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Introduction to Software Engineering

The Observer Design Pattern

For details see Gamma et al. in “Design Patterns”

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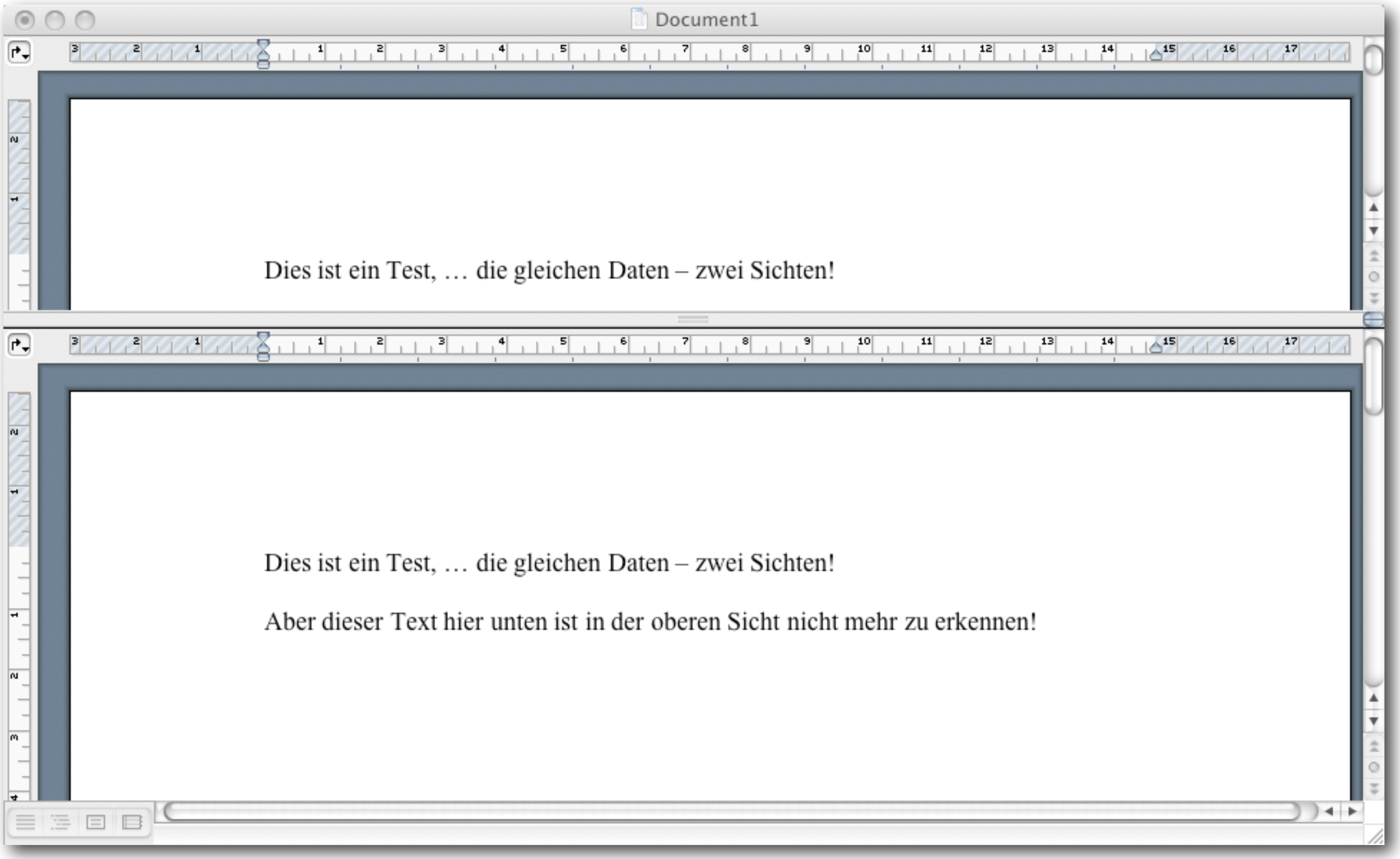
The Observer Design Pattern
Example / Motivation

From the “Lexi” Case Study

- Presentation components rendering views on the document should be separated from the core document data structures
  Need to establish communication.
- Multiple views on the document should be possible, even simultaneously
  Need to manage updates presenting the document.

The Observer Design Pattern

Example / Motivation



Consequences of Object-oriented Programming

Object-oriented programming encourages to **break problems apart into objects that have a small set of responsibilities** (ideally one)... but can **collaborate to accomplish complex tasks**.

- **Advantage:** Makes each object easier to implement and maintain, more reusable, enabling flexible combinations.
- **Disadvantage:** Behavior is distributed across multiple objects; any ***change in the state of one object often affects many others***.

The Observer Design Pattern

Goal: Communication without Coupling

- Change propagation (of object states) can be hard wired into objects, but this binds the objects together and diminishes their flexibility and potential for reuse
- A flexible way is needed to allow objects to tell each other about changes without strongly coupling them

- Prototypical Application:
  Separation of the GUI from underlying data, so that classes defining application data and presentations can be reused independently.

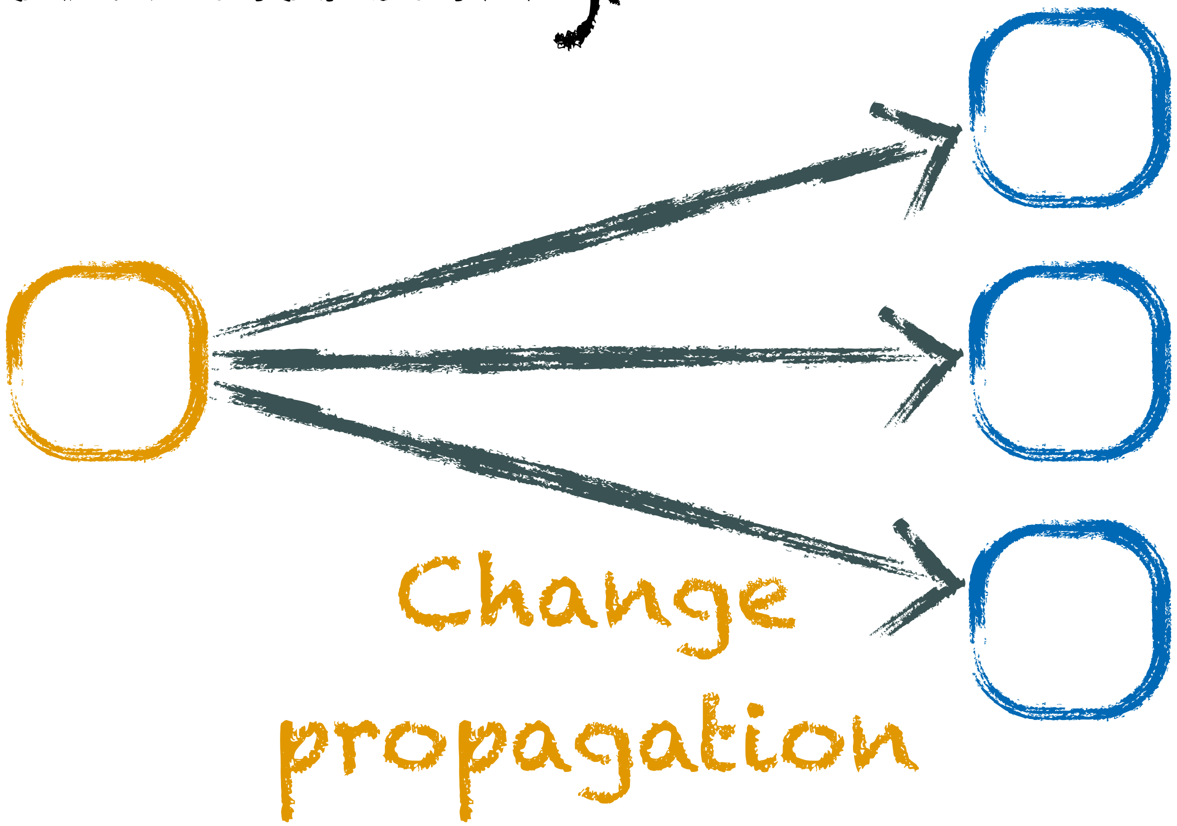
The Observer Design Pattern
Communication without Coupling

