Software Patterns

L03: Structural Design Patterns

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Outline of the talk

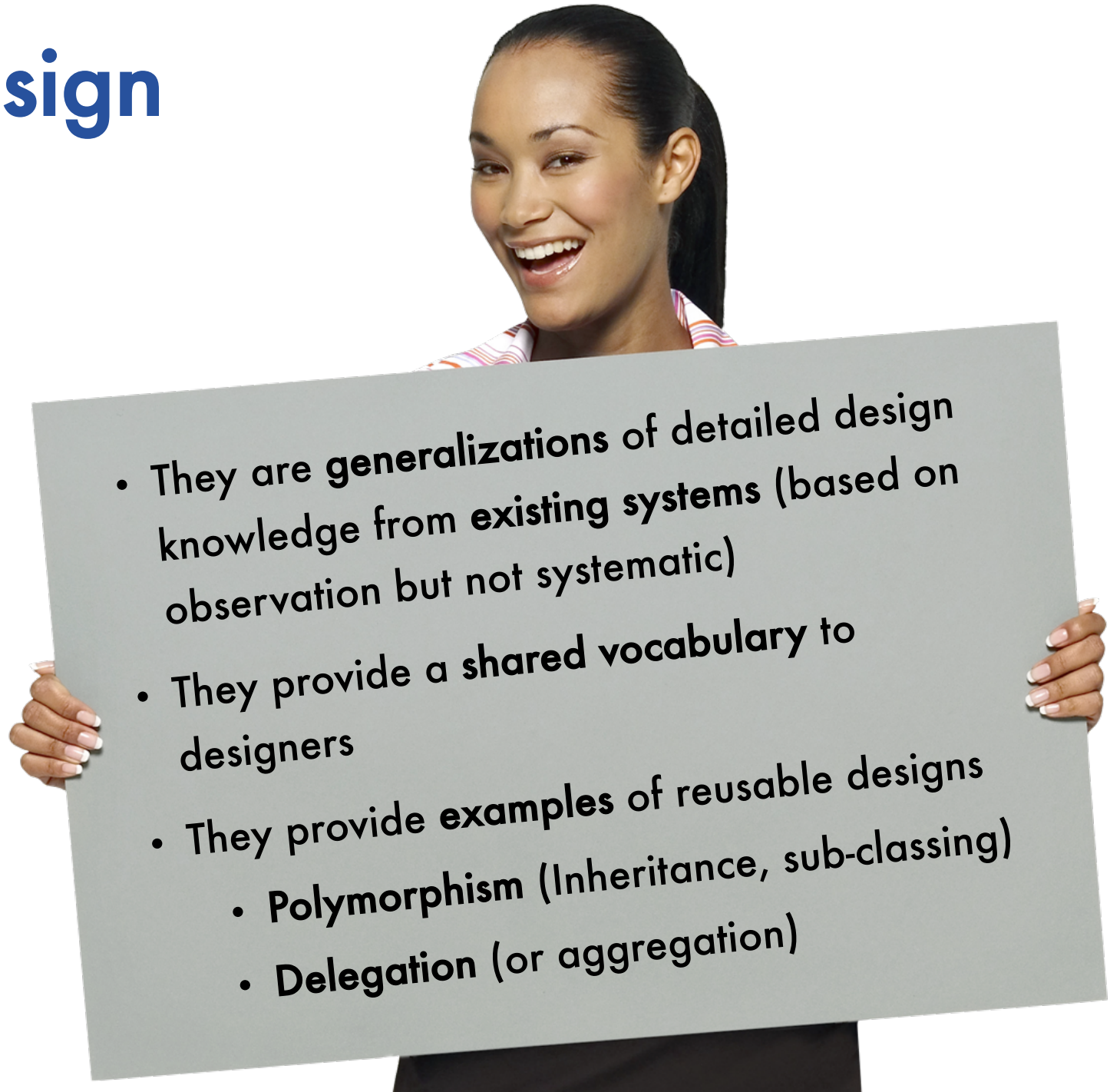
1. Taxonomy of Design Patterns
2. Adapter Pattern
3. Bridge Pattern
4. Proxy Pattern
5. Composite Pattern

Categorization of patterns

- **Architectural Pattern**
  - Expresses a fundamental **structural organization** or schema for software systems
  - Provides a set of predefined **subsystems** and specifies their responsibilities
  - Includes rules and guidelines for organizing the relationships between them
- **Idiom (Coding Pattern)**
  - A low-level pattern specific to a programming language
  - Describes how to implement particular aspects of components or the relationships between them using the features of the given language
- **Design Pattern**
  - Provides a **scheme for refining the subsystems** of a software system or the relationships between them
  - Describes **commonly recurring structure of communicating components** that solves a general design problem within a particular context

[Buschmann et al.]

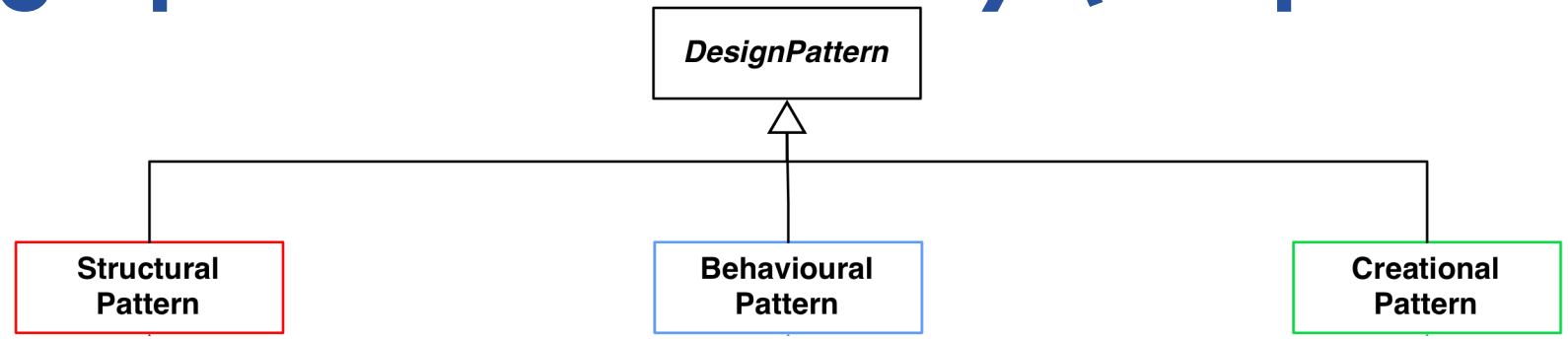
What makes design patterns useful?



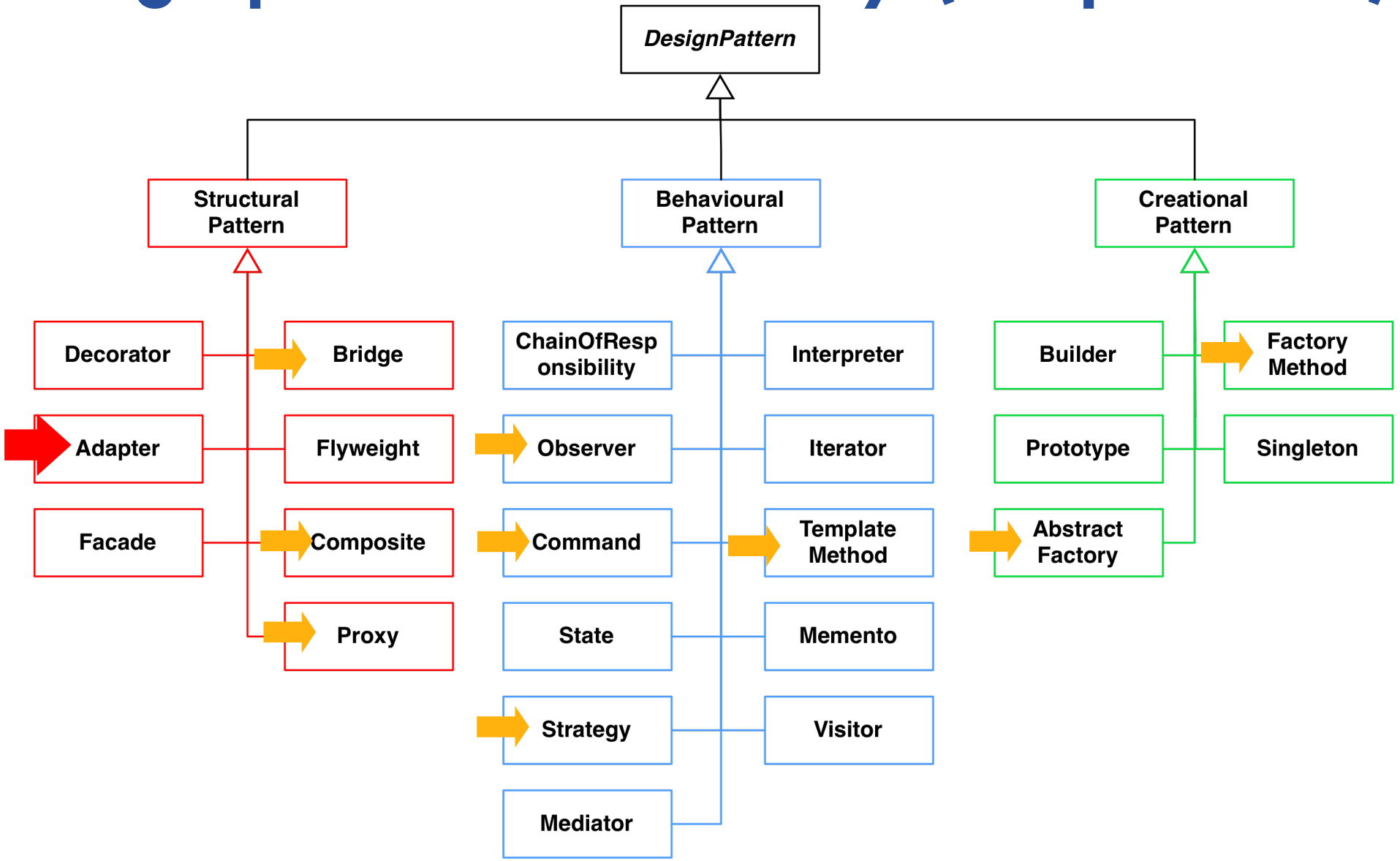
3 types of design patterns ("go4 patterns")

- **Structural Patterns**
  - Reduce coupling between two or more classes
  - Introduce an abstract class to enable future extensions
  - Encapsulate complex structures
- **Behavioral Patterns**
  - Allow a choice between algorithms and the assignment of responsibilities to objects ("Who does what?")
  - Simplify complex control flows that are difficult to follow at runtime
- **Creational Patterns**
  - Allow a simplified view from complex instantiation processes
  - Make the system independent from the way its objects are created, composed and represented

Design patterns taxonomy (23 patterns)



Design patterns taxonomy (23 patterns)



