Design – using OO patterns

Some of these slides are adapted from *Software Engineering: A Practitioner's Approach,* by Roger Pressman.

Design Patterns

- Each of us has encountered a design problem and silently thought: *I wonder if anyone has developed a solution to for this?*
  - What if there was a standard way of describing a problem (so you could look it up), and an organized method for representing the solution to the problem?
- *Design patterns* are a codified method for describing problems and their solution allows the software engineering community to capture design knowledge in a way that enables it to be reused.

Design Patterns

- *Each pattern describes a problem that occurs over and over again in our environment and then describes the core of the solution to that problem in such a way that you can use the solution a million times over without ever doing it the same way twice.*
  - Christopher Alexander, 1977

- "a three-part rule which expresses a relation between a certain context, a problem, and a solution."

Basic Concepts

- *Context* allows the reader to understand the environment in which the problem resides and what solution might be appropriate within that environment.

- A set of requirements, including limitations and constraints, acts as a *system of forces* that influences how
  - the problem can be interpreted within its context and
  - how the solution can be effectively applied.

Describing a Pattern

- *Pattern name*—describes the essence of the pattern in a short but expressive name
- *Problem*—describes the problem that the pattern addresses
- *Motivation*—provides an example of the problem
- *Context*—describes the environment in which the problem resides including application domain
- *Forces*—lists the system of forces that affect the manner in which the problem must be solved; includes a discussion of limitation and constraints that must be considered
- *Solution*—provides a detailed description of the solution proposed for the problem
- *Intent*—describes the pattern and what it does
- *Collaborations*—describes how other patterns contribute to the solution
- *Consequences*—describes the potential trade-offs that must be considered when the pattern is implemented and the consequences of using the pattern
- *Implementation*—identifies special issues that should be considered when implementing the pattern
- *Known uses*—provides examples of actual uses of the design pattern in real applications
- *Related patterns*—cross-references related design patterns

Design patterns (GOF)

- Design Patterns communicate solutions to common problems.
  - It's a problem-solution pair.
- The seminal book on design patterns, *Design Patterns, Elements of Reusable Object-Oriented Software* by Gamma et al, identifies three categories of design patterns
  - Creational
  - Structural
  - Behavioral

Kinds of Patterns

- ***Creational patterns*** focus on the "creation, composition, and representation of objects, e.g.,
  - **Singleton pattern:** Control the creation of instances to just on3
  - **Abstract factory pattern:** centralize decision of what factory to instantiate
  - **Factory method pattern:** centralize creation of an object of a specific type choosing one of several implementations

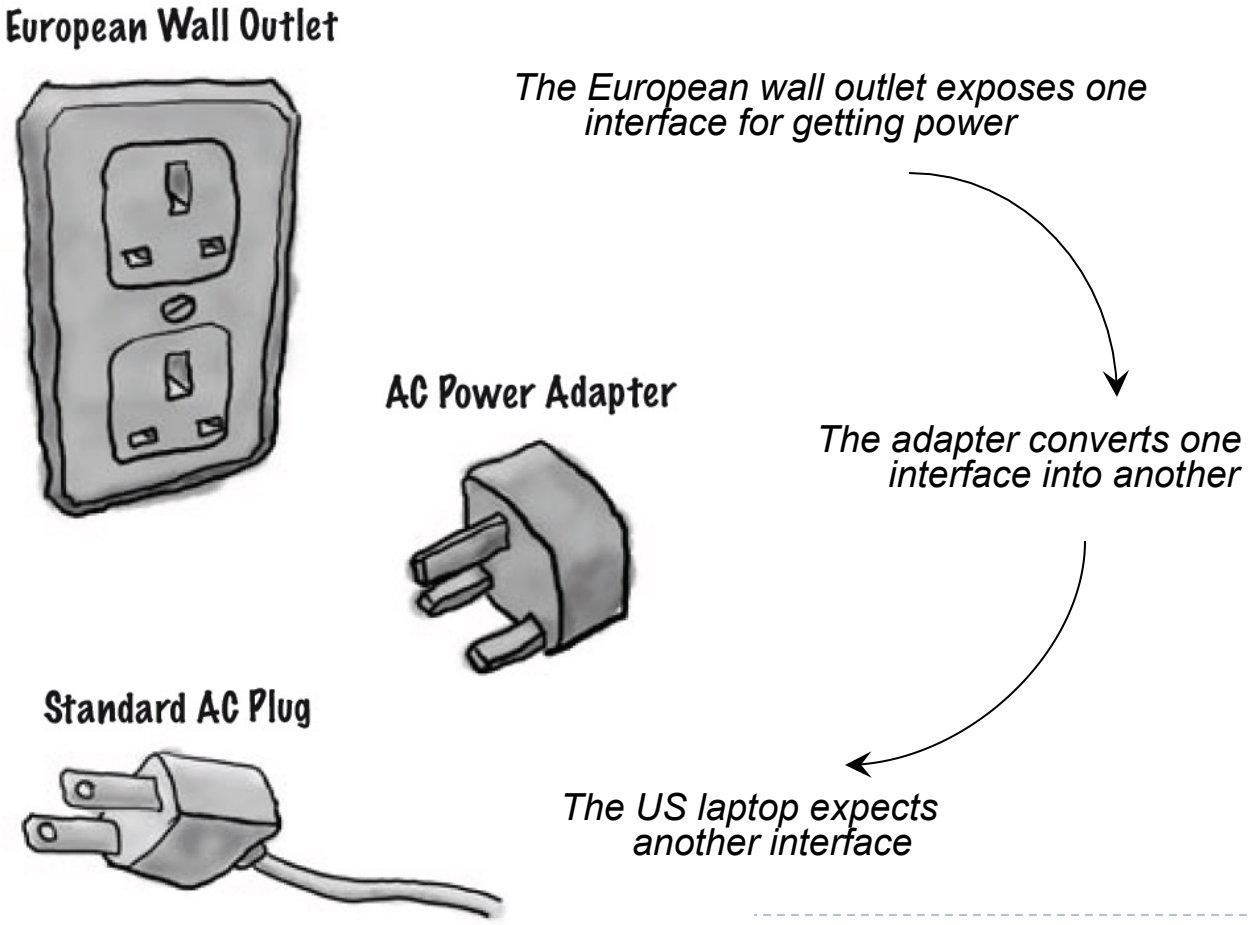
- ***Structural patterns*** focus on problems and solutions associated with how classes and objects are organized and integrated to build a larger structure, e.g.,
  - **Adapter pattern:** 'adapts' one interface for a class into one that a client expects
  - **Aggregate pattern:** a version of the Composite pattern with methods for aggregation of children

- ***Behavioral patterns*** address problems associated with the assignment of responsibility between objects and the manner in which communication is effected between objects, e.g.,
  - **Chain of responsibility pattern:** Command objects are handled or passed on to other objects by logic-containing processing objects
  - **Command pattern:** Command objects encapsulate an action and its parameters
  - **Observer pattern:** Enable loose coupling between publishers and subscribers