- **Task**
  Decouple a data model (subject) from “parties” interested in changes of its internal state

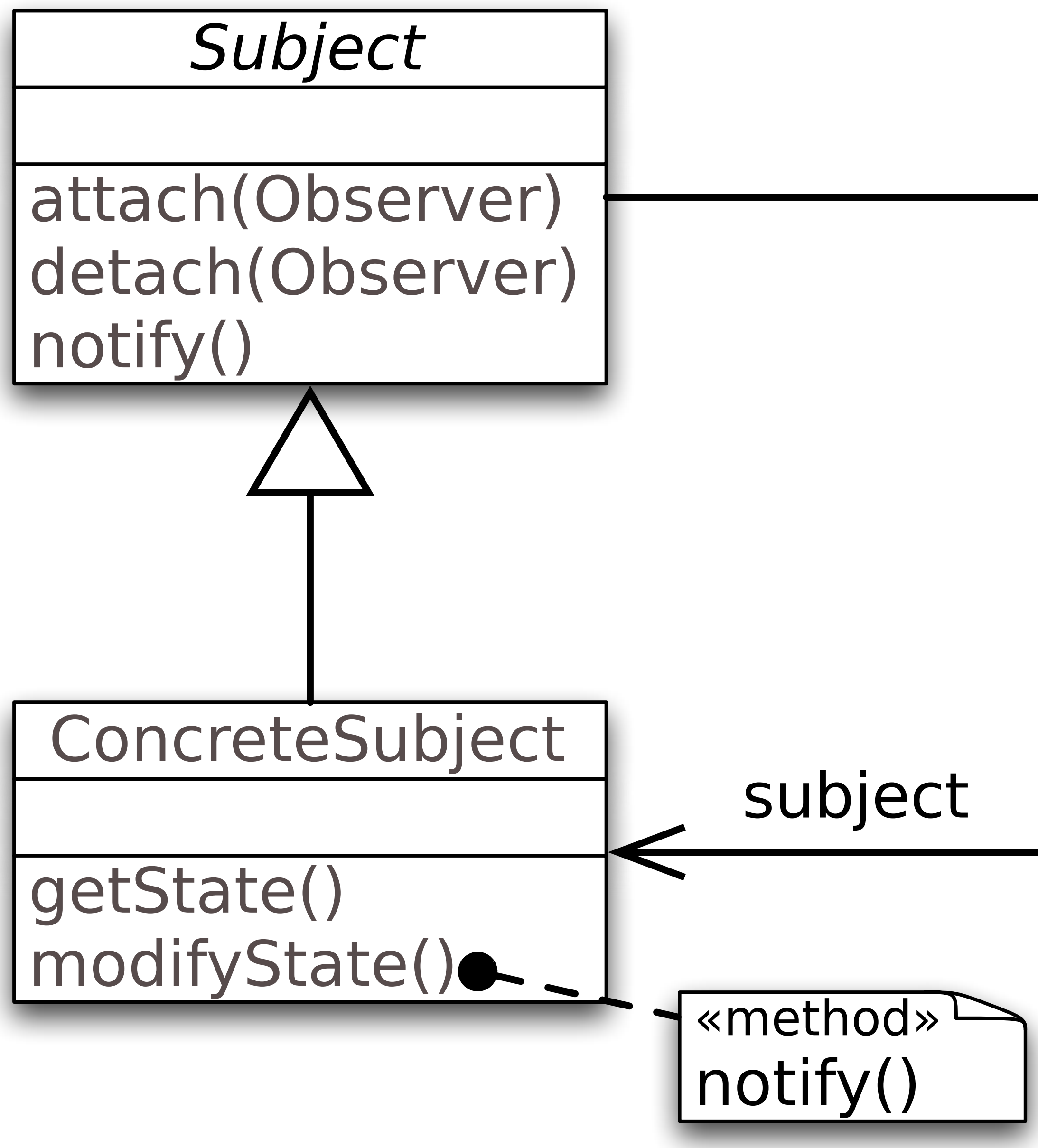
- **Requirements**
  - subject should not know about its observers
  - identity and number of observers is not predetermined
  - novel receivers classes may be added to the system in the future
  - polling is inappropriate (too inefficient)