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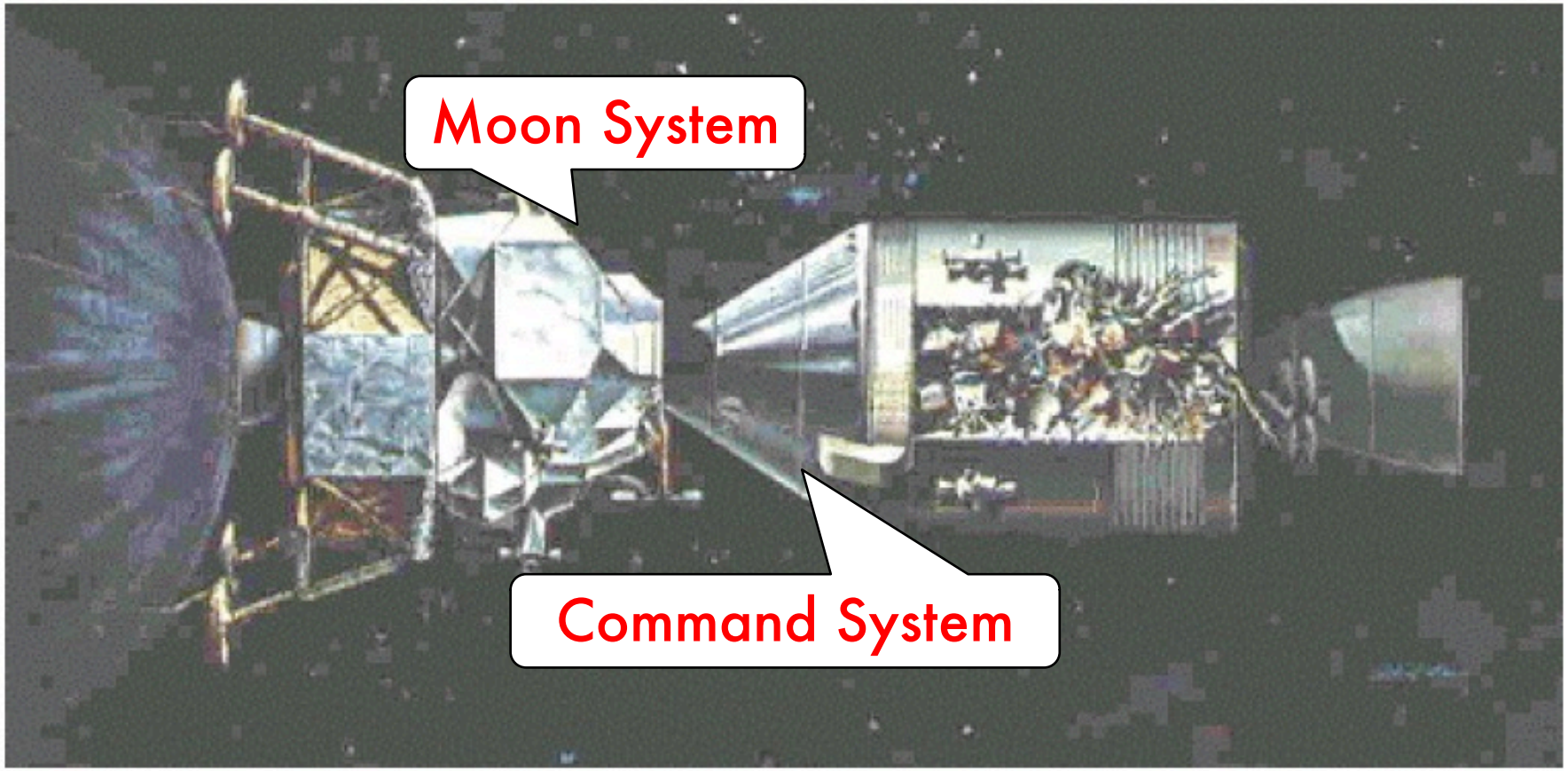
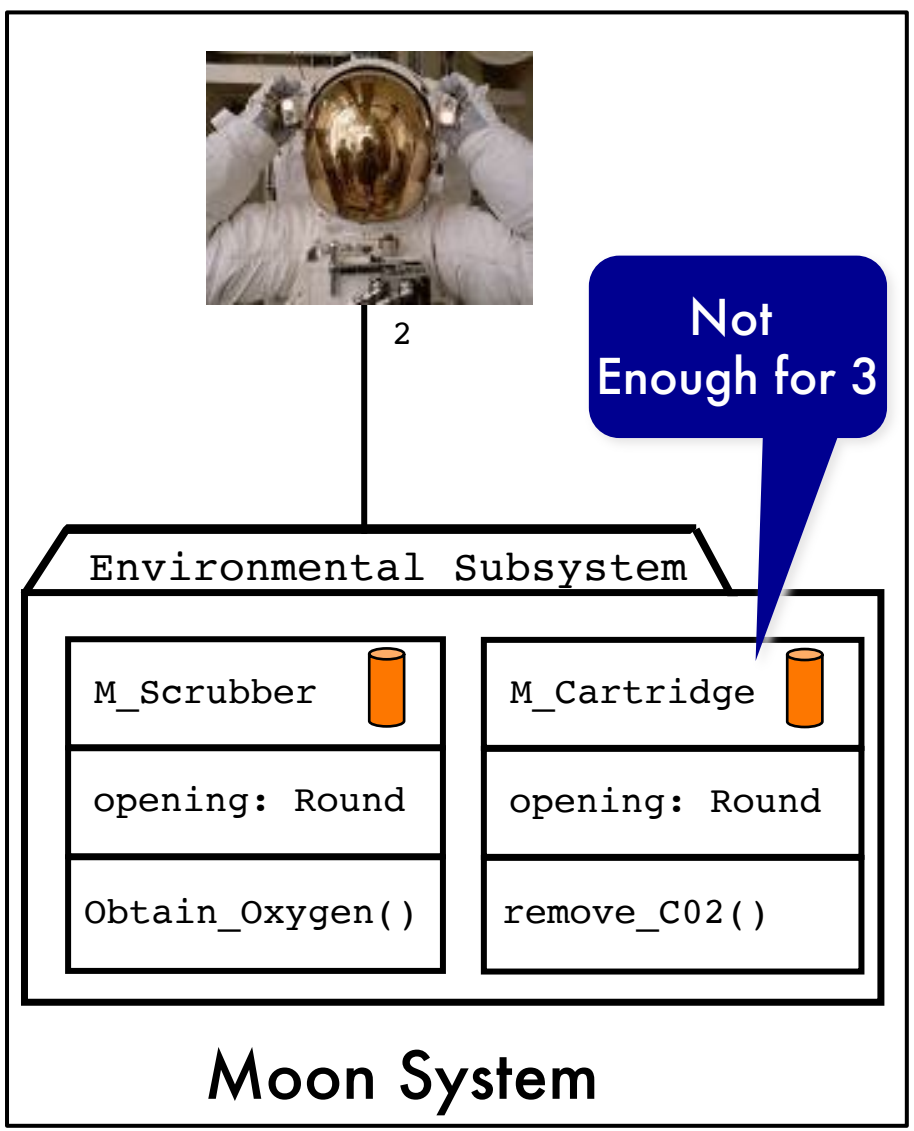
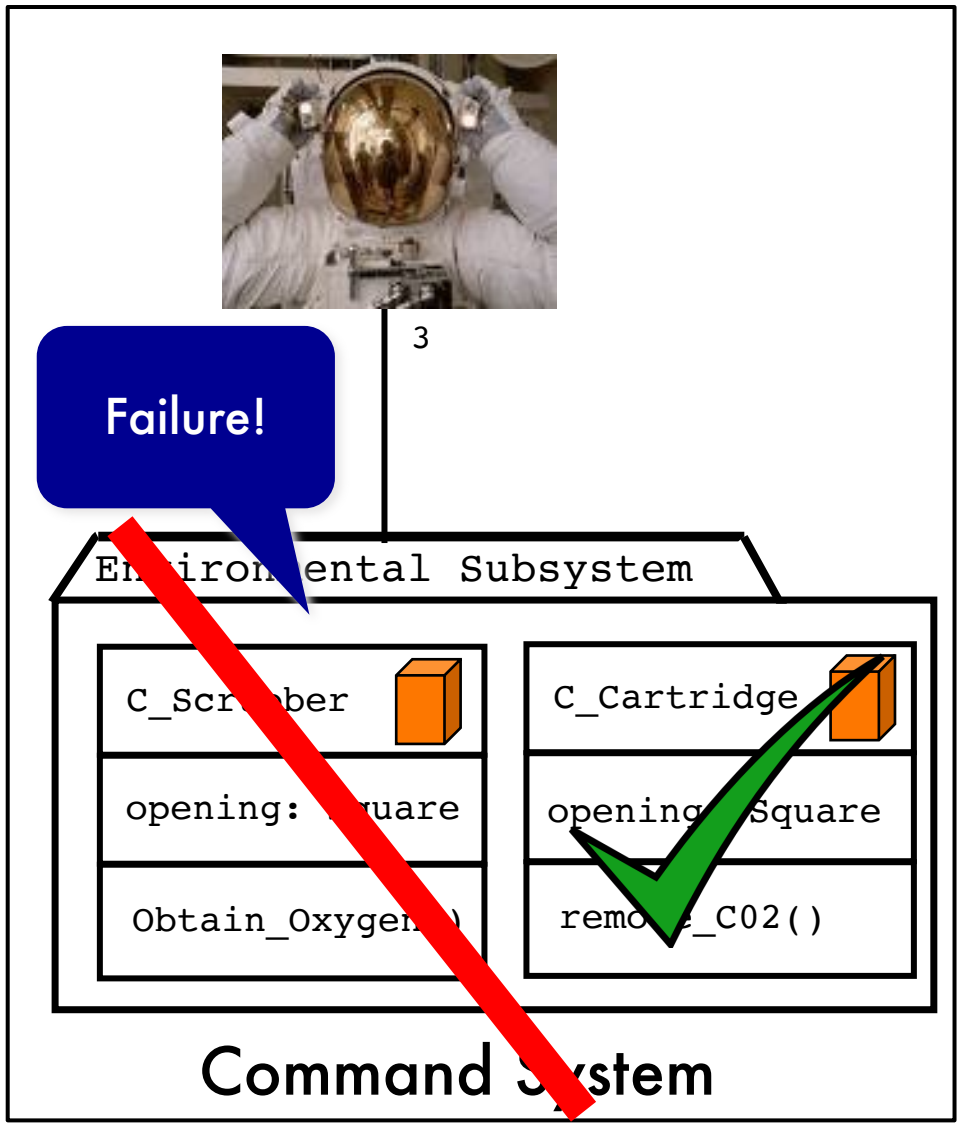
Example Apollo 13: "Houston, we've had a problem!"

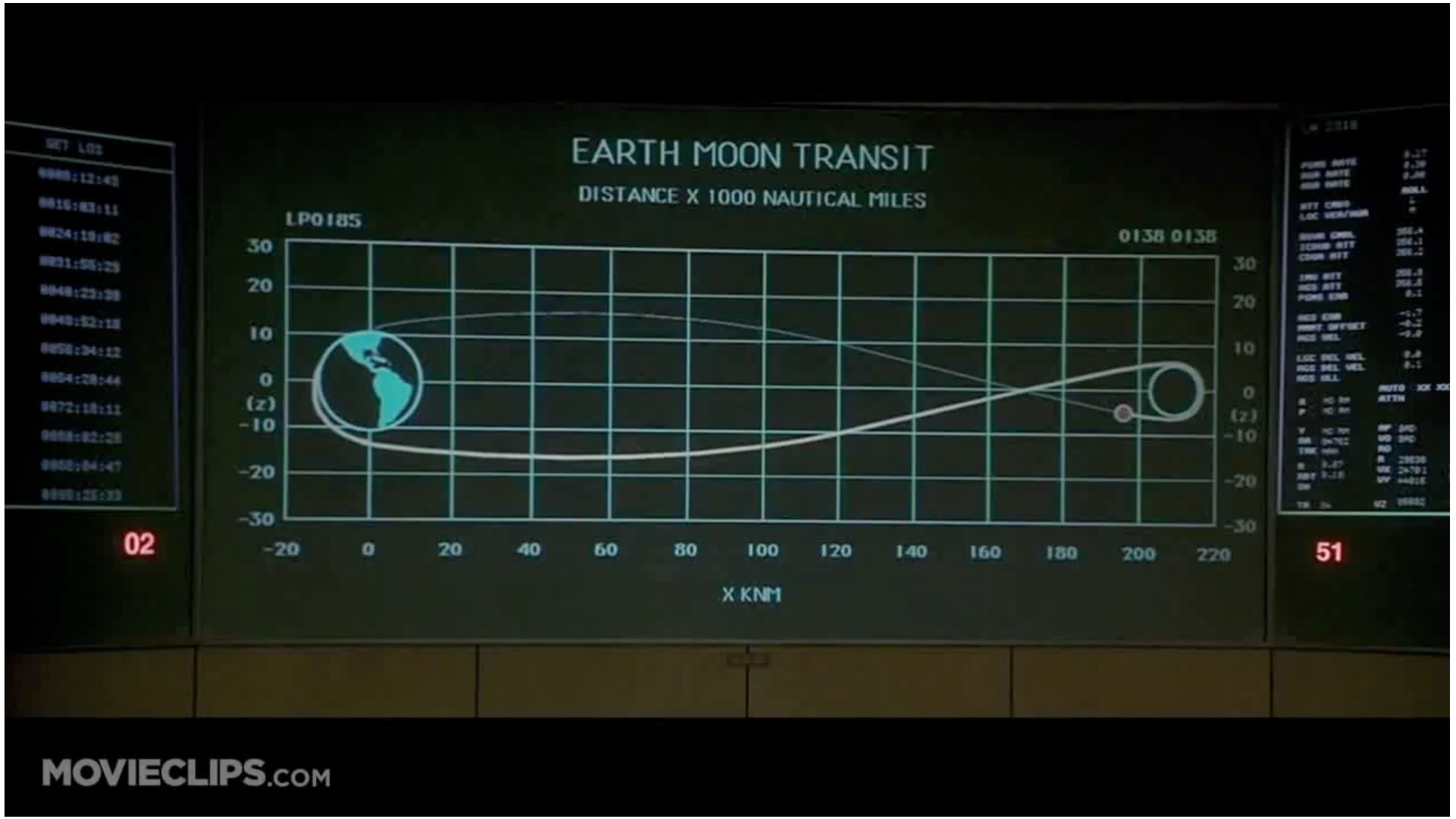


Original design of the Apollo 13 environmental subsystems





"Fitting a square peg in a round hole"



[Source: http://www.hq.nasa.gov/office/pao/History/SP-350/ch-13-4.html]

Adapter pattern

- Connects incompatible components
  - Allows the simplified reuse of existing components
  - Converts the interface of an existing component into another interface expected by the calling component
  - Useful in interface engineering projects and in reengineering projects
    - Used to provide a new interface for (the ugly interface of) legacy systems
- Also known as a wrapper

A famous example

Another example

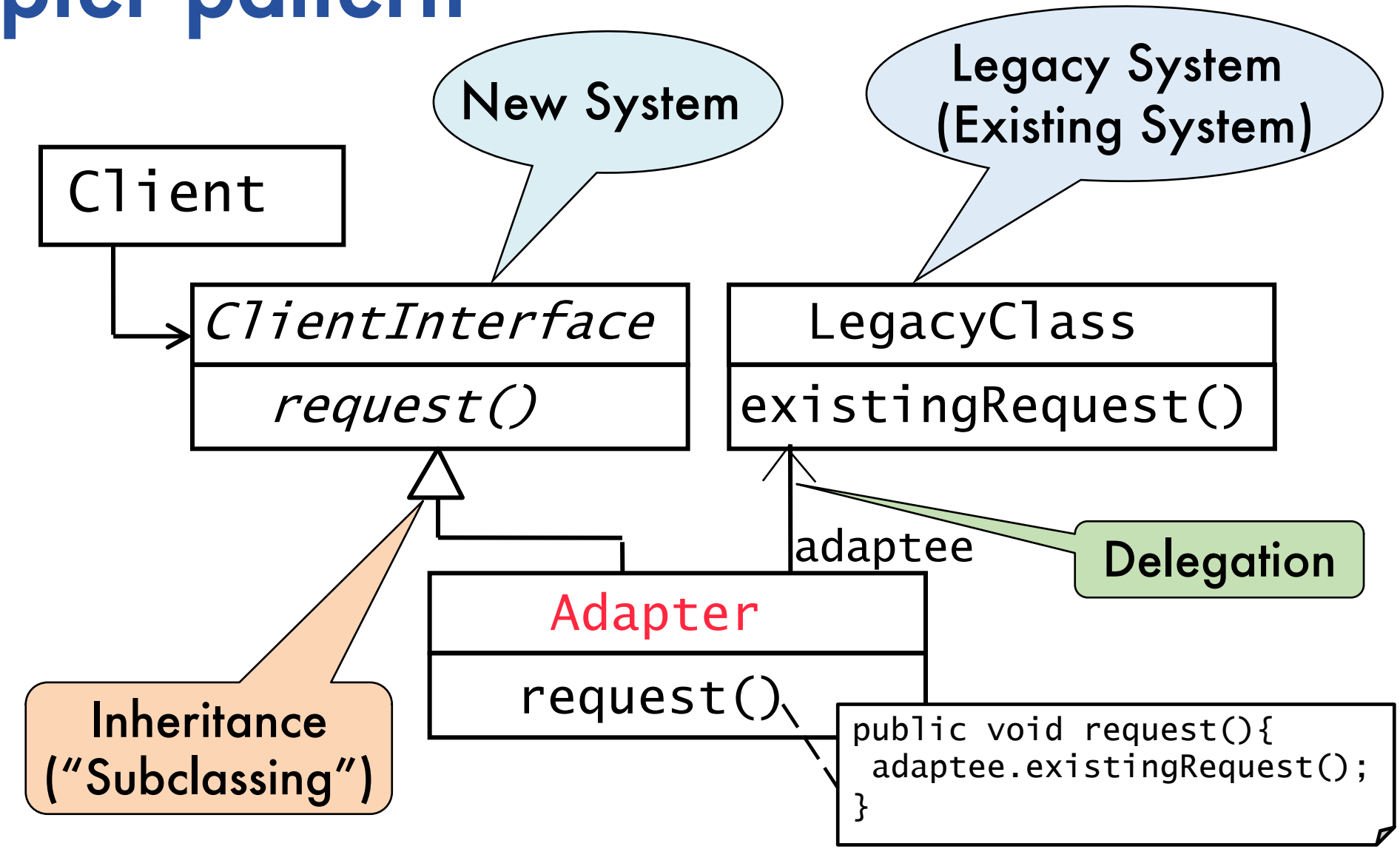
Using the adapter pattern

- Main use: Provide access to legacy systems
- Legacy System:
  - is an old system that continues to be used, even though newer technology or more efficient methods are available
- Why are legacy systems in use?
  - System Cost: System still makes money, the cost for a new system is too high
  - Pragmatism: System is installed and working
  - Poor Engineering: Compiler is no longer available, or source code is lost
  - Availability: System requires high availability, cannot simply be taken out of service to replace it with a new system