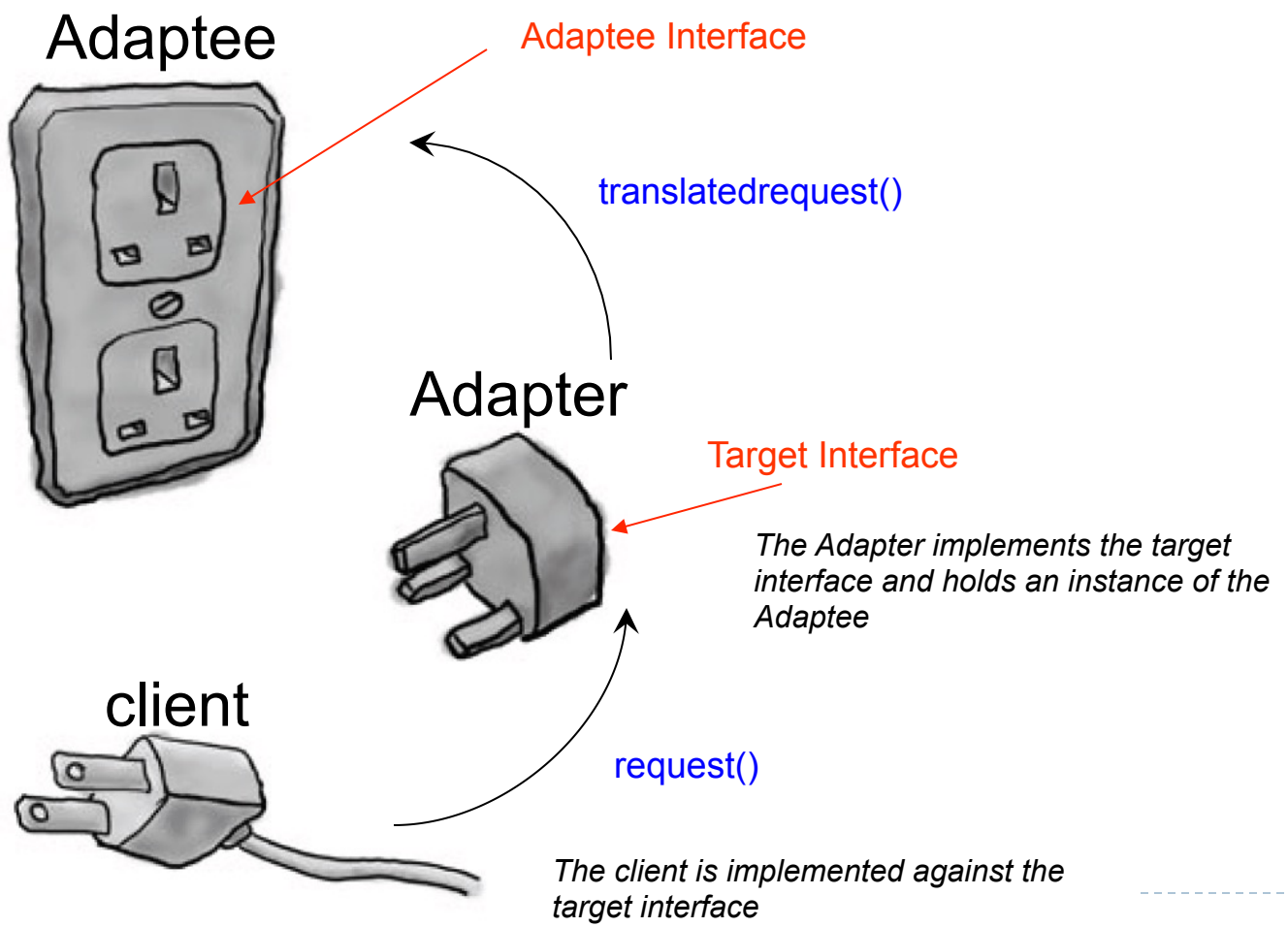
Adapter pattern

Acknowledgement: Head-first Design patterns. Freeman & Freeman

Example Scenario



Adapter Pattern Explained



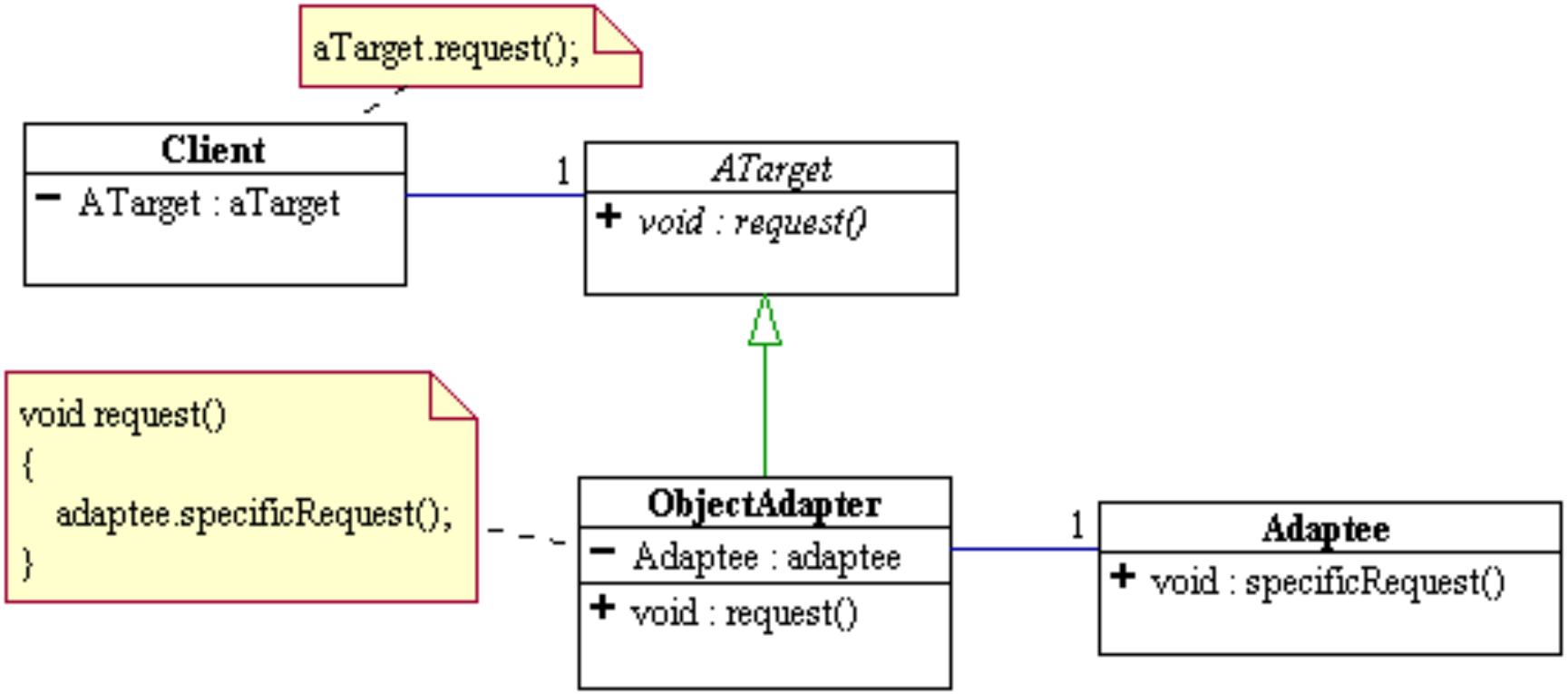
Adapter Pattern

- An adapter pattern converts the interface of a class into an interface that a client expects
- Adapters allow incompatible classes to work together
- Adapters can extend the functionality of the adapted class
- Commonly called “glue” or “wrapper”

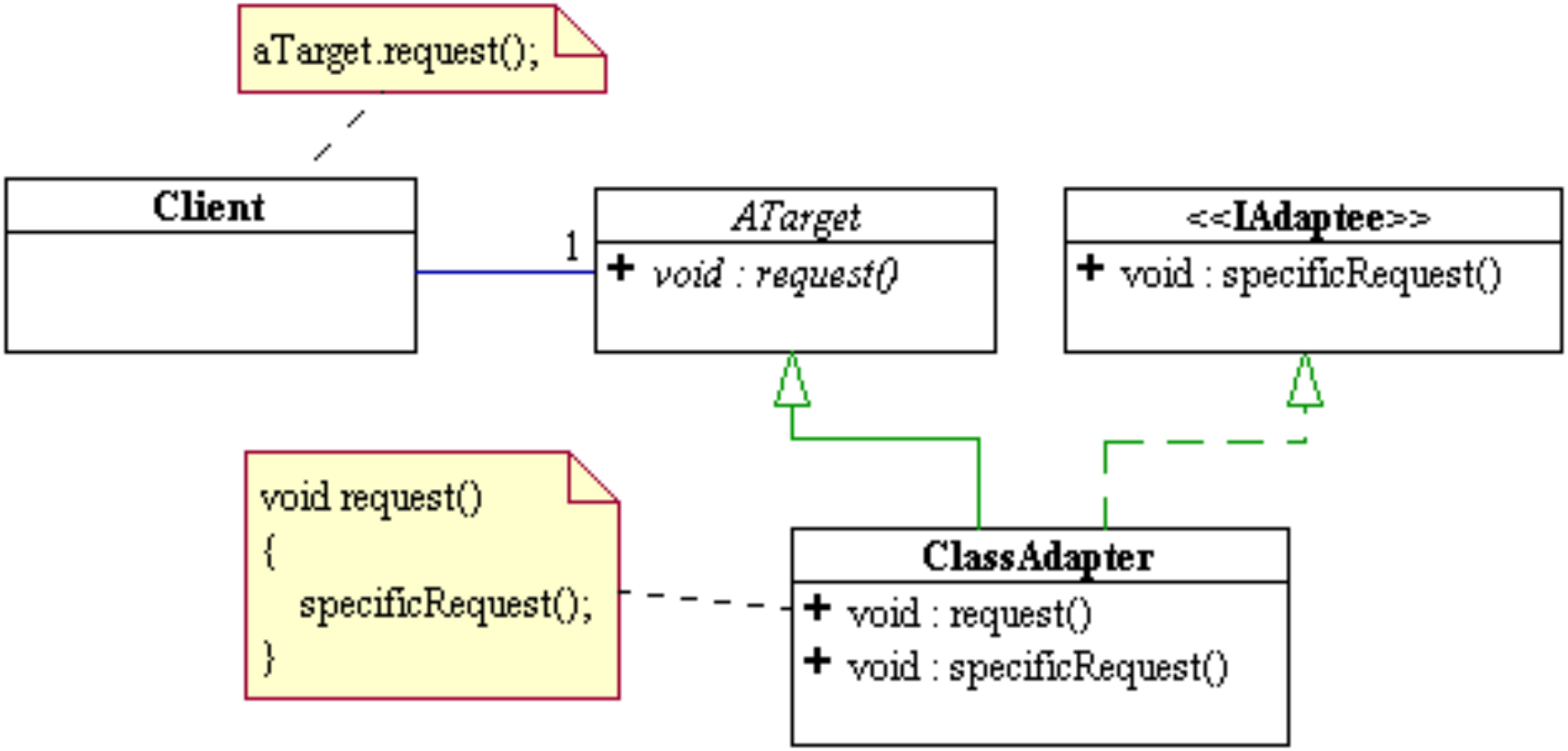
When to Use

- Need to adapt the interface of an existing class to satisfy client interface requirements
  - Adapting Legacy Software
  - Adapting 3rd Party Software

Object Adapter Pattern



Class Adapter Pattern



When to Use Adapters

- Concrete adapter
  When using a class whose interface does not match what you need.
- Abstract adapter
  When creating a reusable class that cooperates with unknown future classes.