The Observer Design Pattern
Intent

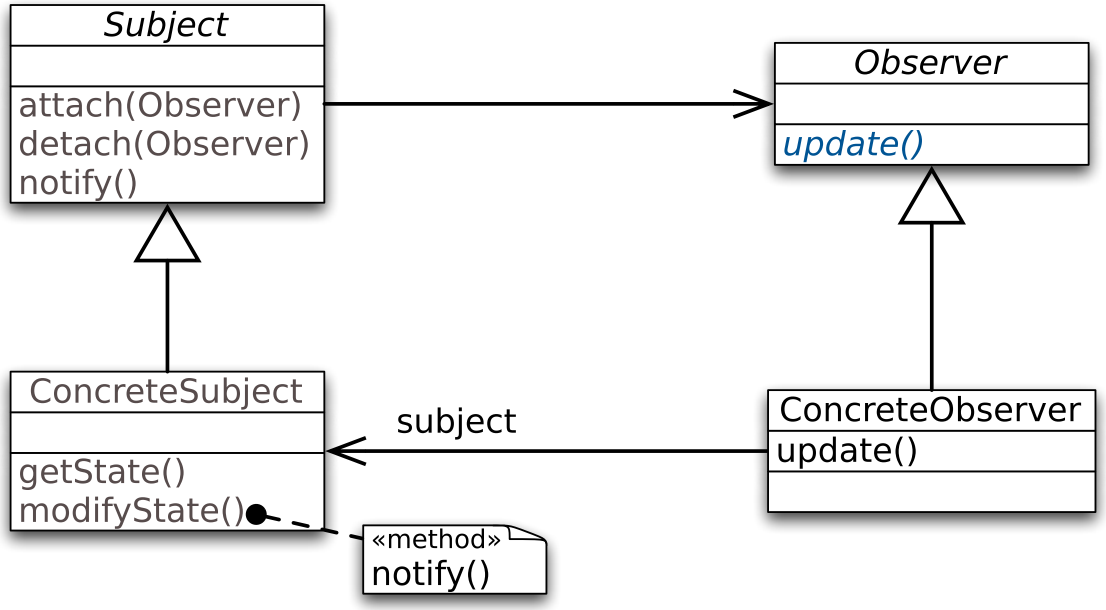
Define a one-to-many dependency between objects so that when an object changes its state, all its dependents are notified and updated automatically.



The Observer Design Pattern
Structure



The Observer Design Pattern
Participants



Subject...

- knows its observer(s)
- provides operations for attaching and detaching **Observer** objects

Observer...

- defines an updating interface for supporting notification about changes in a **Subject**

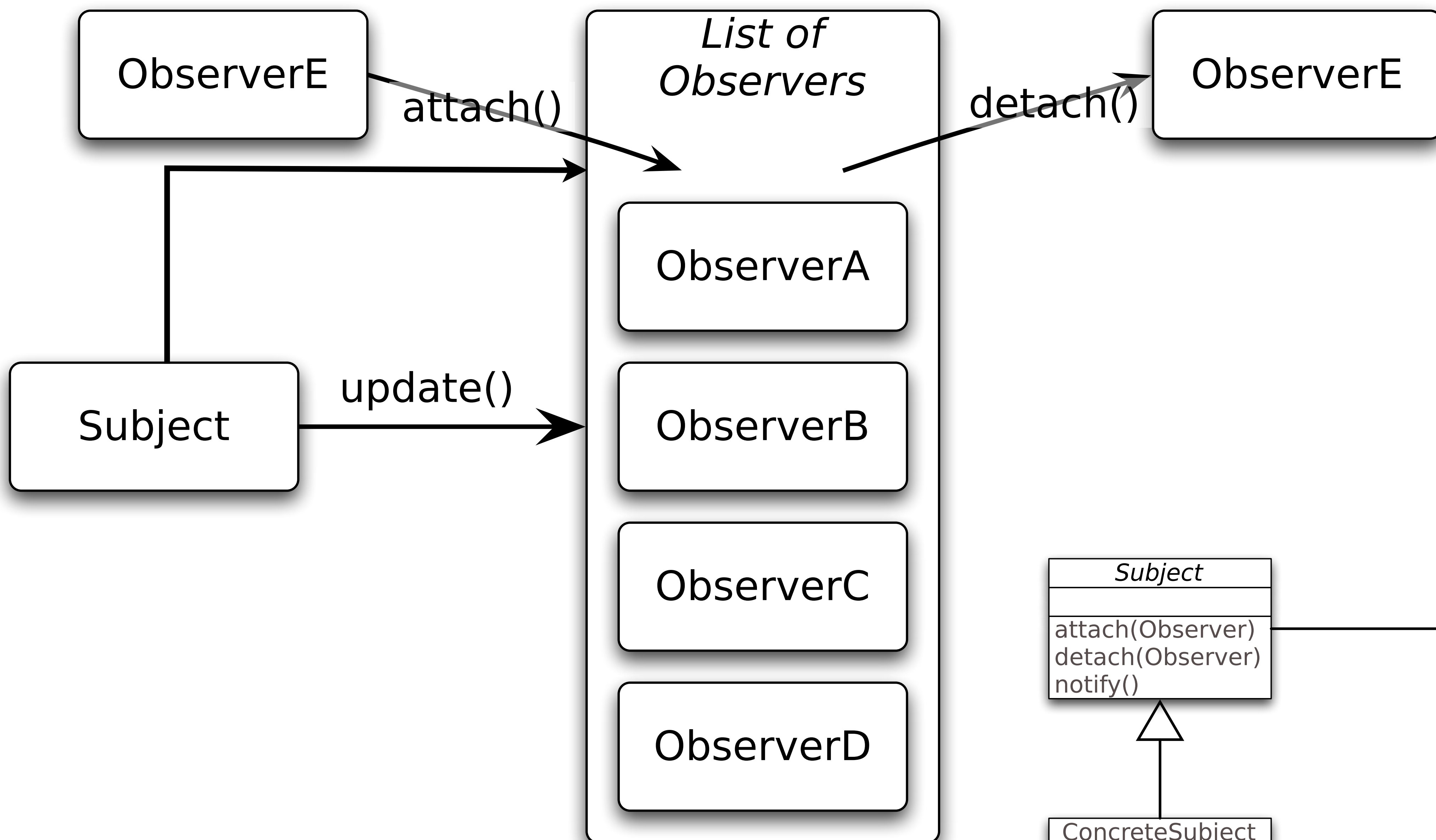
ConcreteSubject...

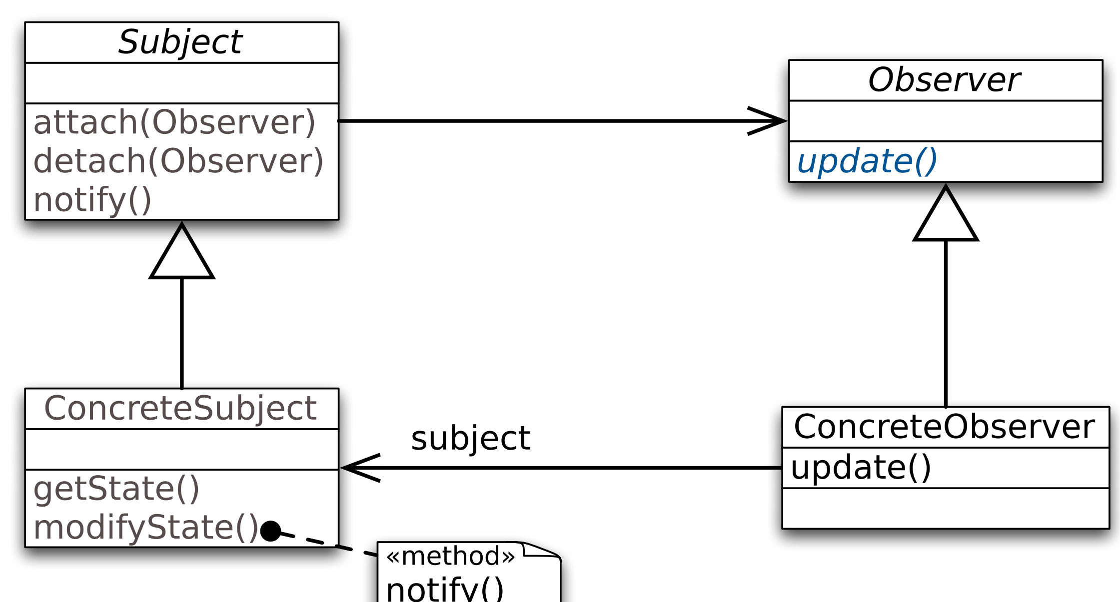
- stores state of interest to **ConcreteObserver** objects
- sends a notification to its observers upon state change