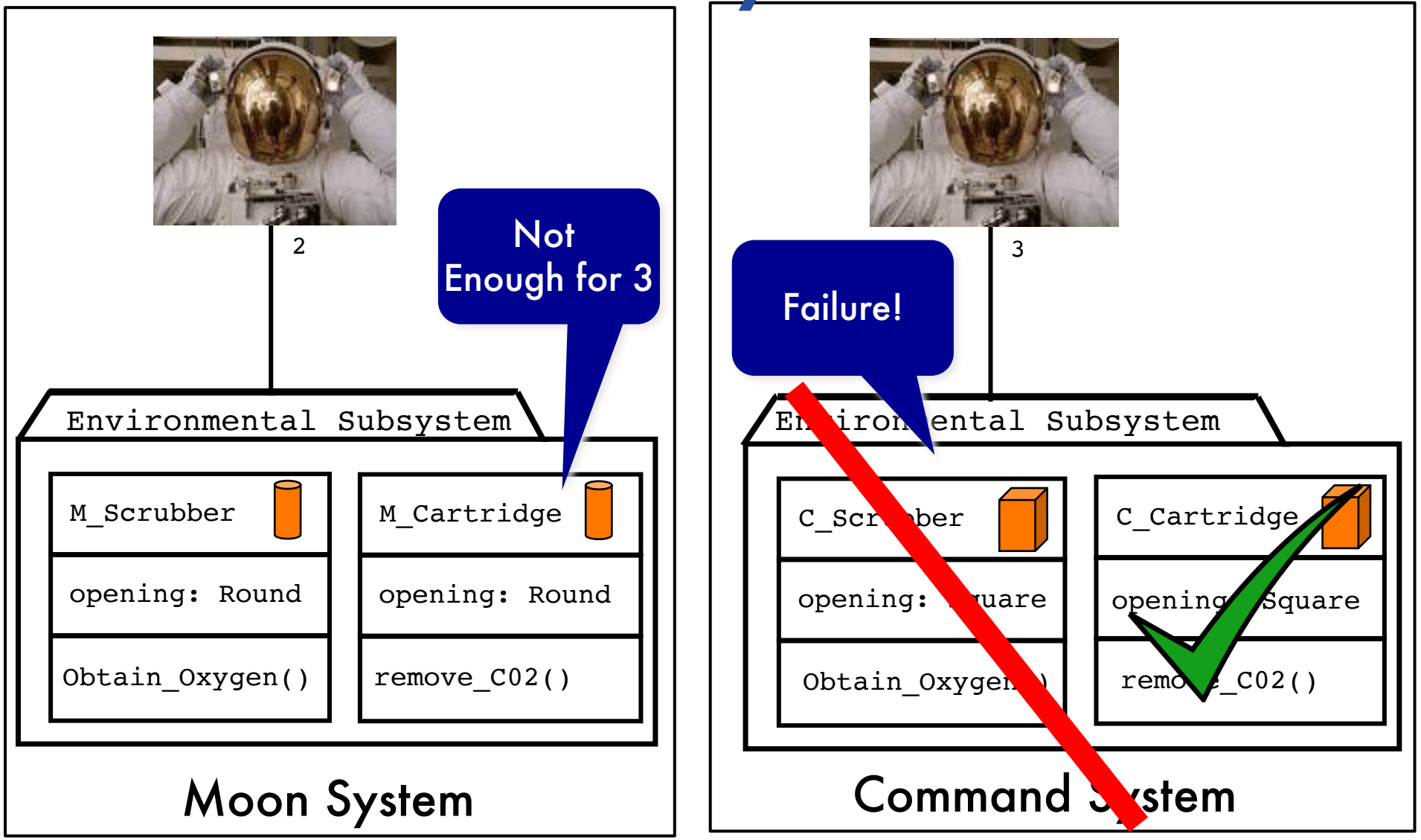
Examples of legacy systems

- Customer relationship management (CRM) systems
- NASA's Space Shuttle program (still uses 1970 technology)
- Air traffic control systems (FAA, Federal Aviation Administration)
- Energy distribution (power grids)
- Nuclear power plants, military defense installations
- SAP R/3 kernel
  - Client-Server Architecture. Last release in 2003
  - The new system is SAP ERP
    - Based on NetWeaver to provide access through Web Services (SOA)
    - SAP ERP is still using legacy SAP R/3 modules

Adapter pattern



Original design of the Apollo 13 environmental subsystems



Original design of the Apollo 13 environmental subsystems

2 3

Not Enough for 3

Environmental Subsystem

M_Scrubber	M_Cartridge
opening: Round	opening: Round
Obtain_Oxygen()	remove_C02()

Moon System

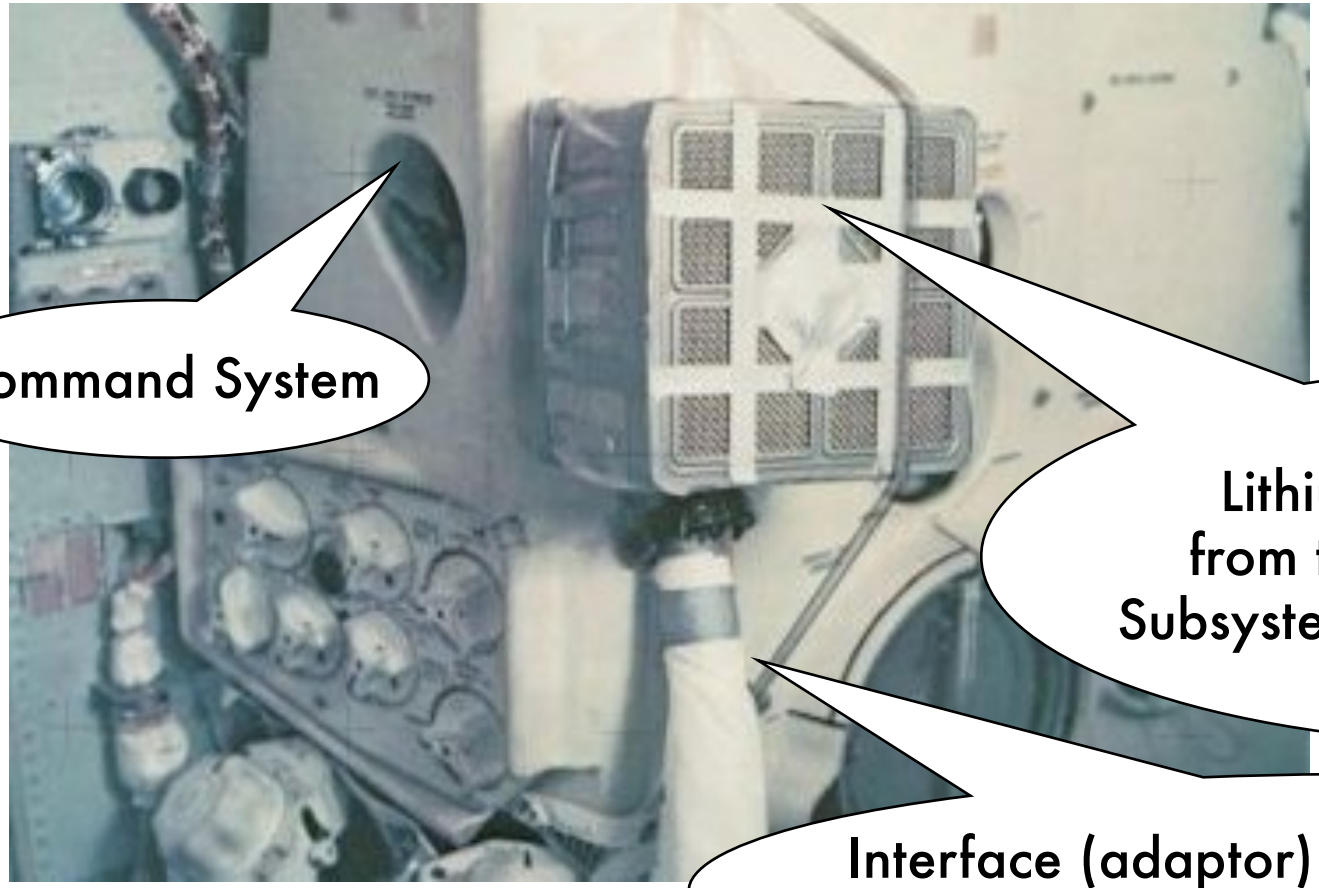
Round_To_Square_Adapter

Obtain_Oxygen()

adaptee

C_Cartridge
opening: Square
remove_C02()

A typical design challenge: connecting incompatible components



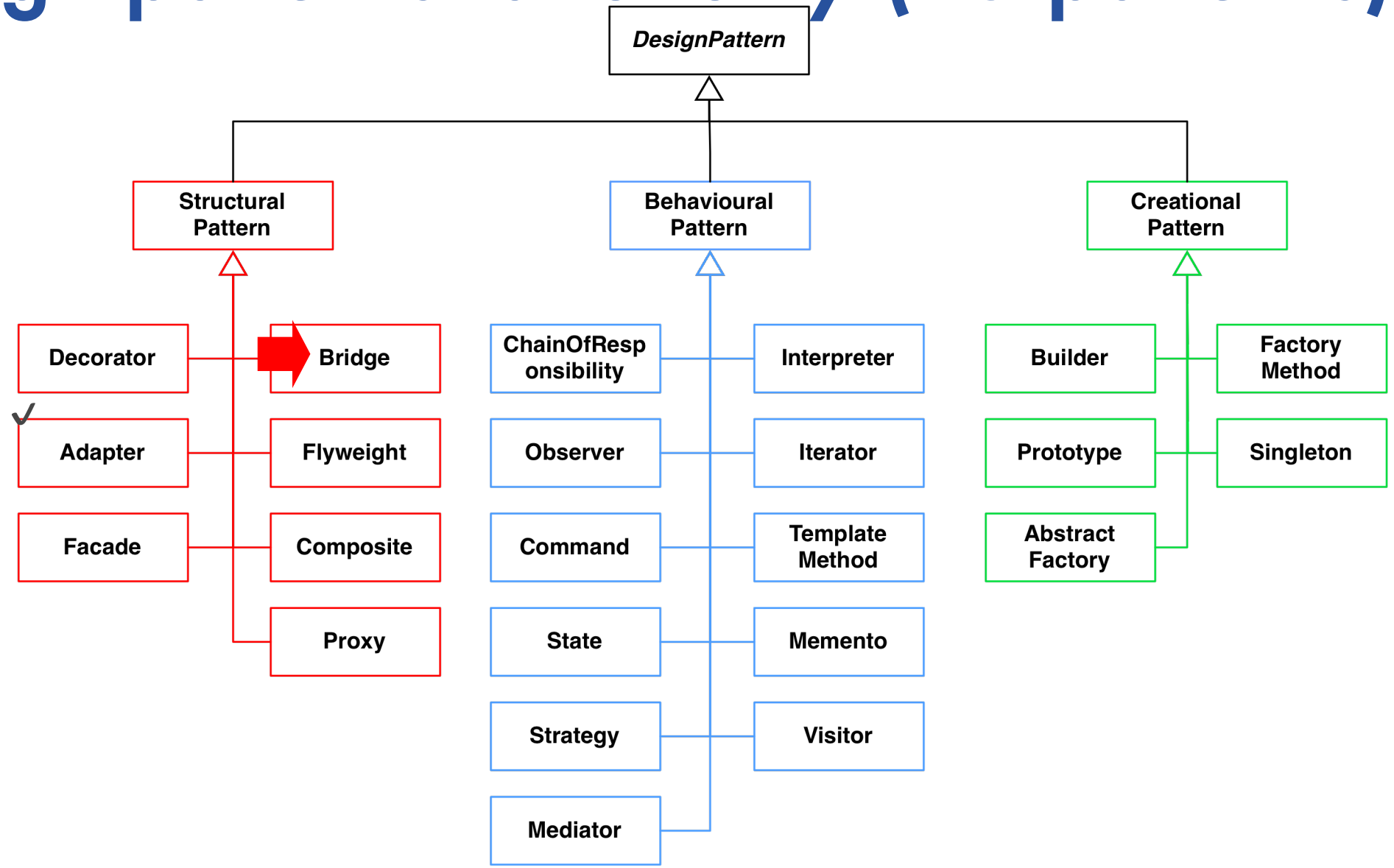
Command System

Lithium hydride canister from the Command System Subsystem using square openings

Interface (adaptor) to the Scrubber in the Lunar System subsystem using round openings

Source: http://www.hq.nasa.gov/office/pao/History/SP-350/ch-13-4.html

Design patterns taxonomy (23 patterns)