Proxy pattern

Acknowledgement: Freeman & Freeman

The Problems

- Expensive & inexpensive pieces of state
  - Example: Large image
  - Inexpensive: size & location of drawing
  - Expensive: load & display
- Remote objects (e.g., another system)
  - Want to access it as if it were local
  - Want to hide all the required communications
  - Example: Java RMI
- Object with varying access rights
  - Some clients can access anything
  - Other clients have subset of functionality available

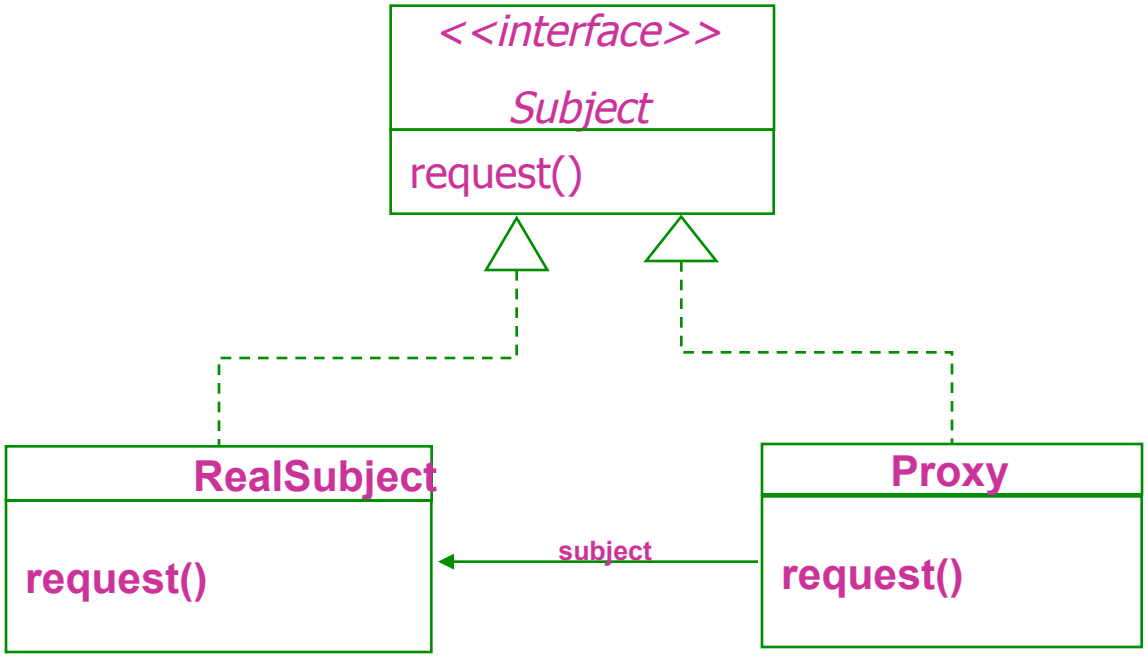
The Design Goal

- In all these cases desire access to object as if it is directly available
- For efficiency, simplicity, or security, put a *proxy* object in front of the real object
- We have a stand-in for the real object to control how the real object behaves

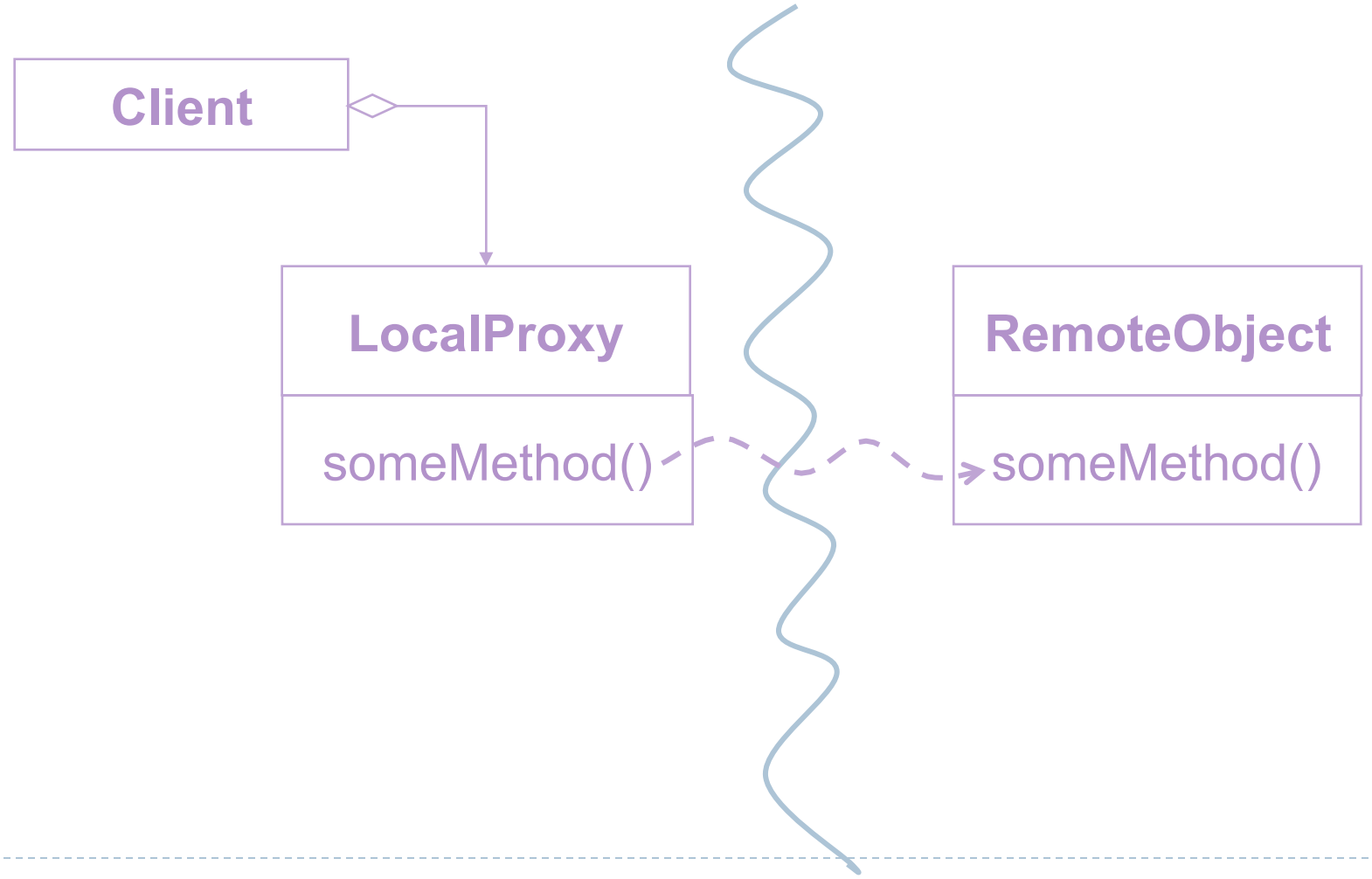
Proxy pattern Defined

- Proxy patterns provides a surrogate or placeholder for another object to control access to it
  - Remote proxy controls access to a remote object
  - Virtual proxy controls access to a resource that is expensive to create
  - Protection proxy controls access to a resource based on access rights