ConcreteObserver

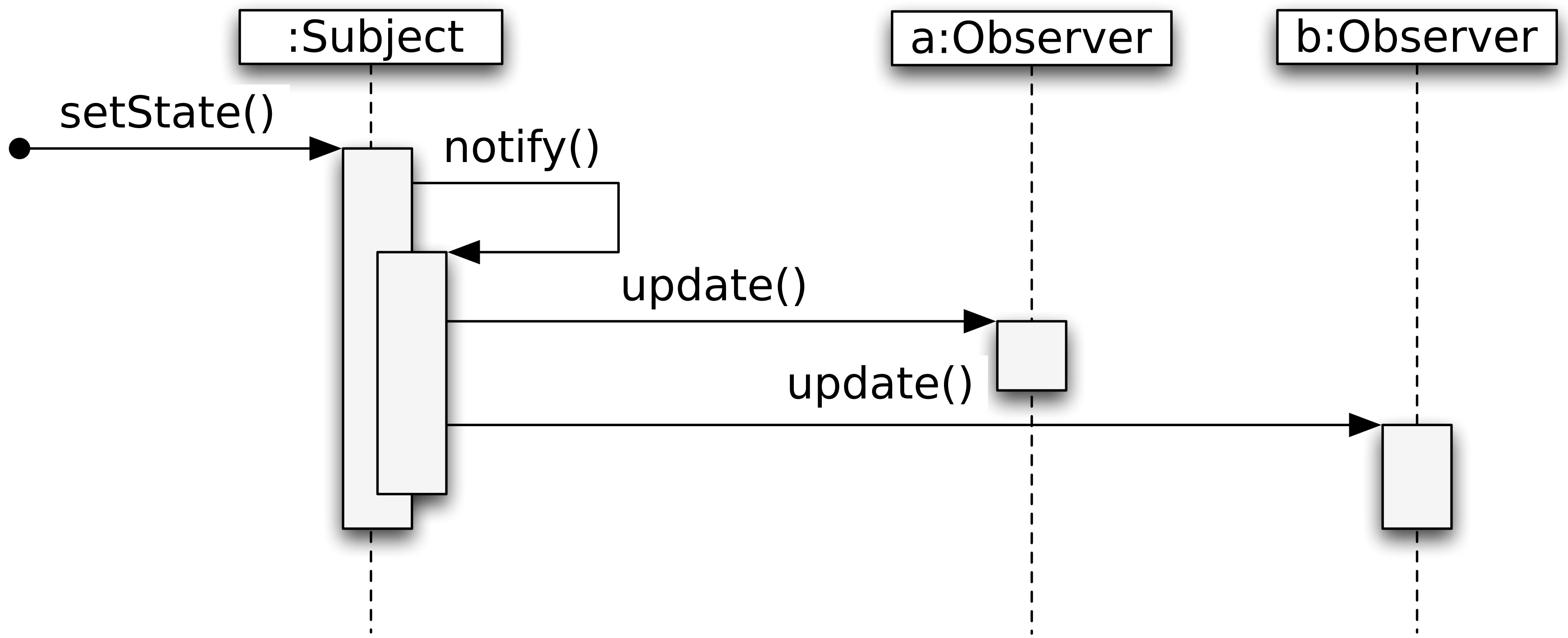
- maintains a reference to a **ConcreteSubject** object
- stores state that should stay consistent with the subject
- implements the **Observer** updating interface

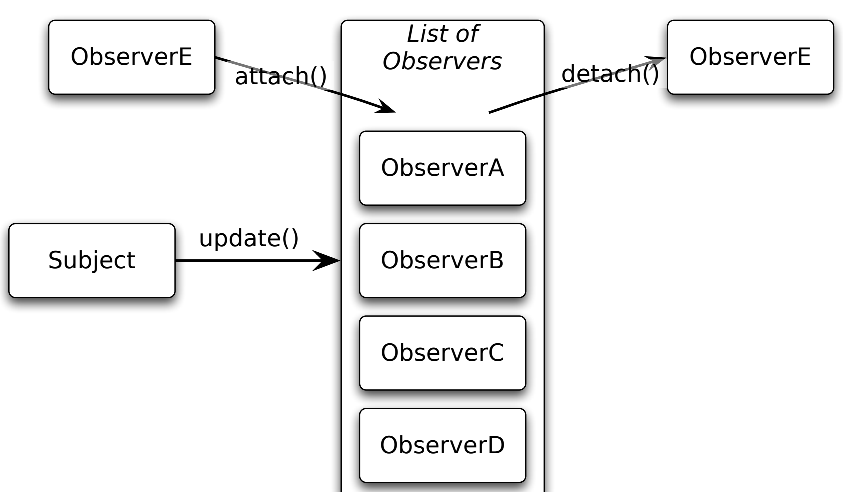
The Observer Design Pattern
Protocol

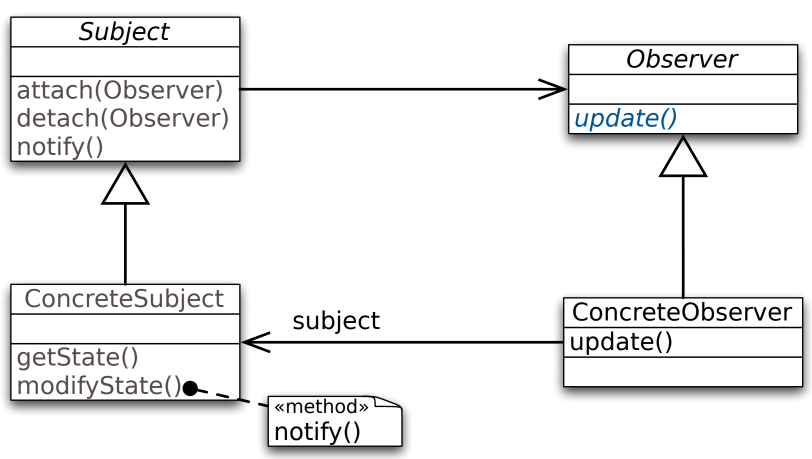




The Observer Design Pattern
Interaction







The Observer Design Pattern
Consequences

- Abstract coupling between Subject and Observer
- Support for broadcast communication:
  - notify doesn't specify its receiver
  - the sender doesn't know the (concrete) type of the receiver