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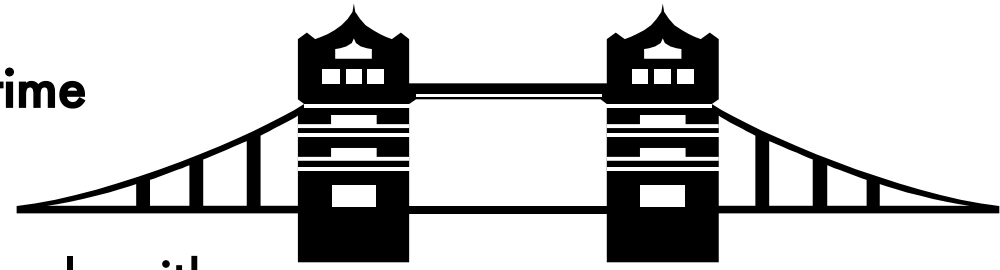
3. **Bridge Pattern**
4. Proxy Pattern
5. Composite Pattern

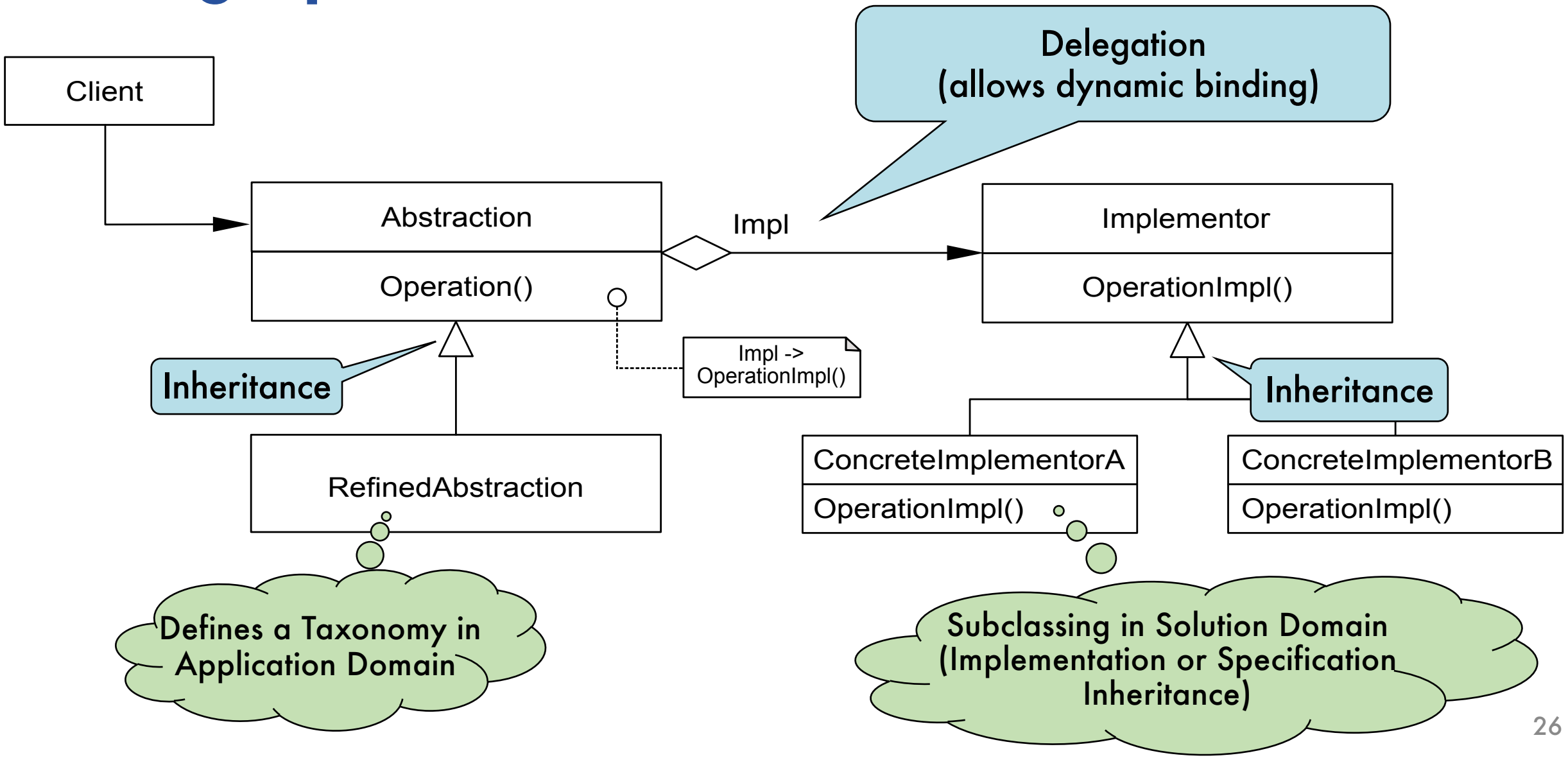
Postpone design decisions to the start time of a system

- **Problem:** Many design decisions have to be made final at **design time** ("design window") or at **compile time**
  - Example: Choosing a specific encryption algorithm
- Often it is desirable to delay design decisions until **run time**
  - Example: We want to support two types of clients
    - One client uses a very old implementation of an algorithm
    - The other client uses a modern implementation of the algorithm



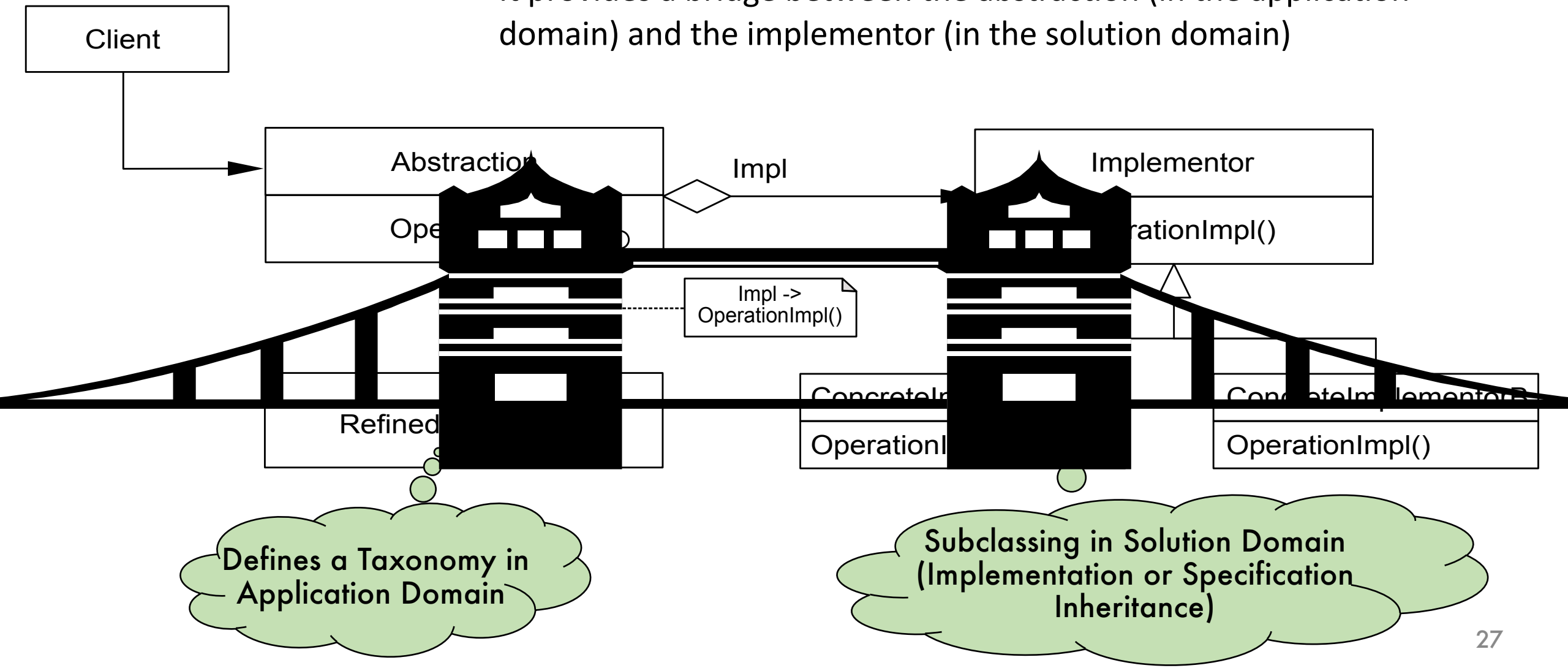
- The **bridge pattern** allows to delay the binding between an interface and its subclass to the start-up time of the system (e.g. in the constructor of the interface class)

Bridge pattern

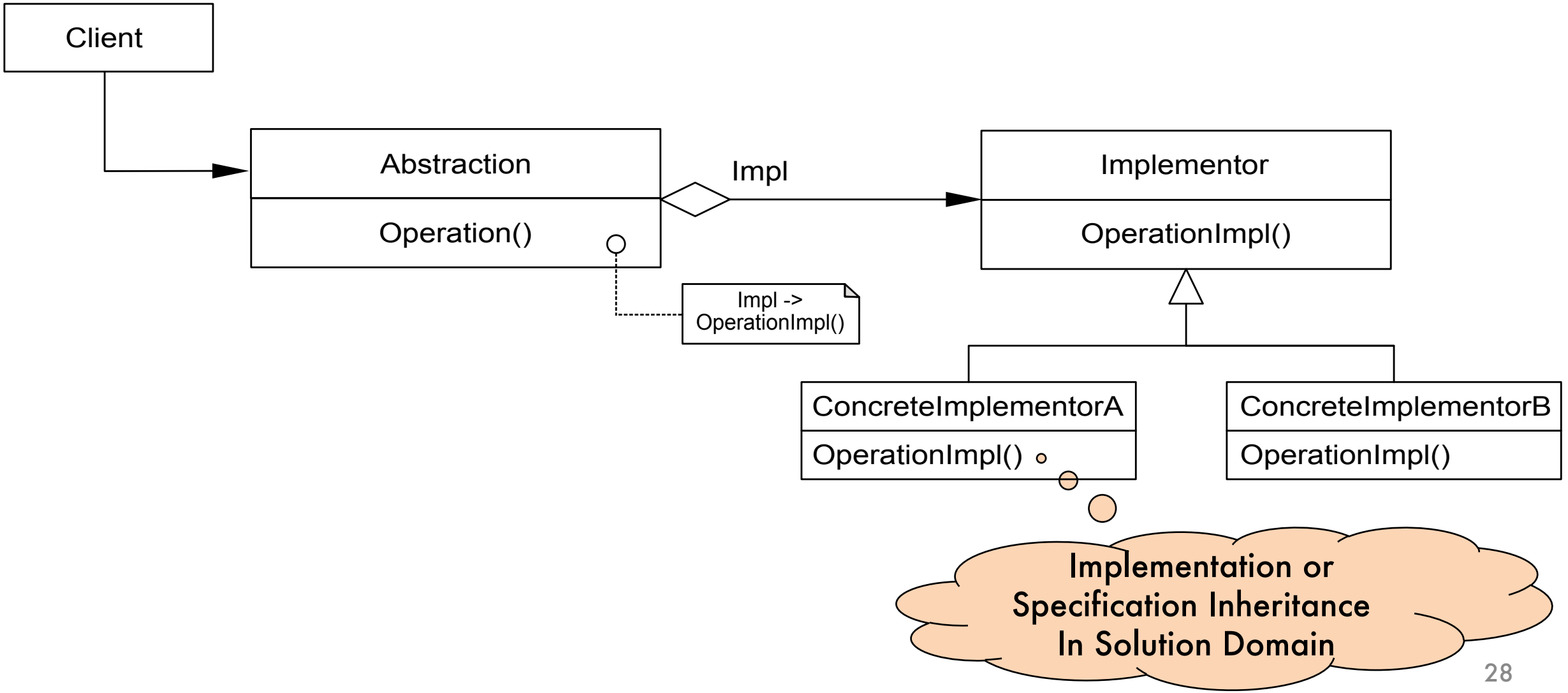


Bridge pattern

- It provides a bridge between the abstraction (in the application domain) and the implementor (in the solution domain)



Often only A "degenerated bridge" is used (no taxonomy)

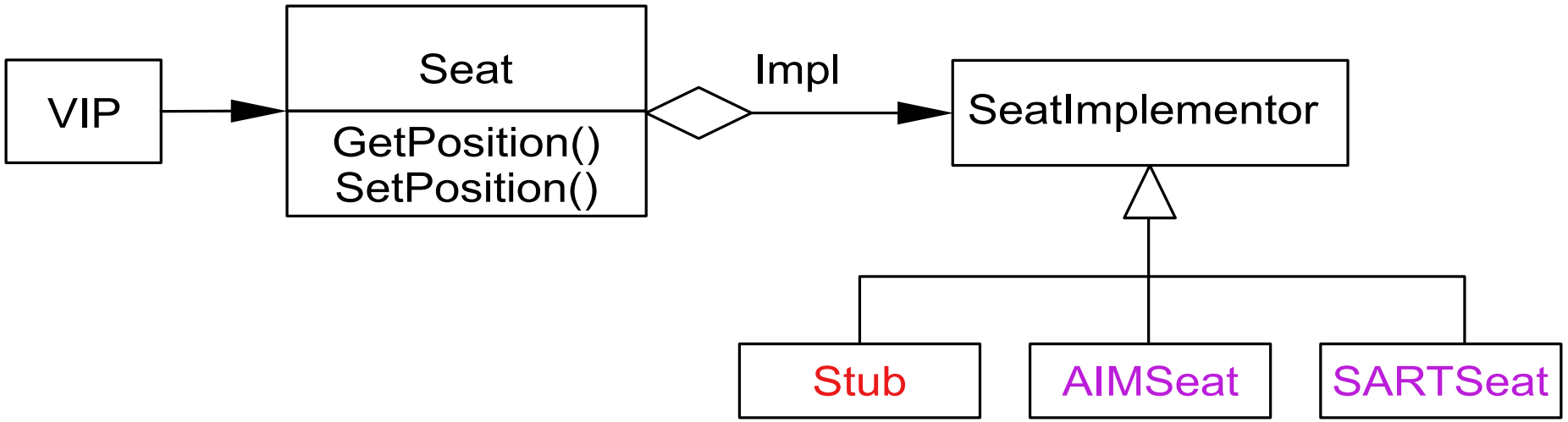


Using the bridge pattern during testing

- Interface to a component that is incomplete, not yet known or unavailable during testing
- Example: The VIP subsystem can adjust the seat position to the preference of the driver