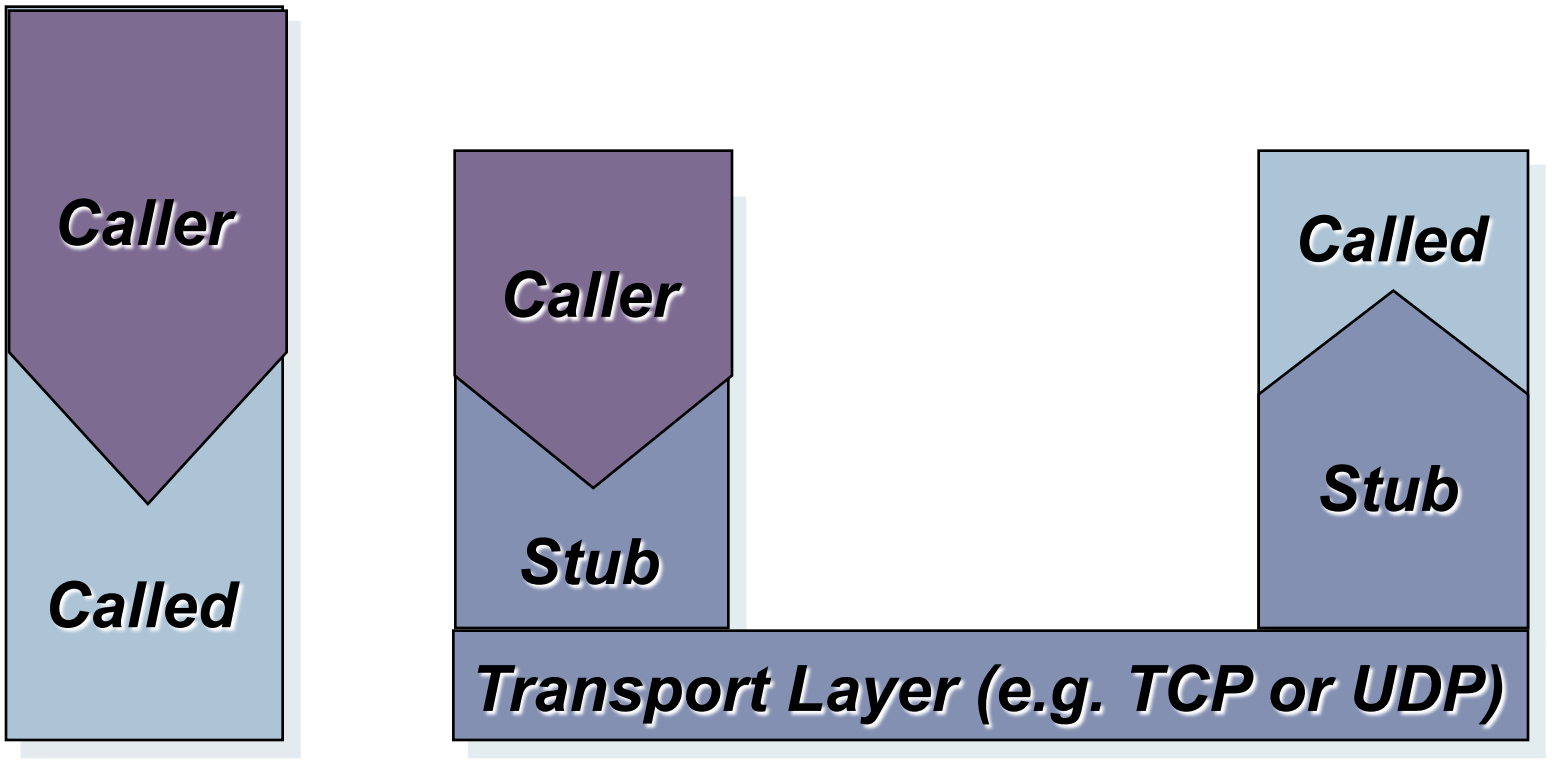
Proxy pattern structure



Example: Accessing Remote Object



Java RMI, the big picture



Categories of Proxies

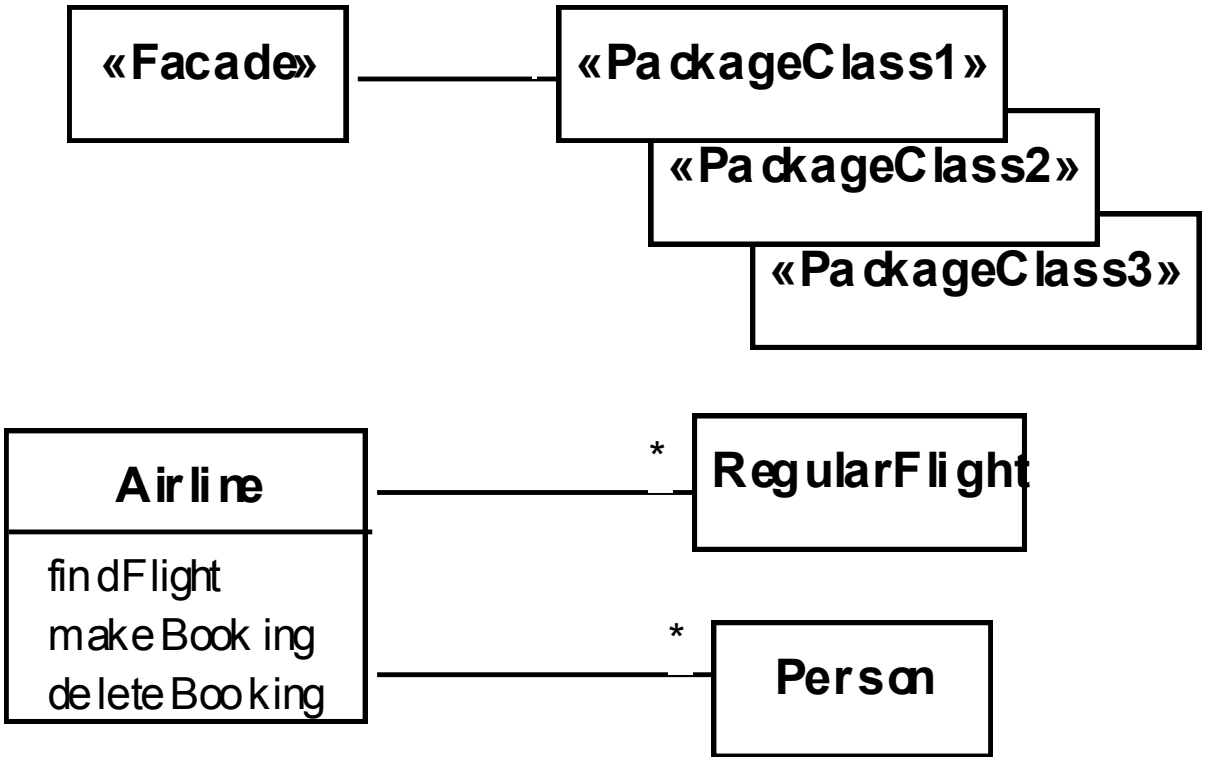
- **Remote proxy** - as above
  - Local representative for something in a different address space
  - Java RMI tools help set these up automatically
  - Object brokers handle remote objects (CORBA or DCOM)
- **Virtual proxy**
  - Stand-in for an object that is expensive to implement or completely access
  - Example – image over the net
  - May be able to access some state (e.g., geometry) at low cost
  - Defer other high costs until it must be incurred
- **Protection proxy**
  - Control access to the "real" object
  - Different proxies provide different rights to different clients
  - For simple tasks, can do via multiple interfaces available to clients
  - For more dynamic checking, need a front-end such as a proxy

The Controller Façade Pattern

- ***Context***:
  - Often, an application contains several complex packages.
  - A programmer working with such packages has to manipulate many different classes
- ***Problem***:
  - How do you simplify the view that programmers have of a complex package?
- ***Forces***:
  - It is hard for a programmer to understand and use an entire subsystem
  - If several different application classes call methods of the complex package, then any modifications made to the package will necessitate a complete review of all these classes.

Façade

- ***Solution:***



Proxies/Adapters/Facades

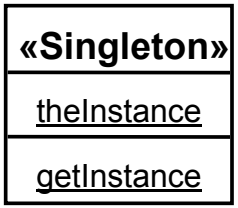
- Proxies and Adapters both place a stand-in object between the client and the real object
- Adapters do so to change the real object's interface
- Proxies do so to optimize access to the object via the same interface.
- Facades ease the use of sub-systems of objects

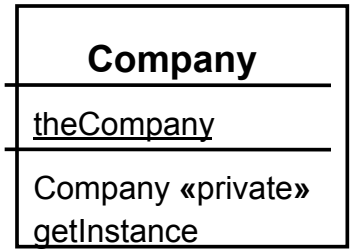
The Singleton Pattern

- ***Context***:
  - It is very common to find classes for which only one instance should exist (*singleton)*
- ***Problem***:
  - How do you ensure that it is never possible to create more than one instance of a singleton class?
- ***Forces***:
  - The use of a public constructor cannot guarantee that no more than one instance will be created.
  - The singleton instance must also be accessible to all classes that require it