The Observer Design Pattern
Consequences

- Unexpected / Uncontrolled updates
  - Danger of update cascades to observers and their dependent objects
  - Update sent to all observers, even though some of them may not be interested in the particular change
  - No detail of what changed in the subject; observers may need to work hard to figure out what changed
  - A common update interface for all observers limits the communication interface: Subject cannot send optional parameters to Observers

The Observer Design Pattern
“Implementation” - abstract class java.util.Observable

- **addObserver(Observer)** Adds an observer to the observer list
- **clearChanged()** Clears an observable change
- **countObservers()** Counts the number of observers
- **deleteObserver(Observer)** Deletes an observer from the observer list
- **deleteObservers()** Deletes observers from the observer list
- **hasChanged()** Returns a true Boolean if an observable change has occurred
- **notifyObservers()** Notifies all observers about an observable change
- **notifyObservers(Object)** Notifies all observers of the specified observable change which occurred
- **setChanged()** Sets a flag to note an observable change

The Observer Design Pattern
"Implementation" - interface *java.util.Observer*

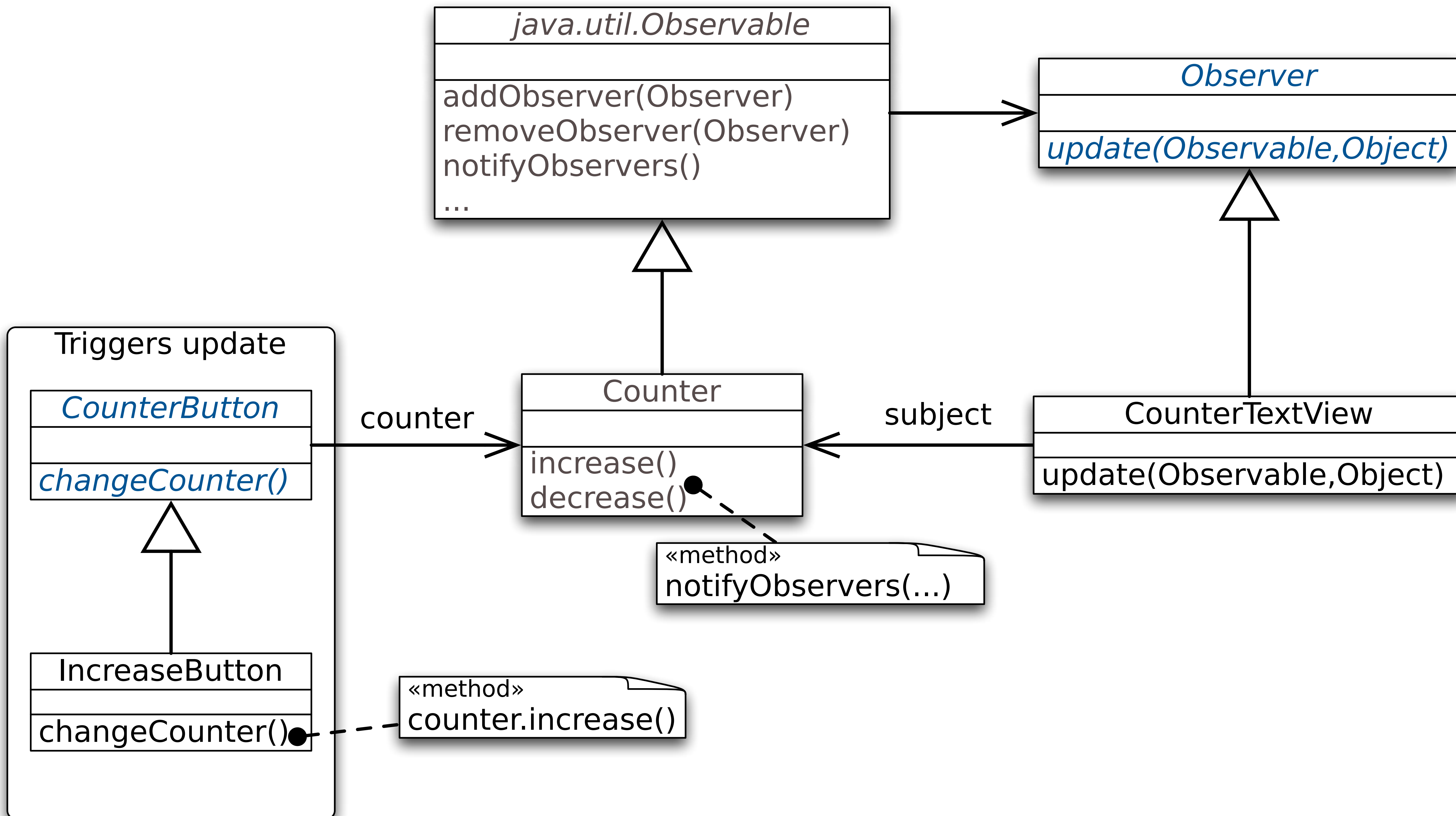
- public abstract void update(Observable o, Object arg)

  This method is called whenever the observed object is changed. An application calls an observable object's notifyObservers method to have all the object's observers notified of the change.

  Parameters:

  - o - the observed object.
  - arg - an argument passed to the notifyObservers method.

The Observer Design Pattern
Example - A **Counter**, a **Controller** and a **View**



The Observer Design Pattern
“Implementation” - class Counter


```
class Counter extends java.util.Observable{
  public static final String INCREASE = "increase";
  public static final String DECREASE = "decrease";
  private int count = 0; private String label;

  public Counter(String label) { this.label= label; }
  public String label() { return label; }
  public int value() { return count; }
  public String toString(){ return String.valueOf(count); }
  public void increase() {
    count++;
    setChanged(); notifyObservers(INCREASE);
  }
  public void decrease() {
    count--;
    setChanged(); notifyObservers(DECREASE);
} }
```

The Observer Design Pattern
“Implementation” - class CounterButton


```
abstract class CounterButton extends Button {

   protected Counter counter;

   public CounterButton(String buttonName, Counter counter) {
      super(buttonName);
      this.counter = counter;
   }

   public boolean action(Event processNow, Object argument) {
      changeCounter();
      return true;
   }

   abstract protected void changeCounter();
}
```