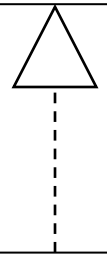
The seat is not yet implemented, so we are using a Stub

Two seat simulators become available: AIM and SART



Seat implementations

```
public interface Seat {
  public int GetPosition();
  public void SetPotision(int newPos);
}
```

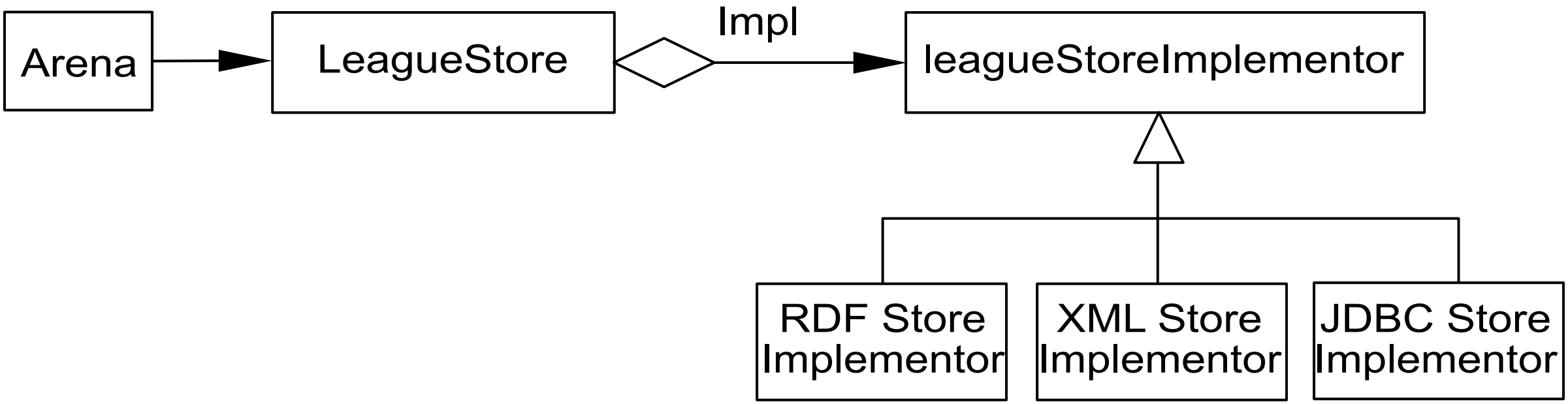


```
public class Stub implements Seat {
  public int GetPosition() {
    return 5.0;
  }
  // ...
}
```

```
public class AimSeat implements SeatImpl {
  public int GetPosition() {
    // call to the AIM simulator
  }
}
```

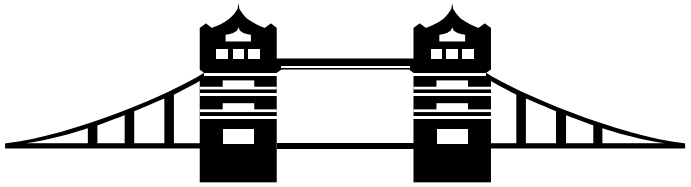
```
public class SARTSeat implements SeatImpl {
  public int GetPosition() {
    // call to the SART simulator
  }
}
```

Another use of the bridge pattern: supporting multiple database vendors



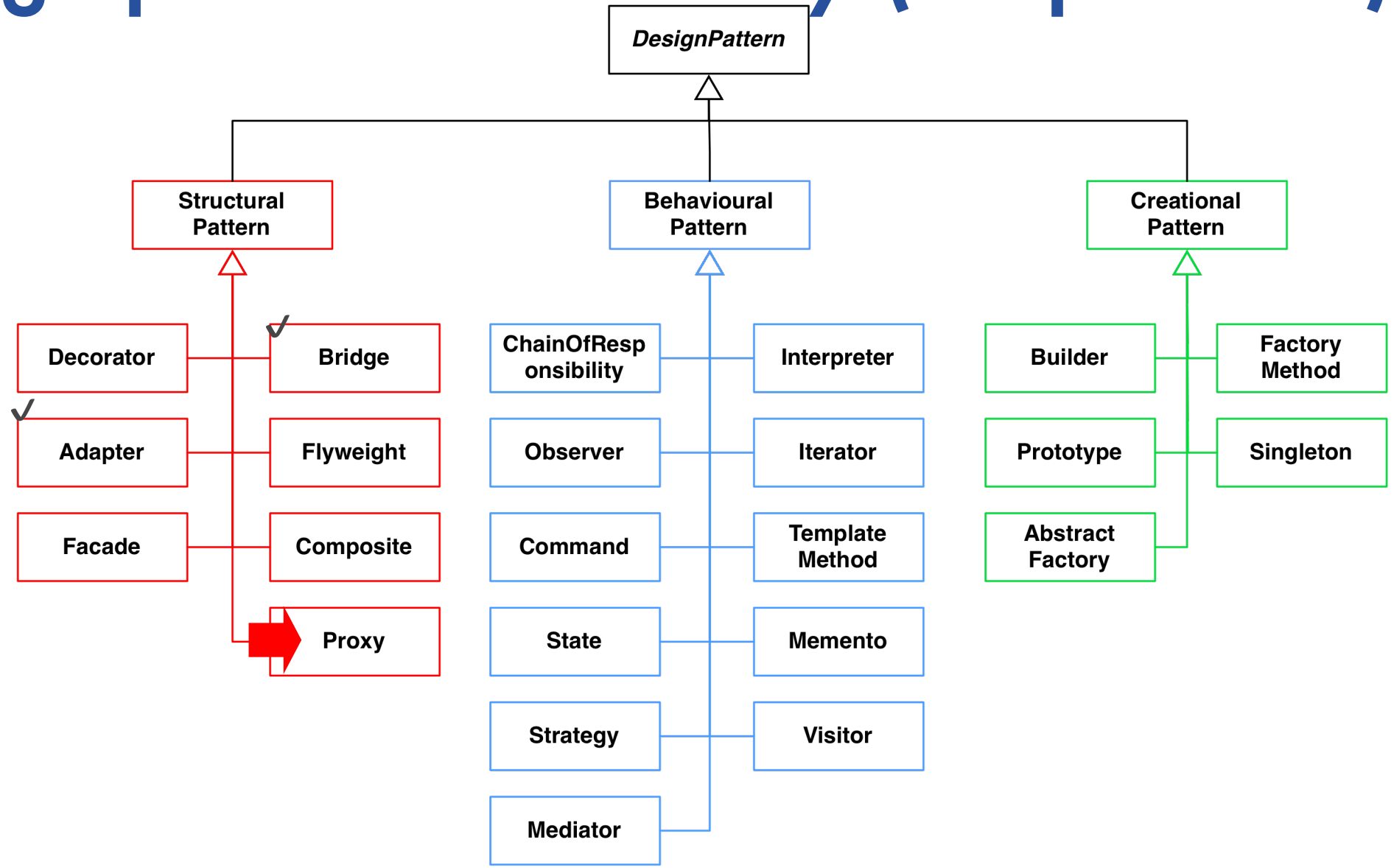
adapter vs bridge

- **Similarities**:
  - Both hide the details of the underlying implementation
- The **adapter** pattern aims at making **unrelated** components work together
  - Applied to systems that are already designed (reengineering, interface engineering projects)
  - "Inheritance followed by delegation"
- A **bridge** is used **up-front in a design** to let abstractions and implementations vary independently
  - Green field engineering of an "**extensible** system"
  - New "beasts" can be added to the "zoo" ("application or solution domain", even if these are not known, when the system is developed
  - "Delegation followed by inheritance"



Is this a bridge or an adapter?

Design patterns taxonomy (23 patterns)



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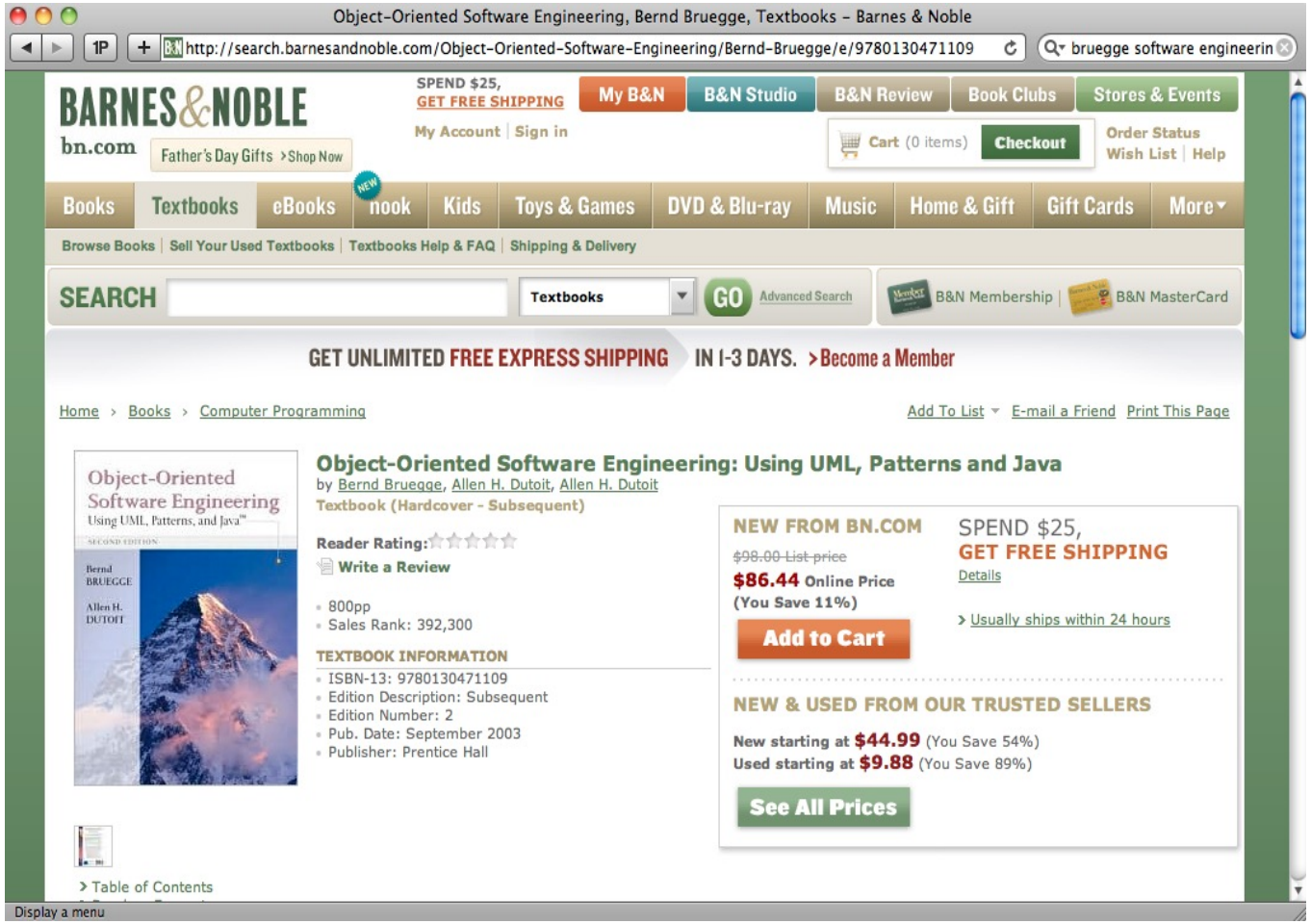
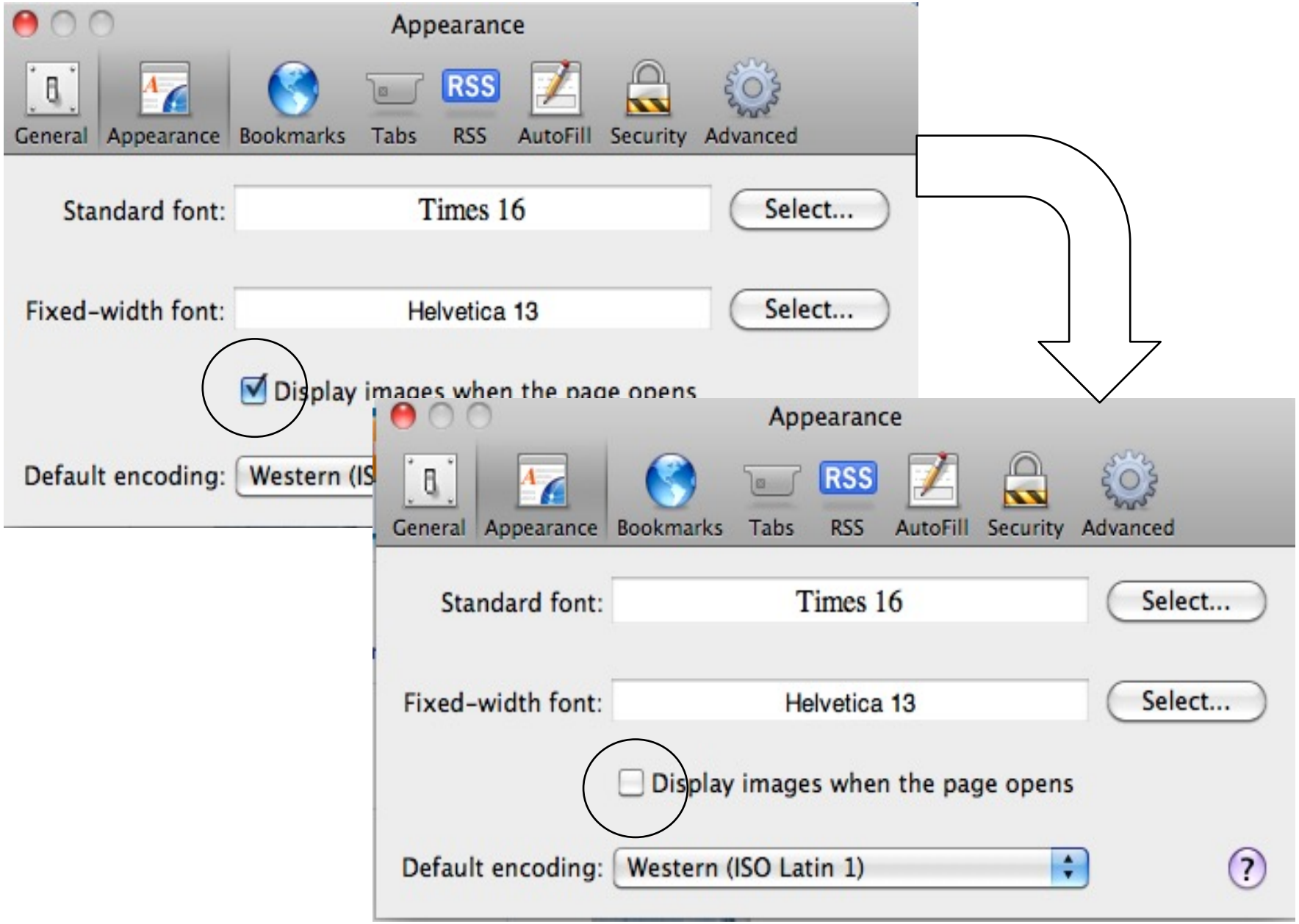
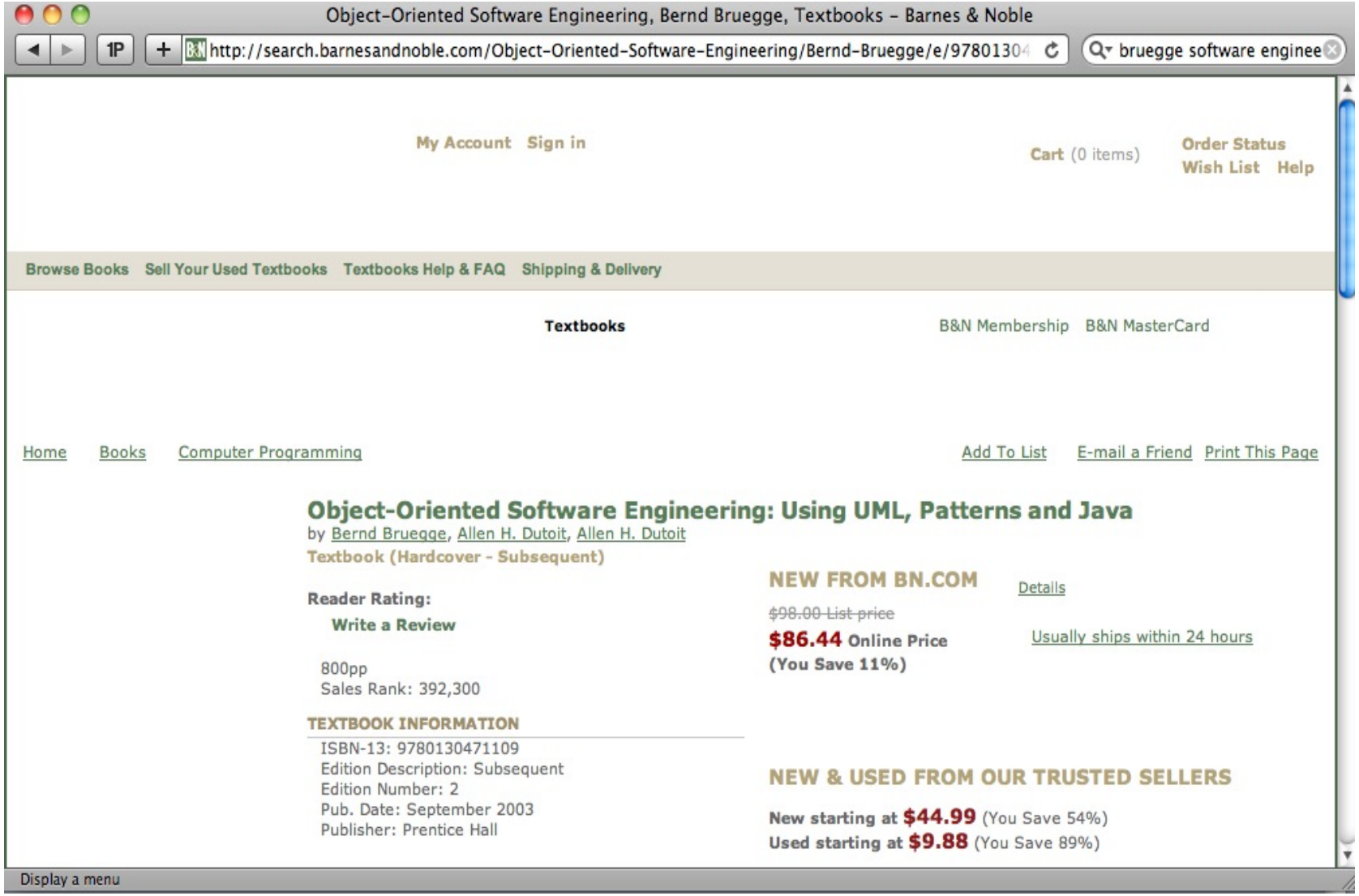
Proxy pattern: motivation