Singleton

- ***Solution:***





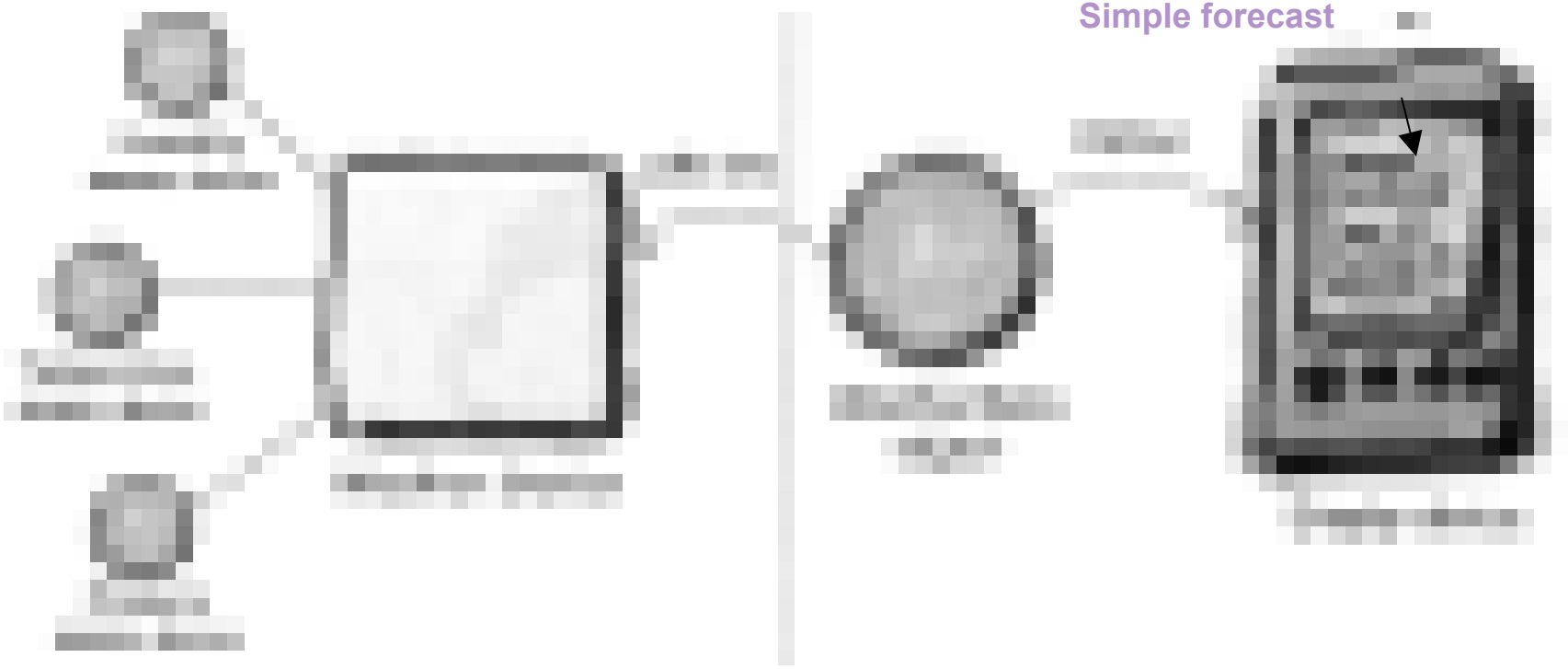

```
if (theCompany==null)
  theCompany= new Company();

return theCompany;
```

Observer pattern

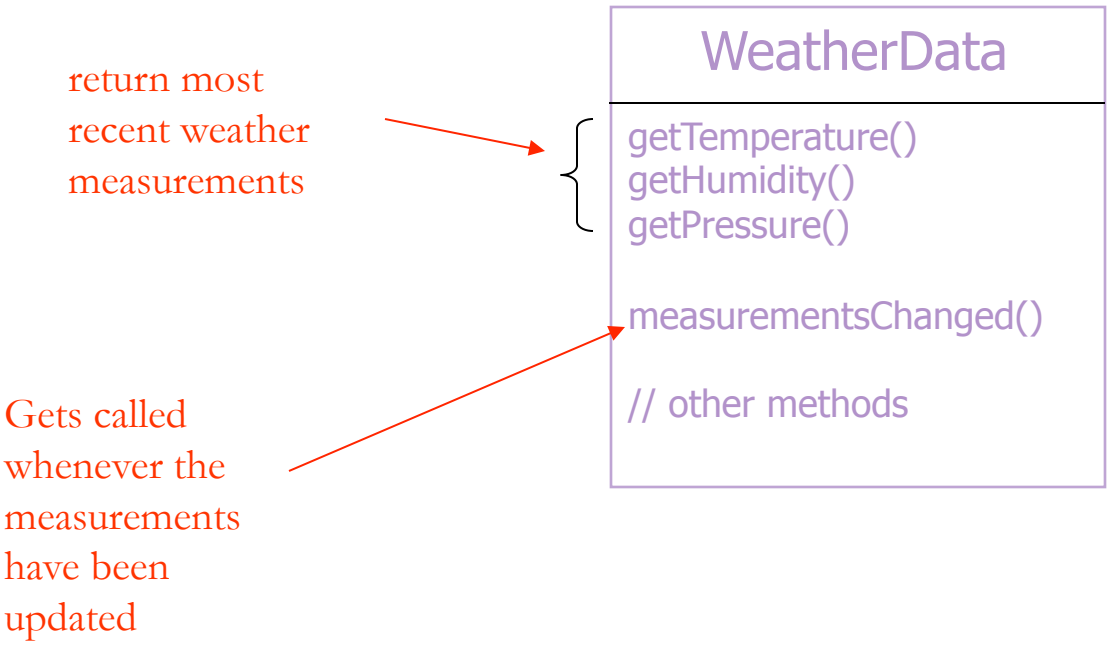
Acknowledgement: Freeman & Freeman

Weather Monitoring application

Display elements:
Current conditions,
Weather statistics,
Simple forecast



WeatherData class



WeatherData Implementation

```
public class WeatherData {
    // instance variable declarations

    public void measurementsChanged() {
            float temp = getTemperature();
            float humidity = getHumidity();
            float pressure = getPressure();

            currentConditionsDisplay.update (temp, humidity, pressure);
            statisticsDisplay.update (temp, humidity, pressure);
            forecastDisplay.update (temp, humidity, pressure);
    }

    // other WeatherData methods here
}
```

The Problem

- Given
  - Clusters of related classes
  - Tight connections within each cluster of classes
  - Loose state dependency between clusters
- Desired
  - Keep each cluster state consistent when state changes in cluster it depends on
  - Provide isolation such that changed cluster has no knowledge of specifics of dependent clusters

Example: UI & Application

- Application classes represent information being manipulated.
- UI provides way to view and alter application state.
- May have several views of state (charts, graphs, numeric tables).
- Views may be added at any time.
- How to tell views when application state has changed?

Approach One – Direct Connect

- Application knows about each View object.
- On state change, call appropriate method in the View object affected
- Issues
  - Application needs to know which method to call in each View
  - Application aware of changes to UI (e.g., add/delete/change Views).

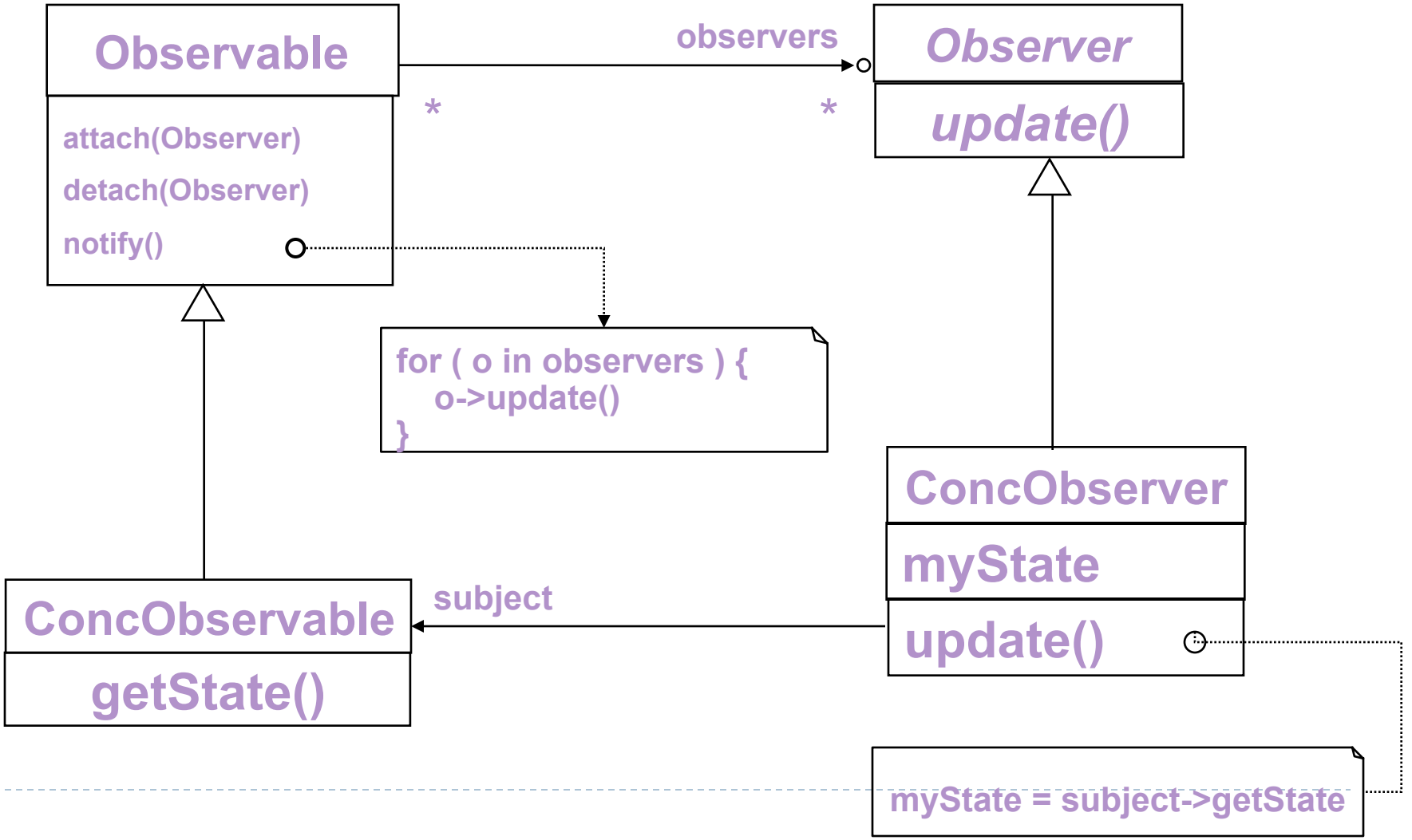
Approach Two : Observer Pattern

- The observer pattern defines a one-to-many dependency between objects so that when one object changes state, all of its dependents are notified and updated automatically

