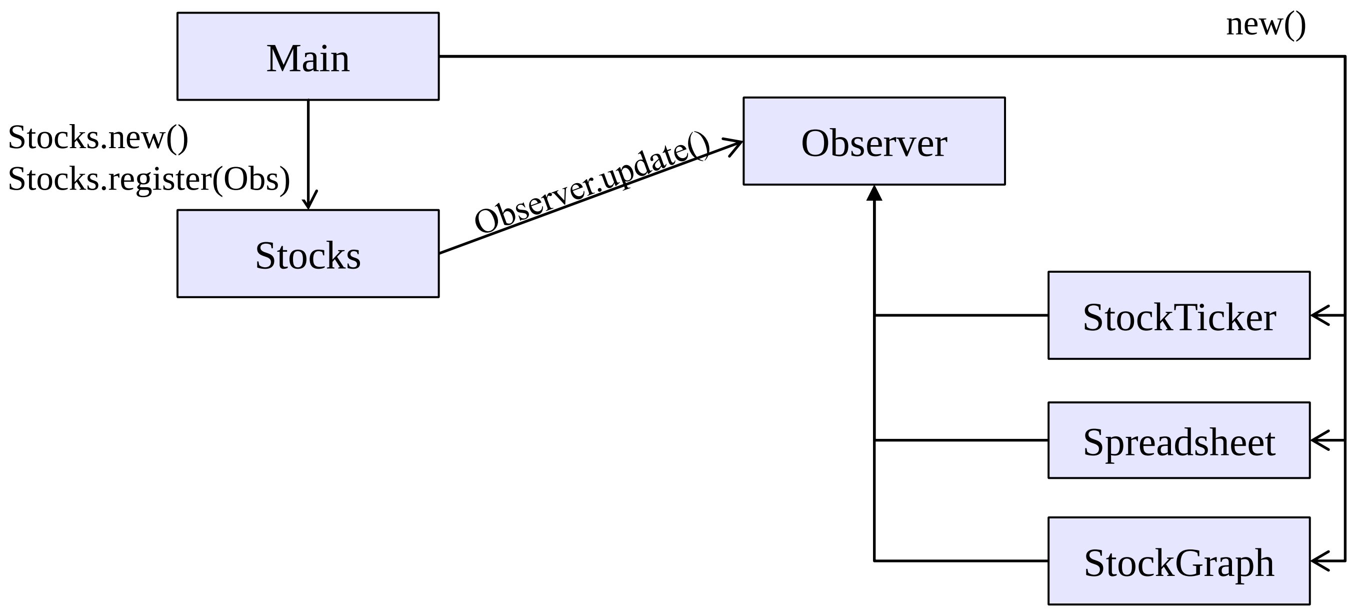
How are observers created?

The observer pattern

Stocks are not responsible for viewer creation

`Main` passes viewers to Stocks as Observers

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

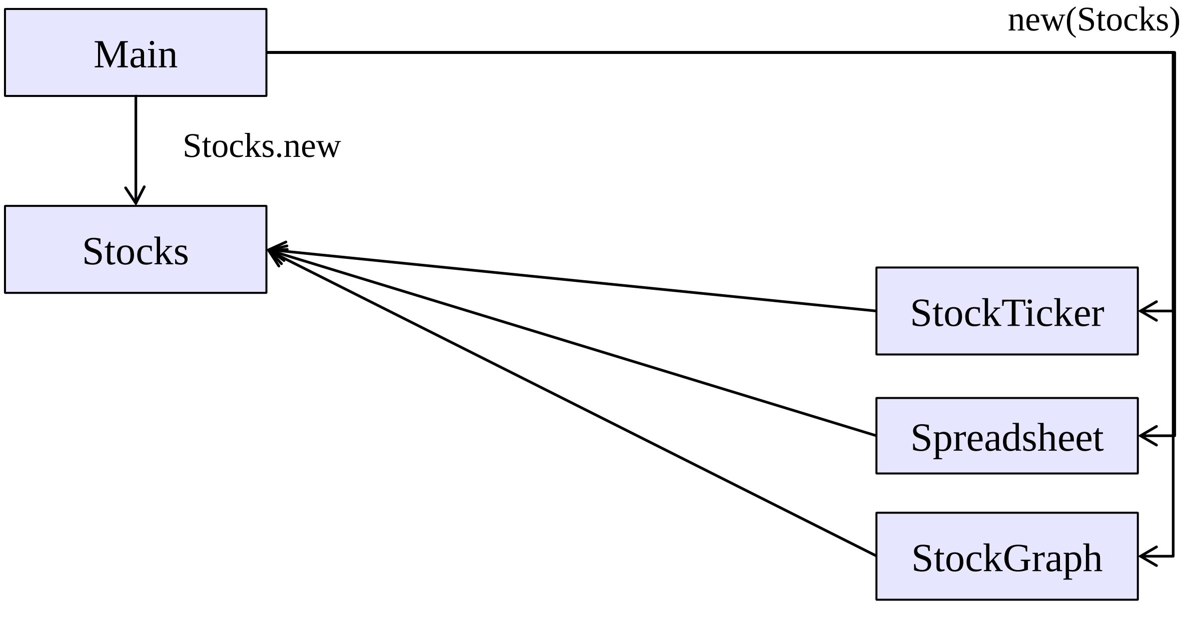


Problem: doesn't know what info each Observer needs

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



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

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