- It is 11:30
- 3 days before the EMSE final exam
- I sit in front of my laptop
- I need to buy Bruegge's book
- I get about 1 kb/sec
- I have 5 minutes before I am meeting my study group
- What I do?
  - Disable the display of images



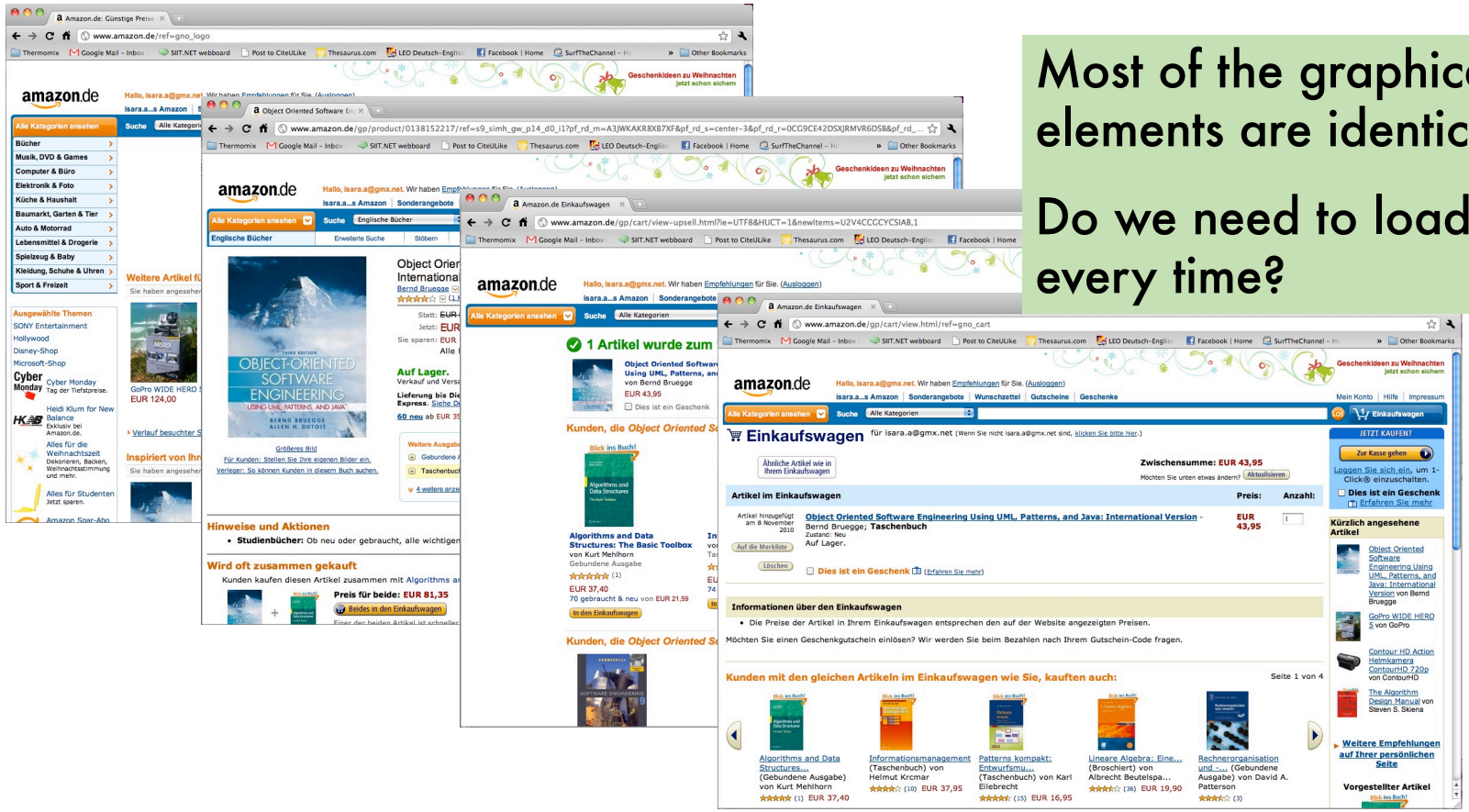

Appearance
General
Appearance
Bookmarks
Tabs
RSS
AutoFill
Security
Advanced
Standard font:
Times 16
Select...
Fixed-width font:
Helvetica 13
Select...
Display images when the page opens
Default encoding:
Western (ISO Latin 1)

Example: web page with dummy images



Another situation: caching

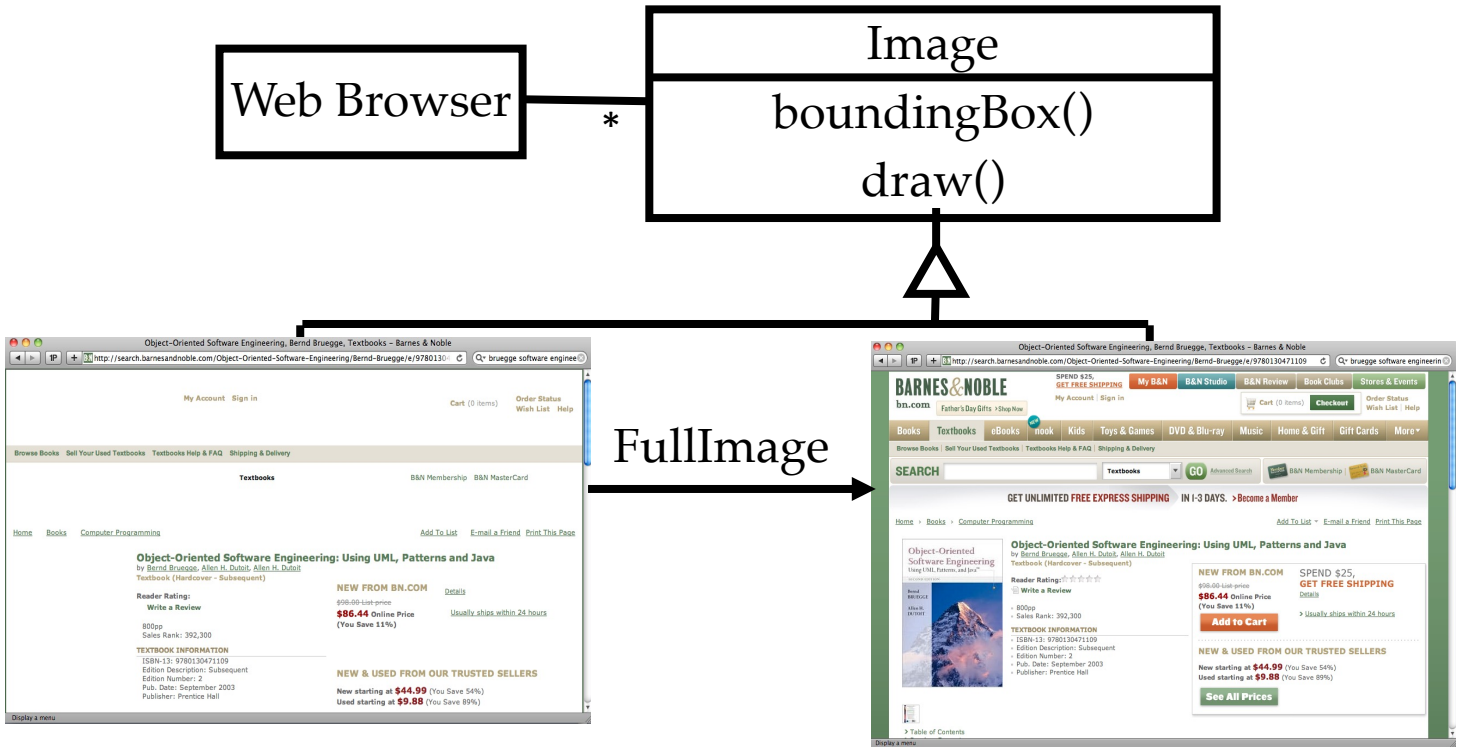
- Sometimes users access the same data repeatedly
- For example, web pages with common elements:



Most of the graphical elements are identical

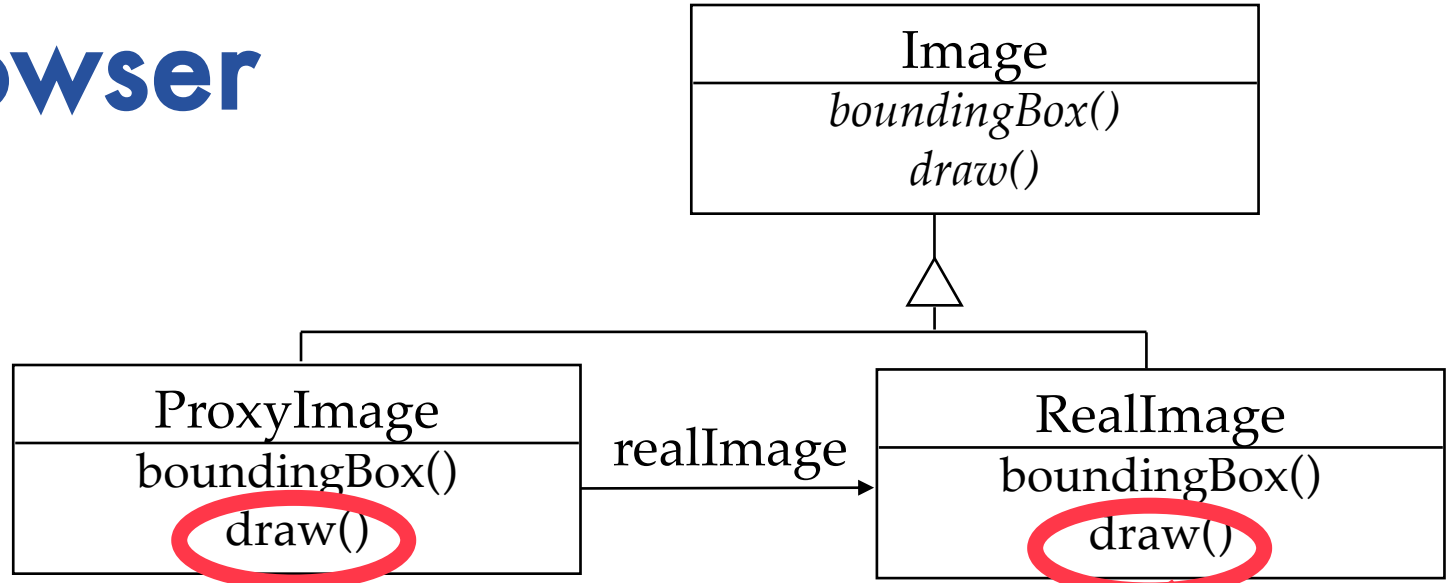
Do we need to load them every time?