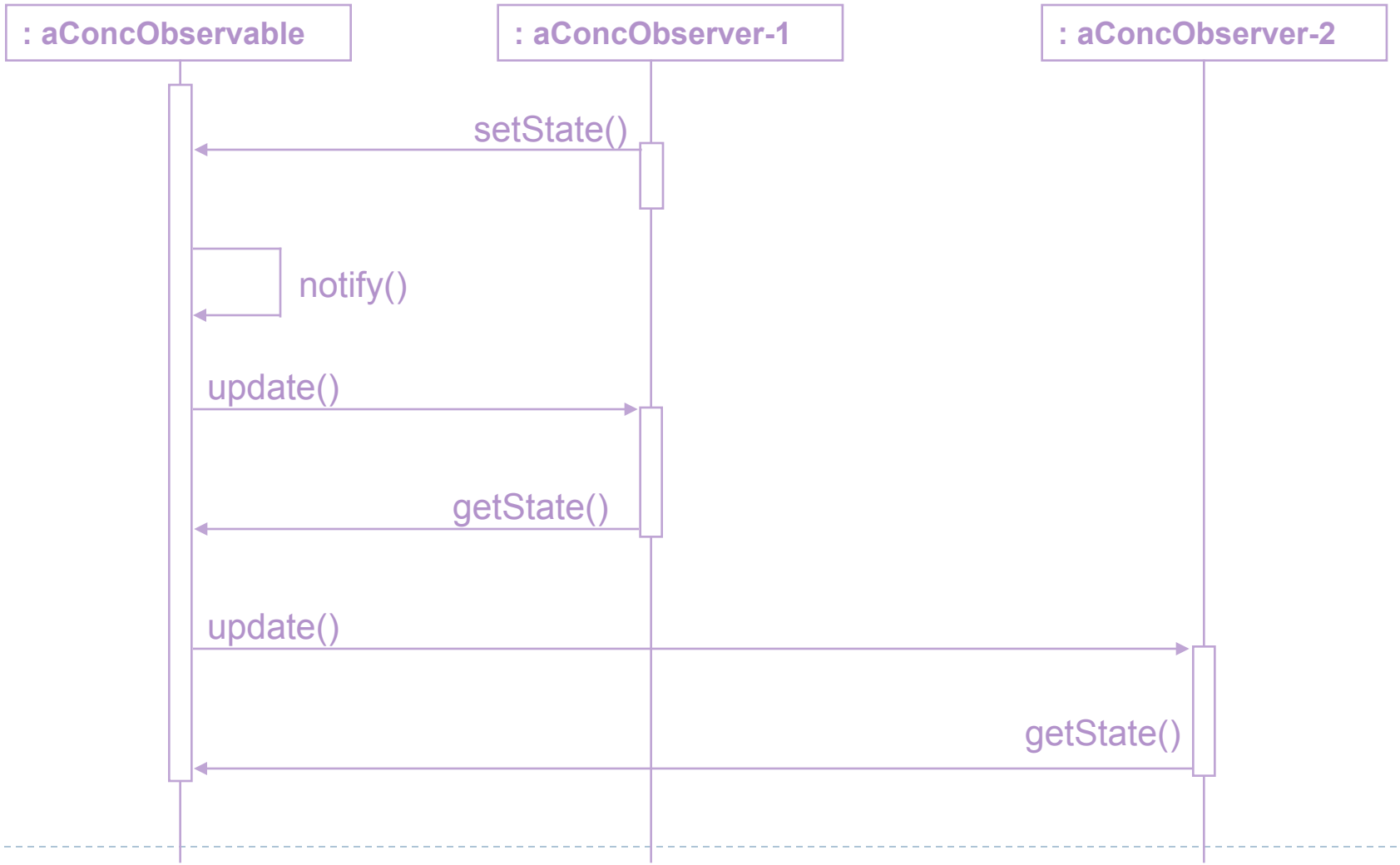
Approach Two – Observer/Subject
(AKA: publish/subscribe)

- Observables: objects with interesting state changes
- Observers: objects interested in state changes
- Observers *register* interest with observable objects.
- Observables *notify* all registered observers when state changes.

Observer Pattern - Class diagram



Interaction Diagram



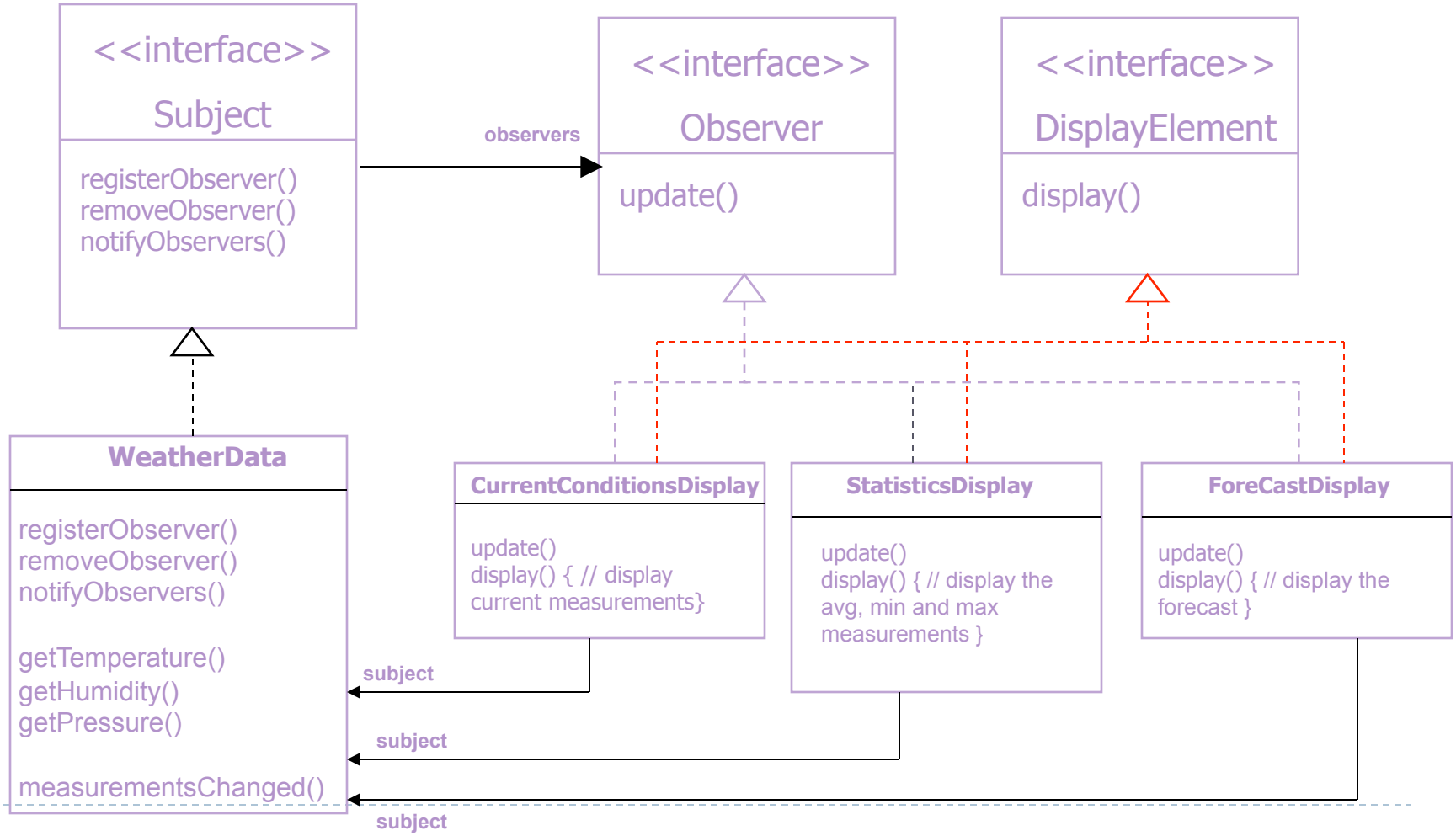
When to Use Observer

- Two subsystems evolve independently but must stay in synch.
- State change in an object requires changes in an unknown number of other objects (broadcast)
- Desire loose coupling between changeable object and those interested in the change.