The Observer Design Pattern
"Implementation" - class IncreaseButton


```
abstract class CounterButton extends Button {

    protected Counter counter;
    public CounterButton(String buttonName, Counter counter) {
        super(buttonName);
        this.counter = counter;
    }
    public boolean action(Event processNow, Object argument) {
        changeCounter();
        return true;
    }

    abstract protected void changeCounter();
}
```

```
class IncreaseButton extends CounterButton{
    public IncreaseButton(Counter counter) {
        super("Increase", counter);
    }
    protected void changeCounter() { counter.increase(); }
}
class DecreaseButton extends CounterButton{/* correspondingly… */}
```

The Observer Design Pattern
“Implementation” - The View Class


```
class CounterTextView implements Observer{
   Counter model;
   public CounterTextView(Counter model) {
      this.model= model;
      model.addObserver(this);
   }
   public void paint(Graphics display) {
      display.drawString(
         "The value of "+model.label()+" is"+model,1,1
      );
   }

   public void update(Observable counter, Object argument) {
      repaint();
   }
}
```

The Observer Design Pattern

Implementation Issues - *Triggering the Update*

- **Methods that change the state, trigger update**
  However, if there are several changes at once, one may not want each change to trigger an update. It might be inefficient or cause too many screen updates

```
class Counter extends Observable {
    public void increase() {
        count++;
        setChanged();
        notifyObservers();
    }
}
```

- **Clients trigger the update**

```
class Counter extends Observable {
    public void increase() {
        count++;
    }
}
class Client {
    public void main() {
        Counter hits = new Counter();
        hits.increase();
        hits.increase();
        hits.setChanged();
        hits.notifyObservers();
    }
}
```

The Observer Design Pattern - Implementation Issues

Passing Information Along with the Update Notification

- Pull Mode -

Observer asks Subject what happened

```
class Counter extends Observable {
   private boolean increased = false;
   boolean isIncreased() { return increased; }
   void increase() {
      count++;
      increased=true;
      setChanged();
      notifyObservers();
   }
}
class IncreaseDetector extends Counter implements Observer {
   void update(Observable subject) {
      if(((Counter)subject).isIncreased()) increase();
   }
}
```

The Observer Design Pattern - Implementation Issues

Passing Information Along with the Update Notification

- Push Mode -

Parameters are added to update

```
class Counter extends Observable {
   void increase() {
      count++;
      setChanged();
      notifyObservers(INCREASE);
   }
}
class IncreaseDetector extends Counter implements Observer {
   void update(Observable whatChanged, Object message) {
      if(message.equals(INCREASE)) increase();
   }
}
```

Ensure that the Subject State is Self-consistent before Notification


```
class ComplexObservable extends Observable {
   Object o = new Object();
   public void trickyChange() {
      o = new Object();
      setChanged();
      notifyObservers();
   }
}

class SubComplexObservable extends ComplexObservable {
   Object anotherO = …;
   public void trickyChange() {
      super.trickyChange(); // causes notification
      anotherO = …;
      setChanged();
      notifyObservers(); // causes another notification
}  }
```

It’s tricky, because the subclass overrides this method and calls it.

The Observer Design Pattern - Implementation Issues

Ensure that the Subject State is Self-consistent before Notification


```
class ComplexObservable extends Observable {
    Object o = new Object();
    public /*final*/ void trickyChange() {
        doTrickyChange();
        setChanged();
        notifyObservers();
    }
    protected void doTrickyChange(){
        o = new Object();
    }
}
class SubComplexObservable extends ComplexObservable {
    Object anotherO = …;
    protected void doTrickyChange() {
        super.doTrickyChange(); // does not cause notification
        anotherO = …;
        setChanged();
        notifyObservers();
}   }
```

The Observer Design Pattern - Implementation Issues

Ensure that the Subject State is Self-consistent before Notification

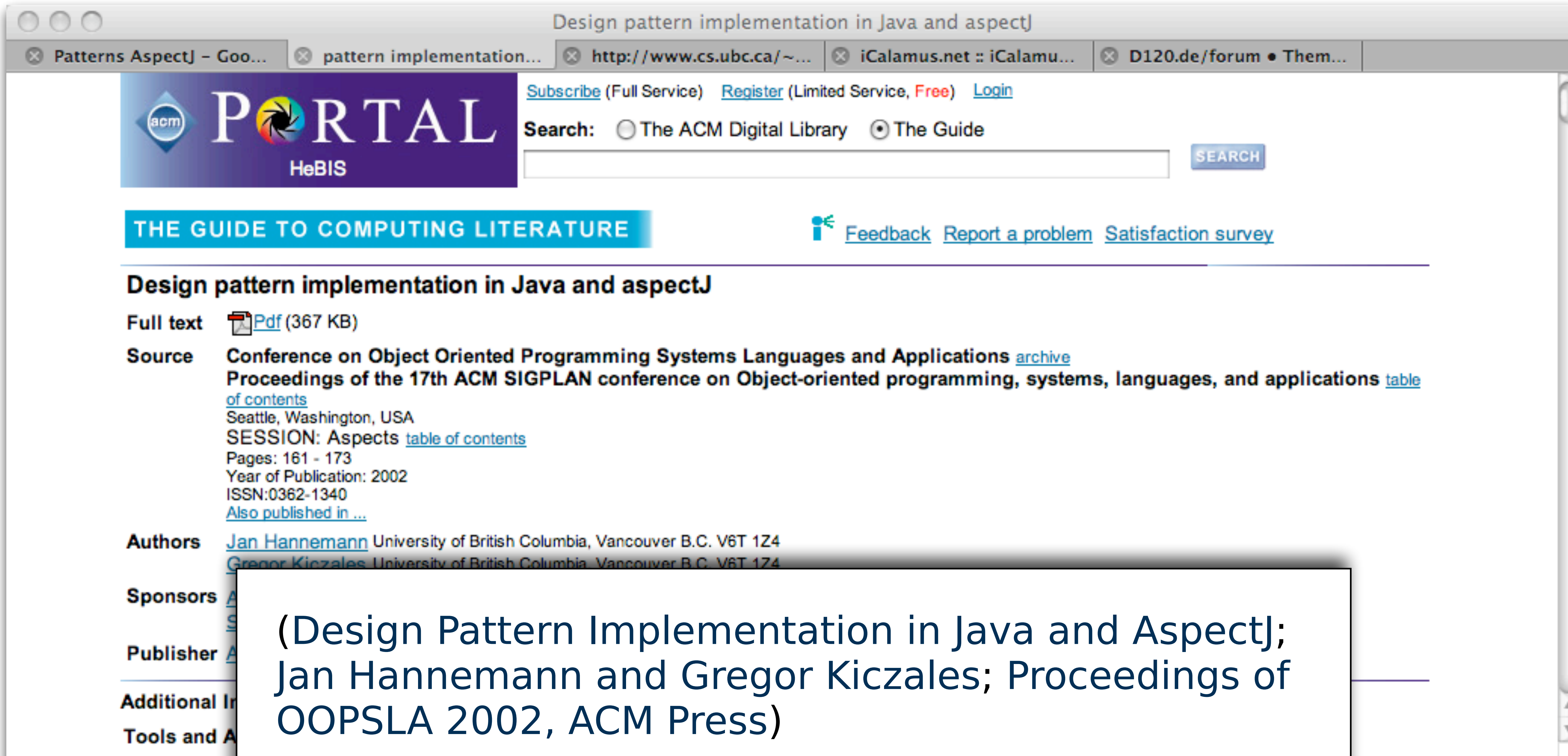

```
class ComplexObservable extends Observable {
    Object o = new Object();
    public /*final*/ void trickyChange() {
        doTrickyChange();
        setChanged();
        notifyObservers();
    }
    protected void doTrickyChange(){
        o = new Object();
    }
}

class SubComplexObservable extends ComplexObservable {
    Object anotherO = …;
    public void doTrickyChange() {
        super.doTrickyChange();
        anotherO = …;
}   }
```