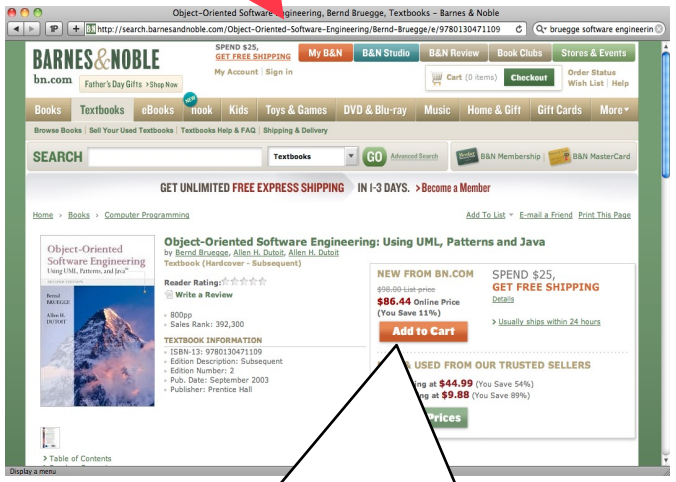
Let's model this!



- ProxyImage and RealImage are both subclasses of Image
- The draw() method is implemented differently in ProxyImage and in RealImage
  - The draw() operation in ProxyImage is executed first. Depending on the browser preferences, it then calls draw() in RealImage
- The Web Browser cannot tell, whether ProxyImage or RealImage is accessed

Web browser example



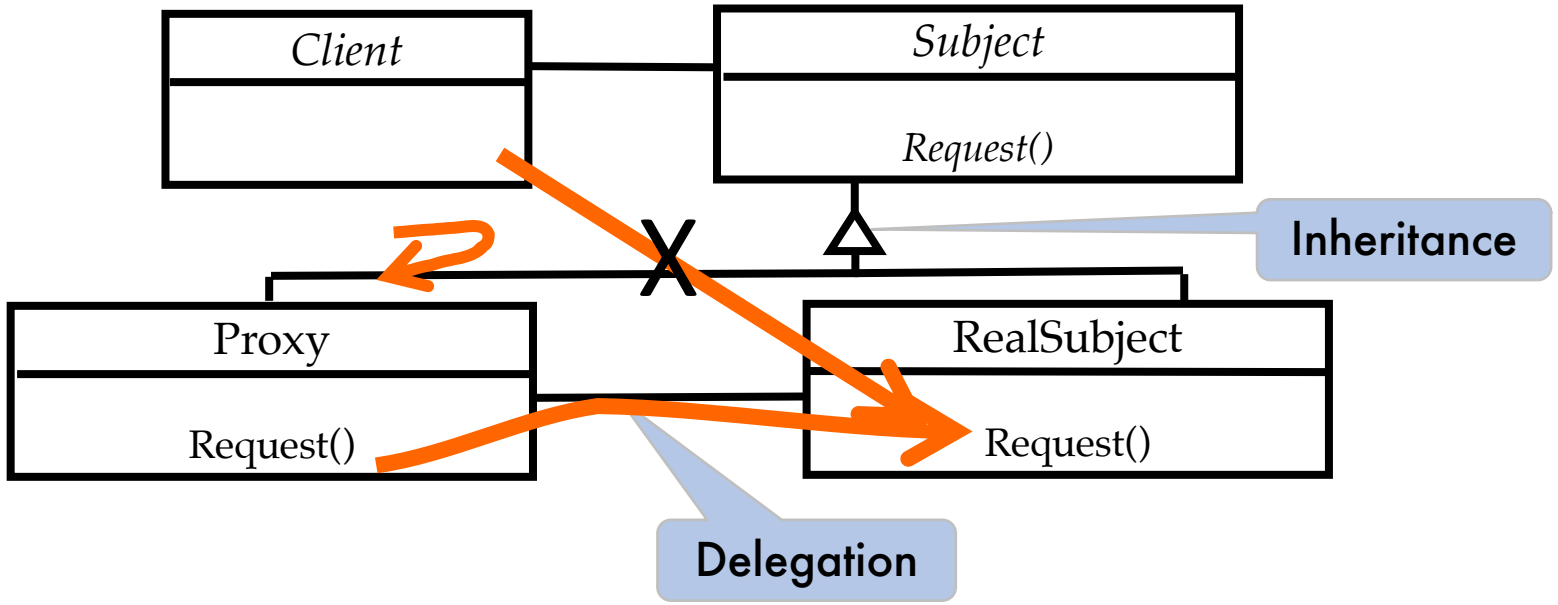


- ProxyImage draws a placeholder
- RealImage draws the image

Small Problem:
Add to Cart is an image ☹

Pro

The Proxy pattern looks so similar to other patterns that use Inheritance and delegation. What is the difference?



- Proxy and RealSubject are subclasses of Subject
- Request() in Proxy calls Request() in RealSubject
- Client never calls Request() in RealSubject

- Client always calls Request() in an instance of type Proxy, which might call Request in RealSubject.
- RealSubject ist also subclass of the abstract class Subject

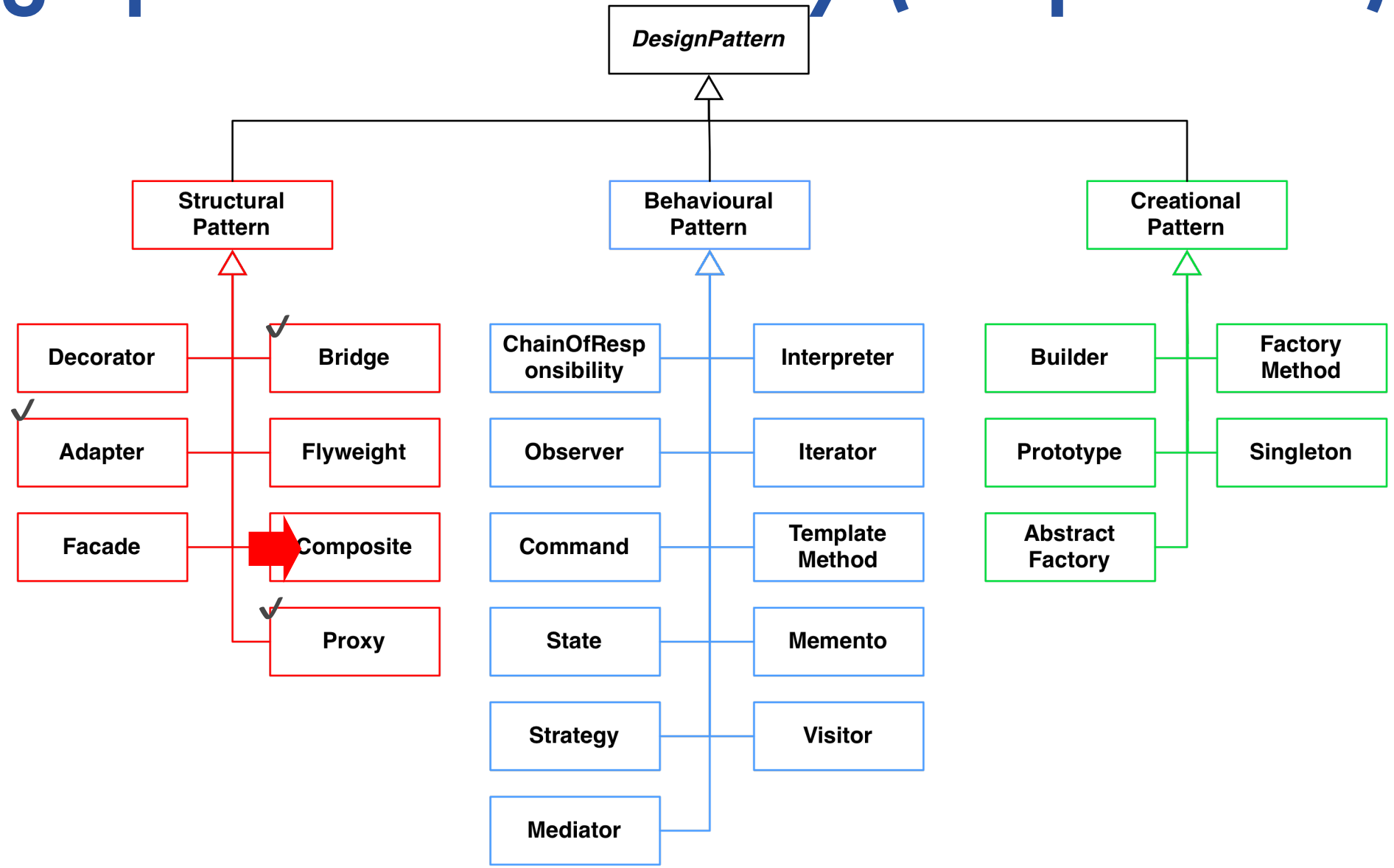
Applicability of the proxy pattern

- What is particularly expensive in object-oriented systems?
  - Object Creation
  - Object Initialization
- Defer object creation and object initialization to the time you need the object
- Proxy pattern:
  - Reduces the cost of accessing objects
    - Creates the real object only if the user asks for it
  - Uses another object ("the proxy") that acts as a stand-in for the real object
  - Provides location transparency

Scenarios where a proxy is appropriate

- Caching (Remote Proxy)
  - The proxy object is a local representative for an object in a different address space (Caching of information)
  - Good if information does not change too often
  - If the information changes, the cache needs to be flushed
- Substitute (Virtual Proxy)
  - The object is quite expensive to create or to download. The Proxy object can act as a stand-in
  - Good for information that is not immediately accessed
  - Good for objects that are not visible (not in line of sight, far away)
  - Example: Google Maps, Fog of War
- Access Control (Protection Proxy)
  - The proxy object provides access control to the real object
  - Good when different objects should have different access and viewing rights for the same document
  - Example: Grade information for a student shared by administrators, teachers and students.

Design patterns taxonomy (23 patterns)



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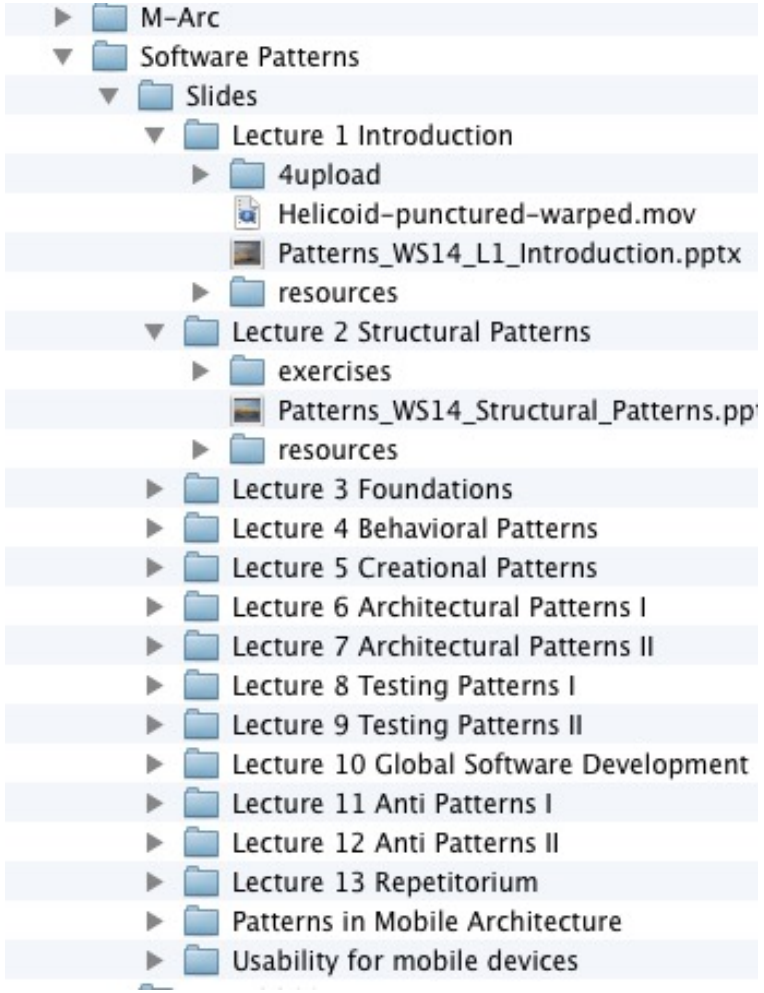
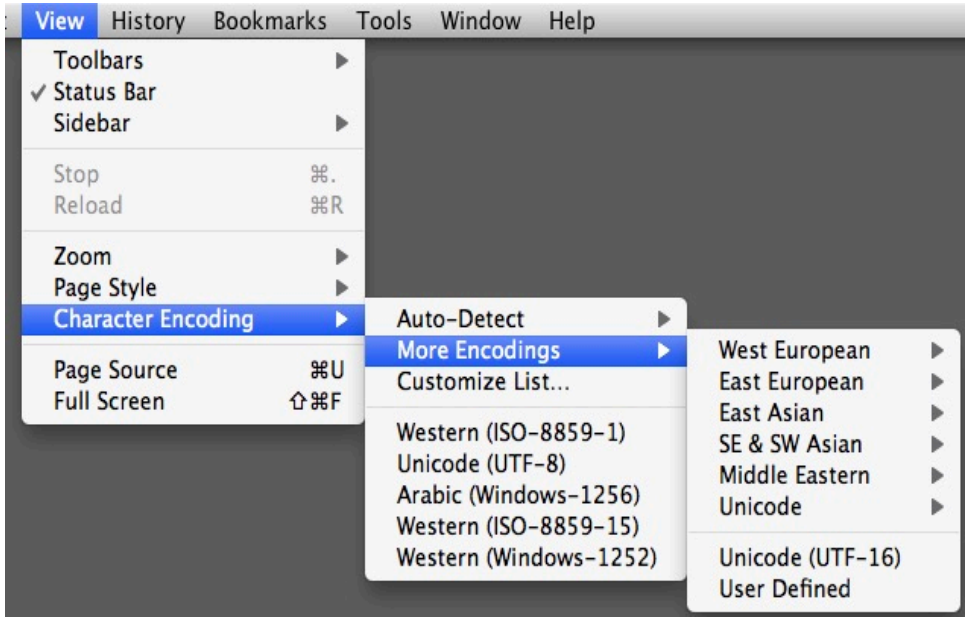
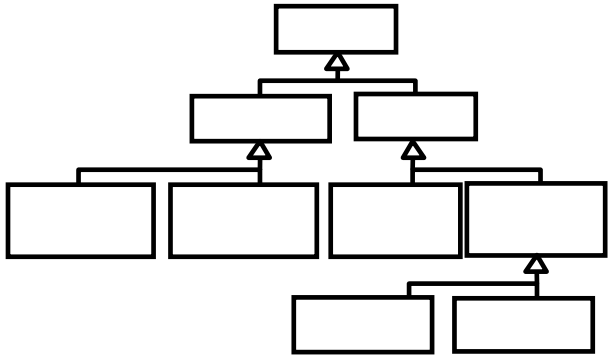
Problem: manage dynamic structures