Consequences

- Subject/observer coupling (loose coupling)
  - Subject only knows it has a list of observers
  - The only thing the Subject knows about an Observer is that it implements a certain interface
  - Observers can be added at any time
  - Does not know any Observer concrete class
  - Subjects don't need to be modified to add new types of Observers
  - Subjects and Observers can be reused independently
- Supports broadcast communication
  - Observables know little about notify receivers
  - Changing observers is trivial
- Unexpected & cascading updates
  - change/notify/update -> change/notify/update
  - May be hard to tell *what* changed

Designing the Weather Station



Observer Pattern – Key points

- Observer pattern defines a one-to-many relationship between objects
- Subjects/Observables update observers using a common interface
- Observers are loosely coupled in that the Observable knows nothing about them, other than that they implement observer interface
- You can PUSH or PULL data from the Observable when using the pattern (pull is considered more "correct")
- Don't depend on specific order of notification for your observers

Composite pattern

Acknowledgement: Freeman & Freeman

The Problem

- Problem
  - Have simple primitive component classes that collect into larger *composite* components
- Desire
  - Treat composites like primitives
  - Support composite sub-assemblies
  - Operations (usually) recurse to subassemblies
- Solution
  - Build composites from primitive elements

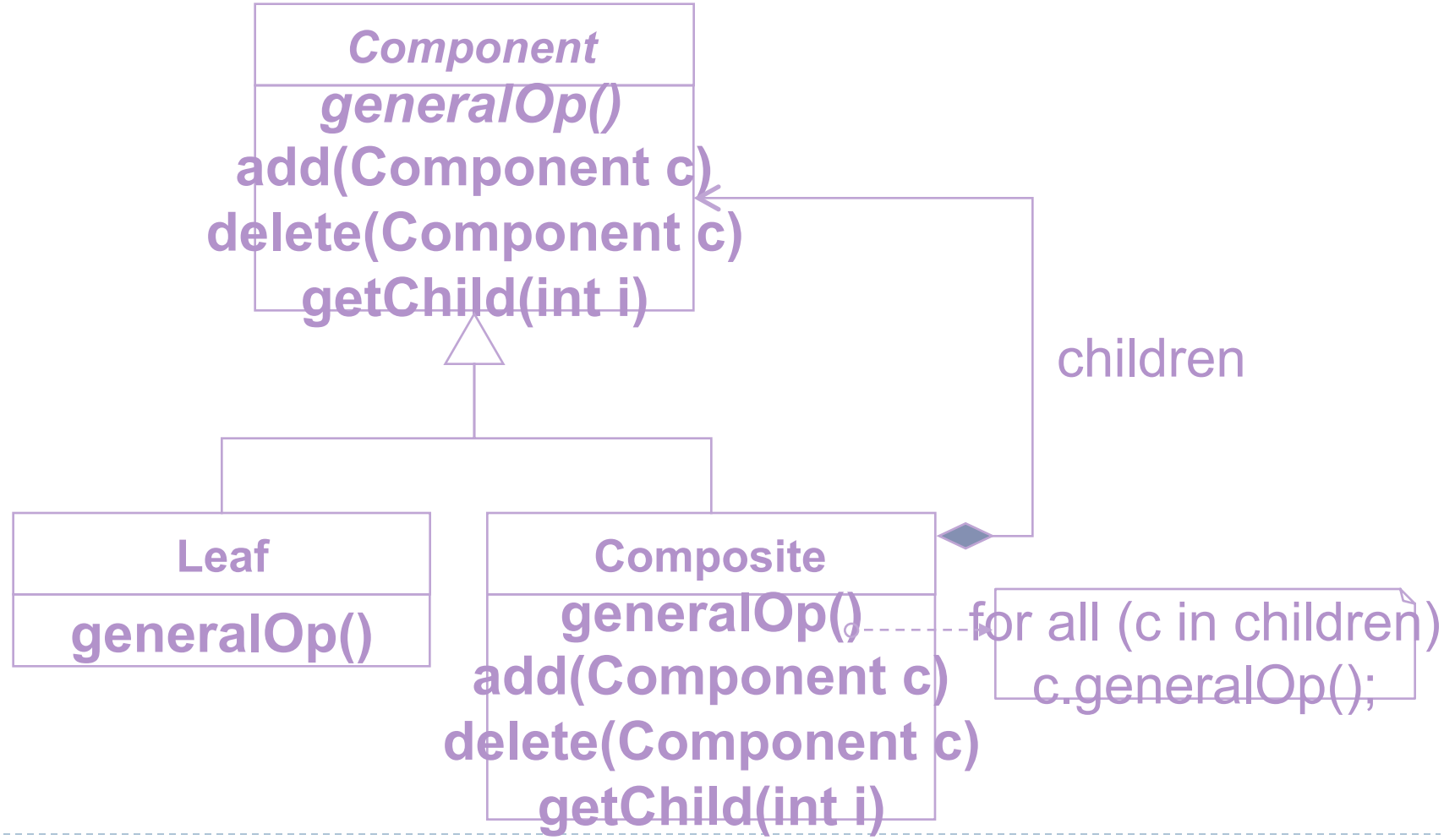
Examples - 1

- File systems
  - Primitives = text files, binary files, device files, etc.
  - Composites = directories (w/subdirectories)
- Make file dependencies
  - Primitives = leaf targets with no dependents
  - Composites = targets with dependents
- Menus
  - Primitives = menu entries
  - Composites = menus (w/submenus)

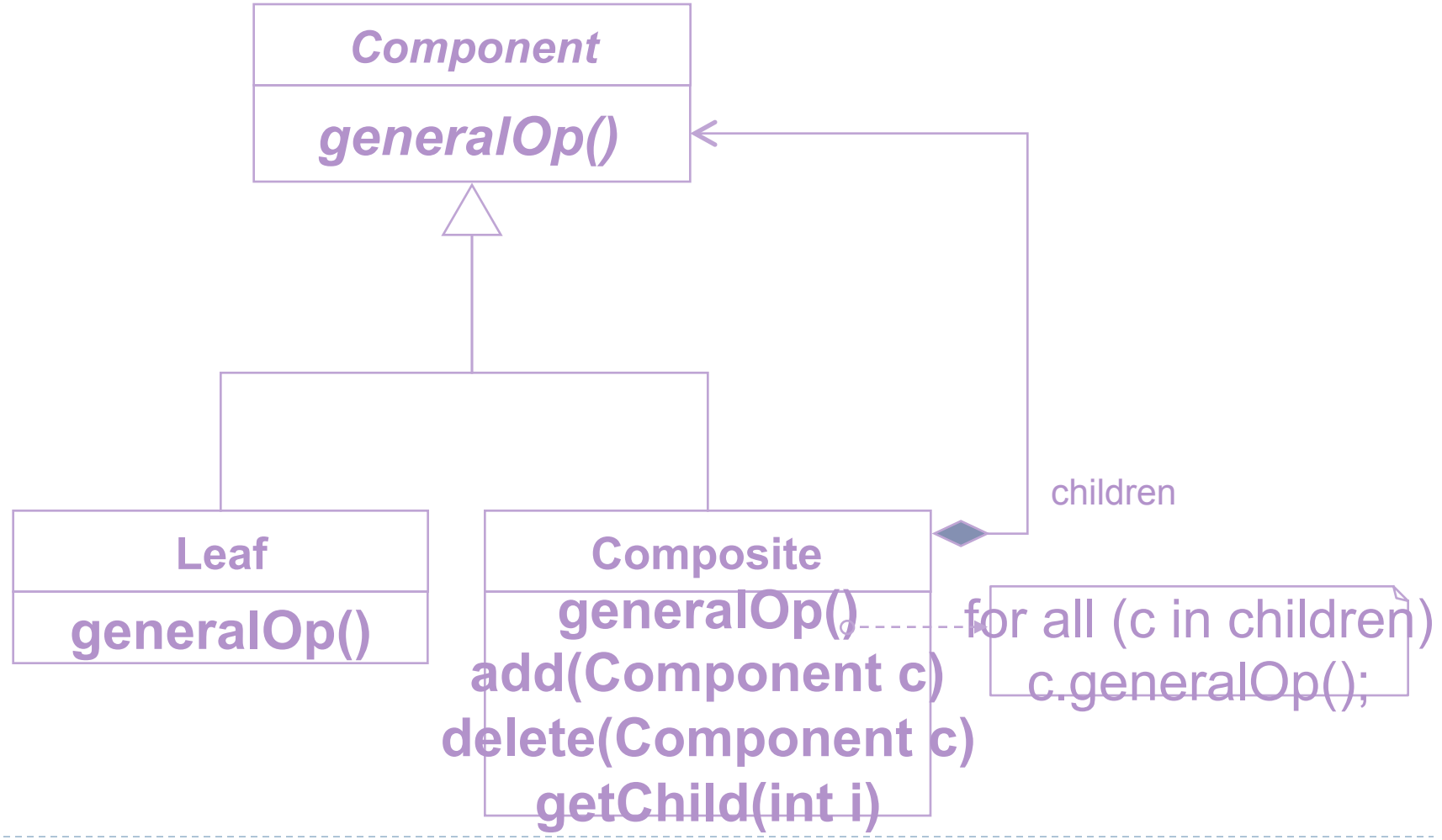
Examples - 2

- GUI Toolkits
  - Primitives = basic components (buttons, textareas, listboxes, etc).
  - Composites = frames, dialogs, panels.
- Drawing Applications
  - Primitives = lines, strings, polygons, etc.
  - Composites = groupings treated as unit.
- HTML/XML
  - Pages as composites of links (hypertext)
  - Pages as collections of paragraphs (with subparagraphs for lists, etc.)