Application of the Template Method Pattern

The Observer Design Pattern - Implementation Issues
Specifying Modifications of Interest

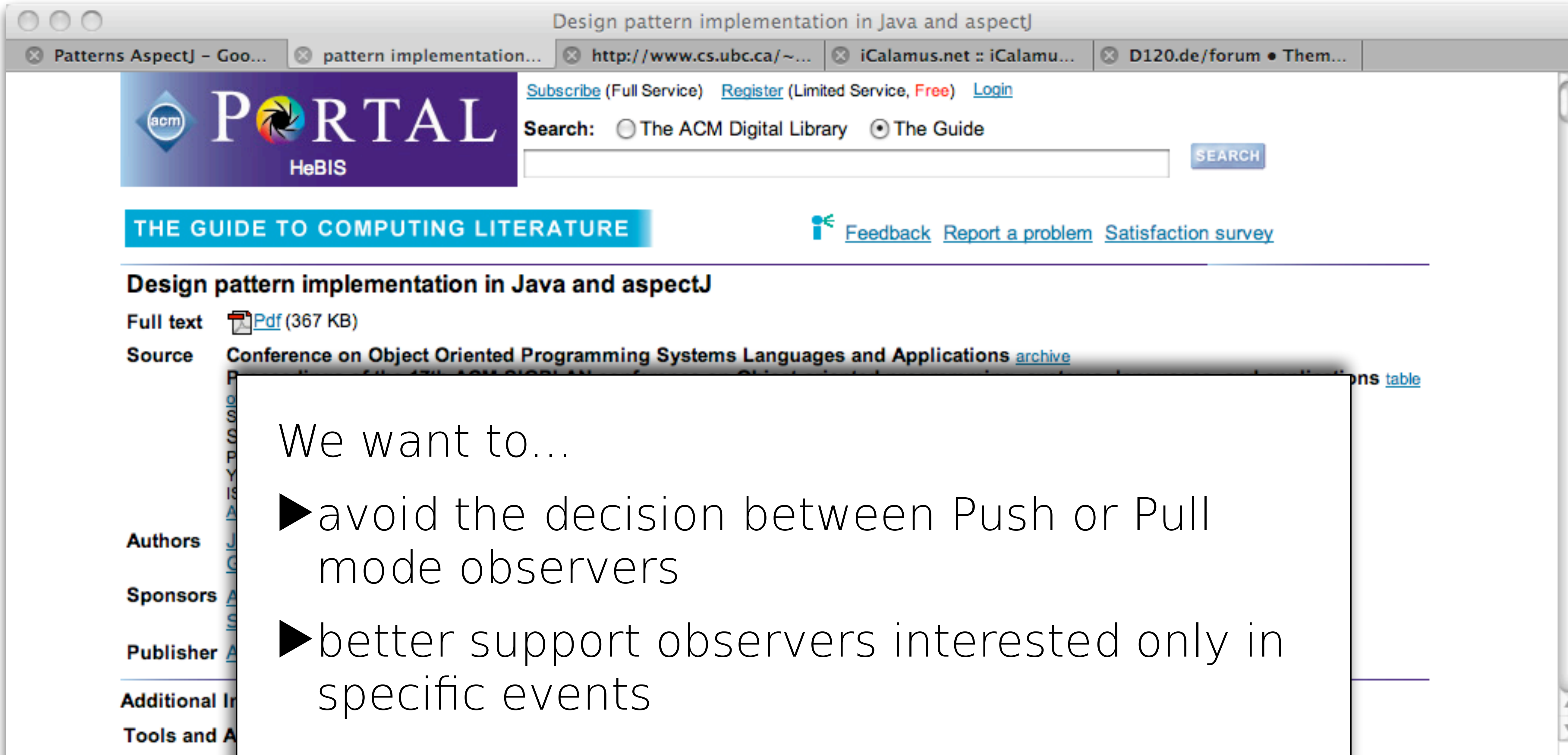
- The normal **addObserver(Observer)** method is extended to enable the specification of the kind of events the Observer is interested in
- E.g. **addObserver(Observer, Aspect)** where Aspect encodes the type of events the observer is interested in
- When the state of the Subject changes the Subject sends itself a message **triggerUpdateForEvent(anAspect)**

The Observer Design Pattern
Alternative Implementation using AspectJ



(Design Pattern Implementation in Java and AspectJ; Jan Hannemann and Gregor Kiczales; Proceedings of OOPSLA 2002, ACM Press)

The Observer Design Pattern
Alternative Implementation using AspectJ



We want to...

- avoid the decision between Push or Pull mode observers
- better support observers interested only in specific events

The Observer Design Pattern
Alternative Implementation using AspectJ

Parts Common to Potential Instantiations of the Pattern

Will be implemented in a reusable ObserverProtocol aspect.

1. The existence of **Subject** and **Observer** *roles*
   (i.e. the fact that some classes act as Observers and some as Subjects)
2. Maintenance of a mapping from **Subject**s to **Observer**s
3. The general update logic: **Subject** changes trigger Observer updates

Parts Specific to Each Instantiation of the Pattern

4. Which classes can be **Subject**s and which can be **Observer**s
5. A set of changes of interest on the **Subject**s that trigger updates on the **Observer**s
6. The specific means of updating each kind of **Observer** when the update logic requires it

The Observer Design Pattern
Alternative Implementation using AspectJ


```
public abstract aspect ObserverProtocol {

   // Realization of the Roles of the Observer Design Pattern
   protected interface Subject  { }
   protected interface Observer { }

  ...
}
```

The part common to instantiations of the pattern.