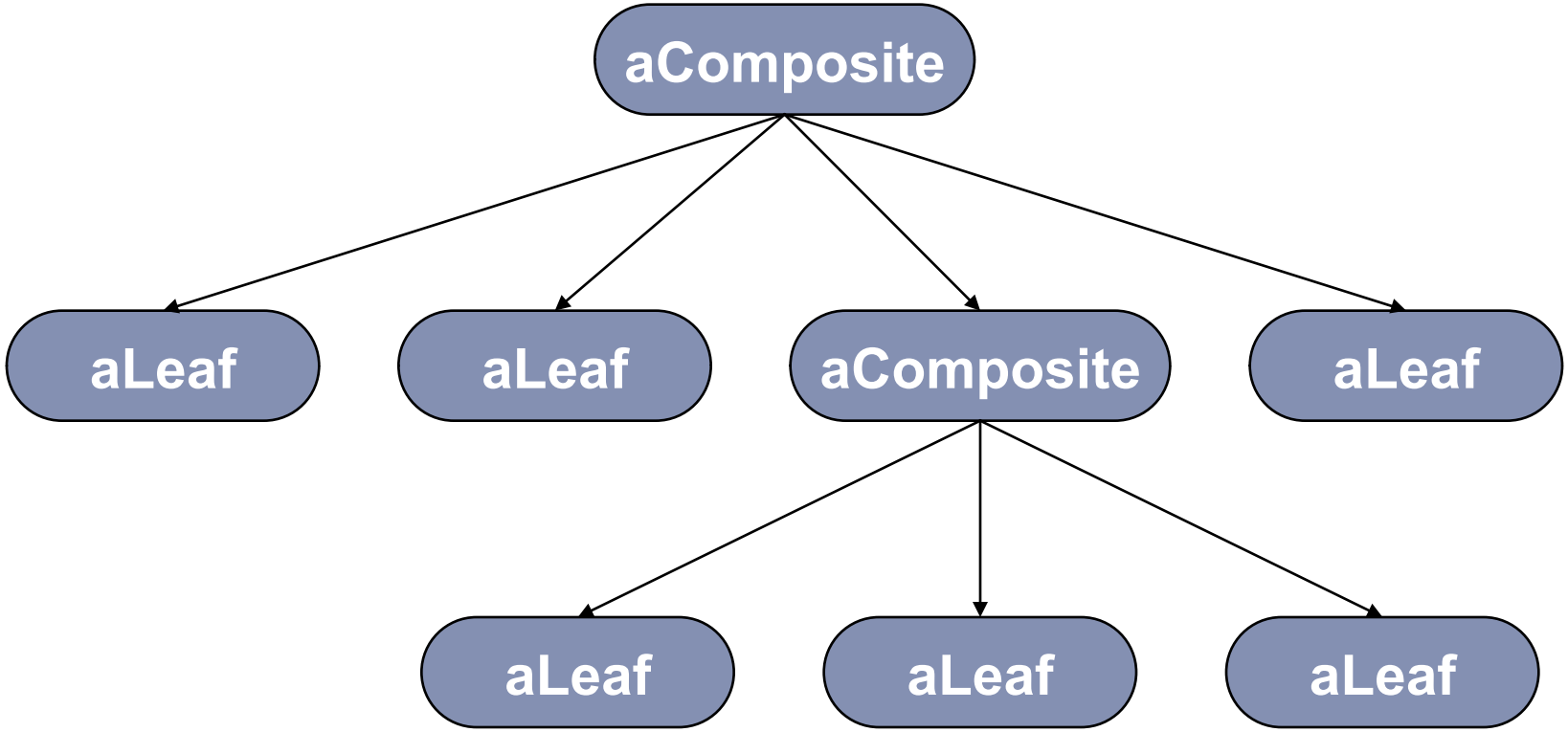
Class Diagram (Alternative 1)



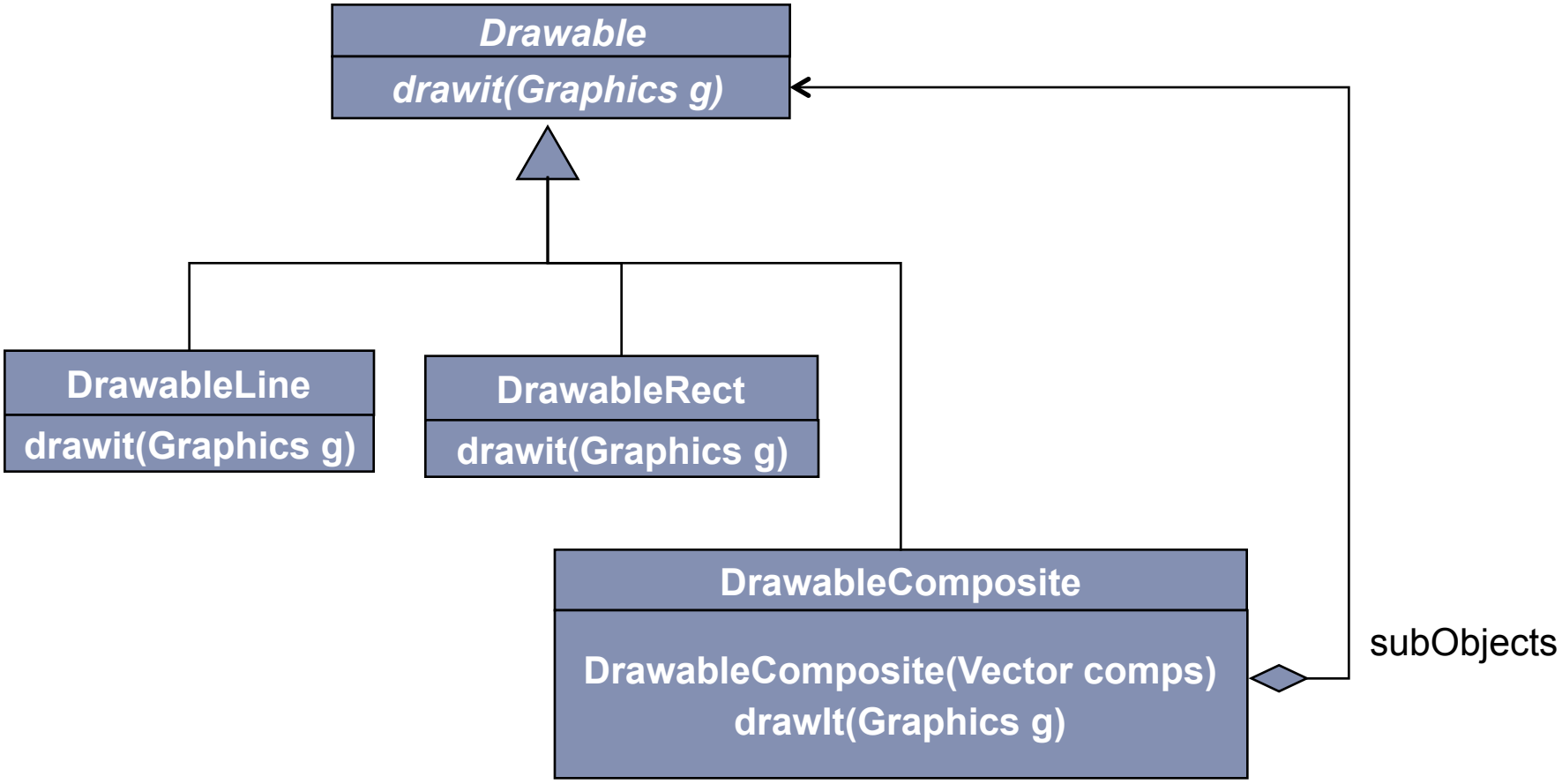
Class Diagram (Alternative 2)



Example Object Structure



Example: Drawable Figures



Discussion

- Clients (usually) ignore differences between primitives & composites
- Clients access (most) components via the generic interfaces
  - Primitives implement request directly
  - Composites can handle directly or forward
- Arbitrary composition to indefinite depth
  - Tree structure – no sharing of nodes
  - General digraph – supports sharing, multiple parents – be careful!
- Eases addition of new components
  - Almost automatic

Evaluating Designs

- The application of "well-known" design patterns that promote loosely coupled, highly cohesive designs.
- Conversely, identify the existence of recurring *negative* solutions – AntiPatterns
- AntiPattern : use of a pattern in an inappropriate context.
- Refactoring : changing, migrating an existing solution (antipattern) to another by improving the structure of the solution.