The Observer Design Pattern

Alternative Implementation using AspectJ


```
public abstract aspect ObserverProtocol {
    ...
    // Mapping and Managing Subjects and Observers
    private WeakHashMap<Subject, List<Observer>> perSubjectObservers;
    protected List<Observer> getObservers(Subject s) {
        if (perSubjectObservers == null)
            perSubjectObservers = new WeakHashMap<Subject, List<Observer>>()
        List<Observer> observers = perSubjectObservers.get(s);
        if ( observers == null ) {
            observers = new LinkedList<Observer>();
            perSubjectObservers.put(s, observers);
        }
        return observers;
    }
    public void addObserver(Subject s,Observer o){
        getObservers(s).add(o);
    }
    public void removeObserver(Subject s,Observer o){
        getObservers(s).remove(o);
    }
  ...
}
```

The part common to instantiations of the pattern.

The Observer Design Pattern

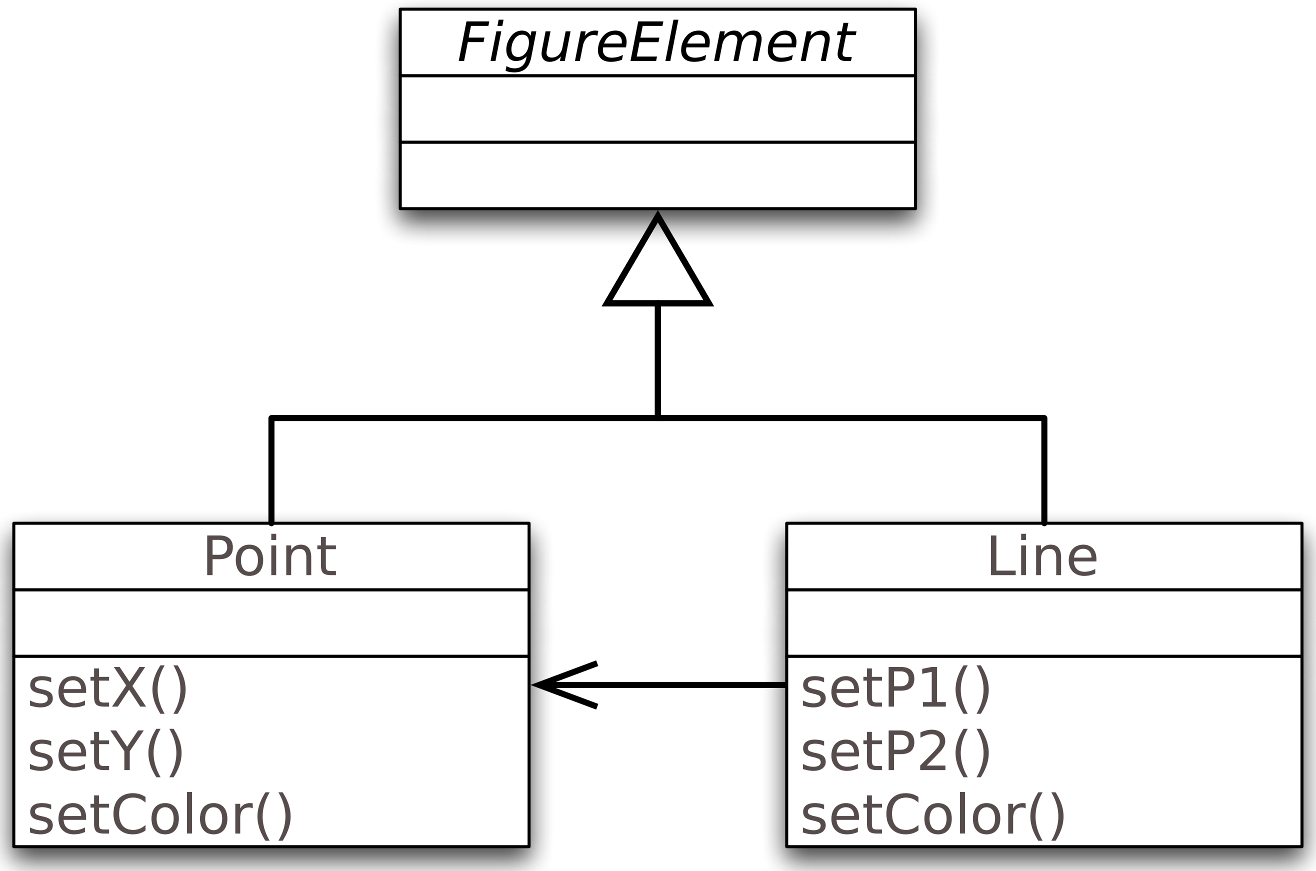
Alternative Implementation using AspectJ


```
public abstract aspect ObserverProtocol {
    ...
    // Notification related functionality
    abstract protected pointcut subjectChange(Subject s);

    abstract protected void updateObserver(Subject s, Observer o);

    after(Subject s): subjectChange(s) {
        Iterator<Observer> iter = getObservers(s).iterator();
        while ( iter.hasNext() ) {
            updateObserver(s, iter.next());
        }
    }
}
```

The part common to instantiations of the pattern.

The Observer Design Pattern

Alternative Implementation using AspectJ - Example



The Observer Design Pattern
Alternative Implementation using AspectJ - Example

Task: Observe Changes of the Color

```
public aspect ColorObserver extends ObserverProtocol {

    declare parents: Point  implements Subject;
    declare parents: Line   implements Subject;
    declare parents: Screen implements Observer;

    protected pointcut subjectChange(Subject s):
        (call(void Point.setColor(Color)) ||
         call(void Line.setColor(Color)) ) && target(s);

    protected void updateObserver(Subject s, Observer o) {
        ((Screen)o).display("Color change.");
    }
}
```

To create a mapping between an Observer and a Subject:

```
ColorObserver.aspectOf().addObserver(P, S);
```

The Observer Design Pattern

Alternative Implementation using AspectJ - Assessment

- *Locality*
  All code that implements the Observer pattern is in the abstract and concrete observer aspects, none of it is in the participant classes; there is no coupling between the participants.
  Potential changes to each Observer pattern instance are confined to one place.
- *Reusability*
  The core pattern code is abstracted and reusable. The implementation of ObserverProtocol is generalizing the overall pattern behavior. The abstract aspect can be reused and shared across multiple Observer pattern instances.
- *Composition transparency*
  Because a pattern participant's implementation is not coupled to the pattern, if a Subject or Observer takes part in multiple observing relationships their code does not become more complicated and the pattern instances are not confused.
  Each instance of the pattern can be reasoned about independently.
- *(Un)pluggability*
  It is possible to switch between using a pattern and not using it in the system.

The Observer Design Pattern

- Intent
  Define a one-to-many dependency between objects so that when an object changes it's state, all its dependents are notified and updated automatically.
- How it is implemented depends on the available programming language mechanisms; the consequences may also change!