- Tree structures representing **part-whole hierarchies** with arbitrary **depth** and **width** can be used in the solution of many problems

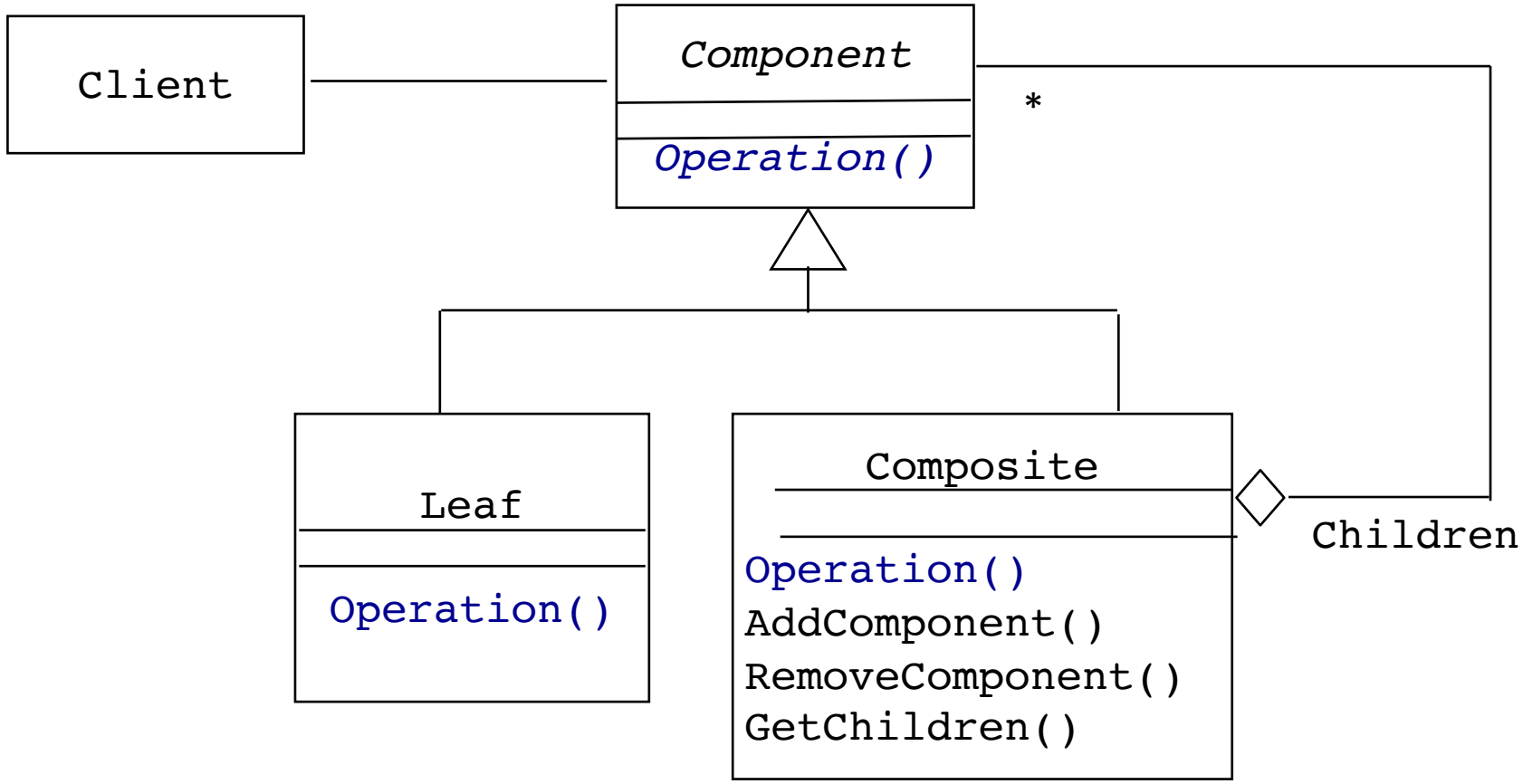






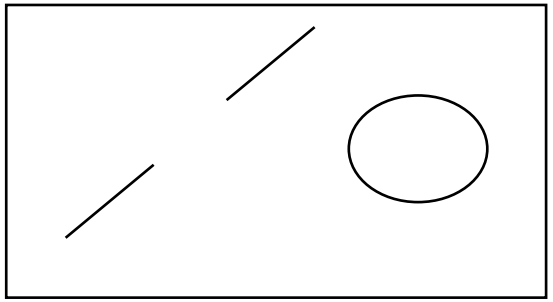
Solution: composite pattern (extract component)

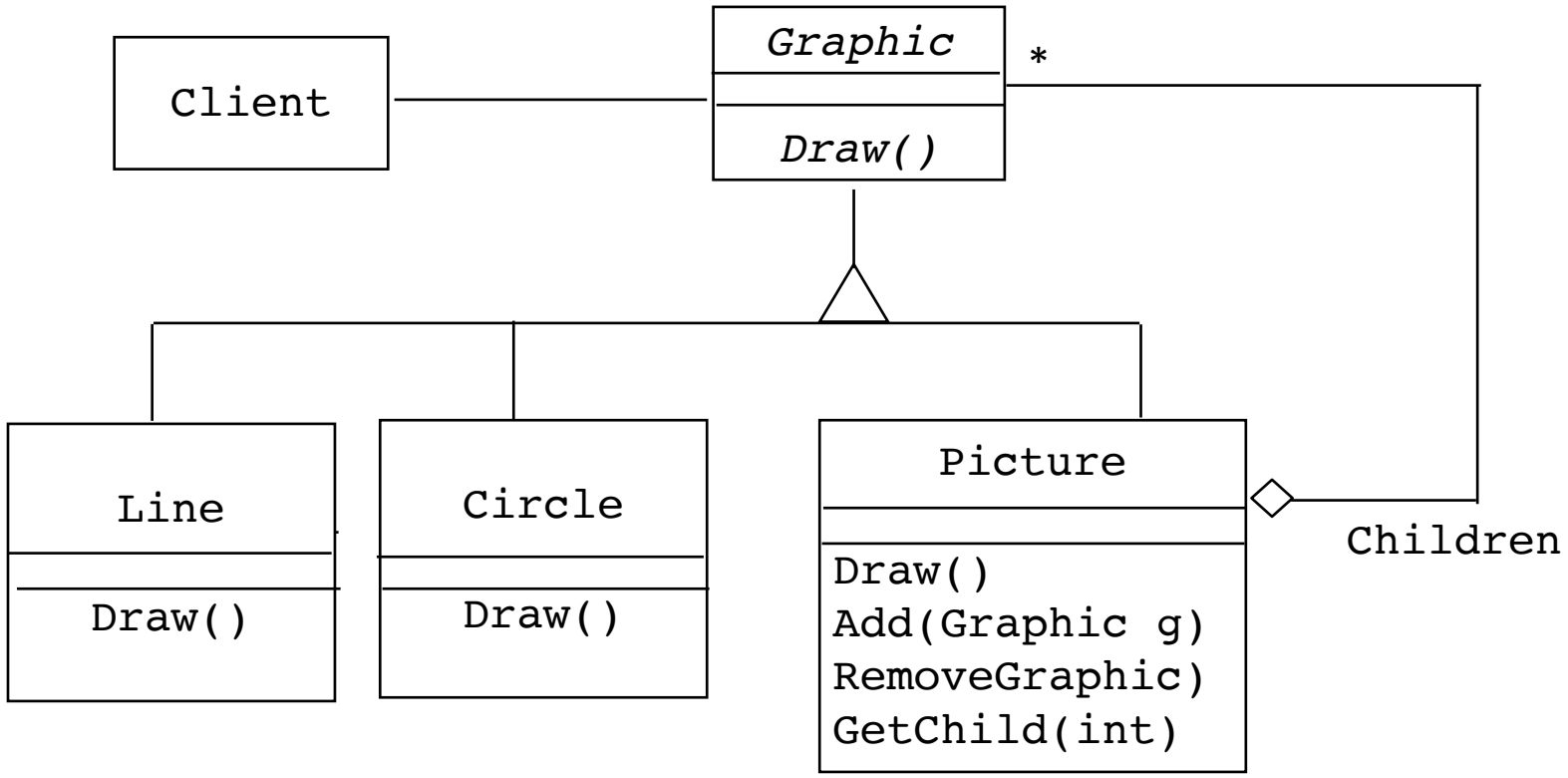
- Let a client treat individual objects and compositions of these objects uniformly



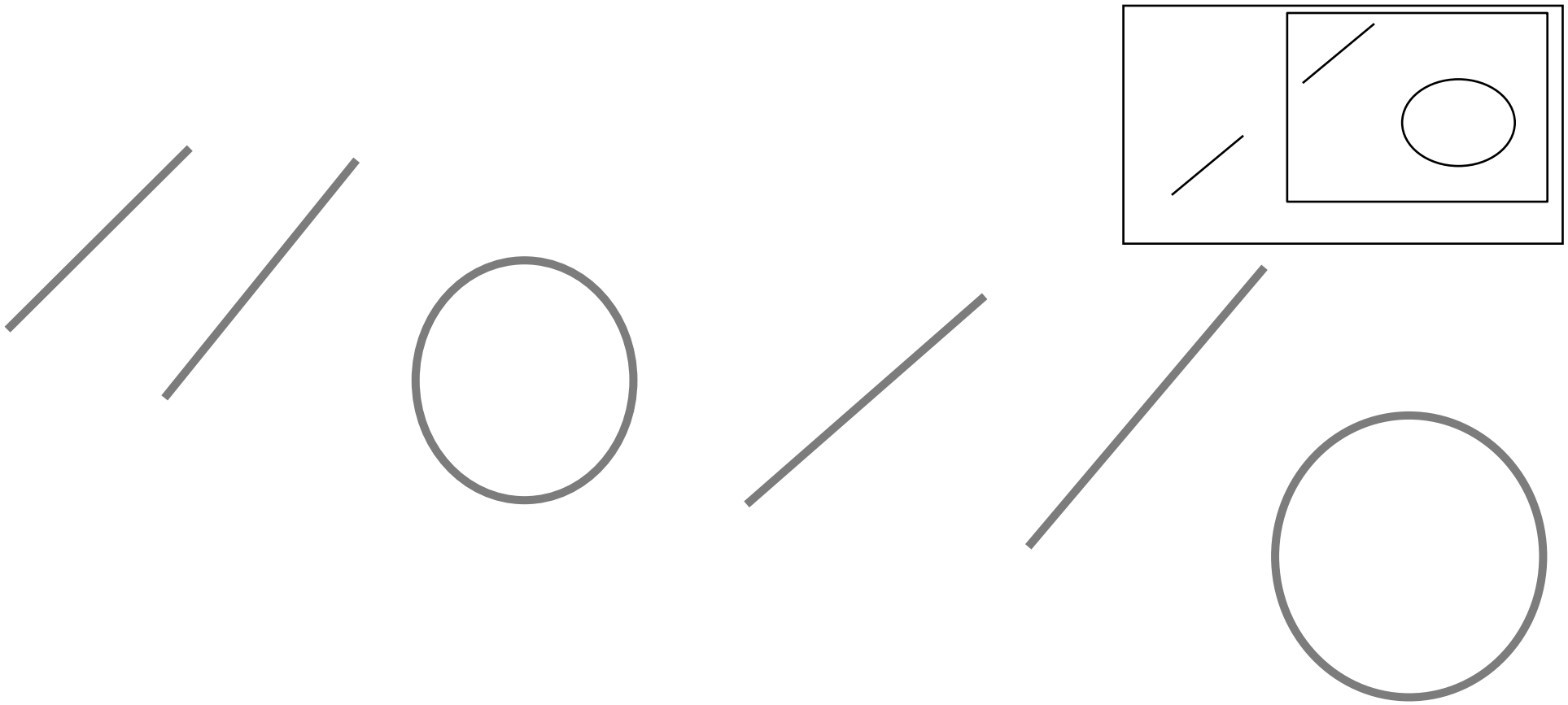
Composite pattern in graphic applications

- The Graphic class represents both primitives (Line, Circle) and containers (Picture).

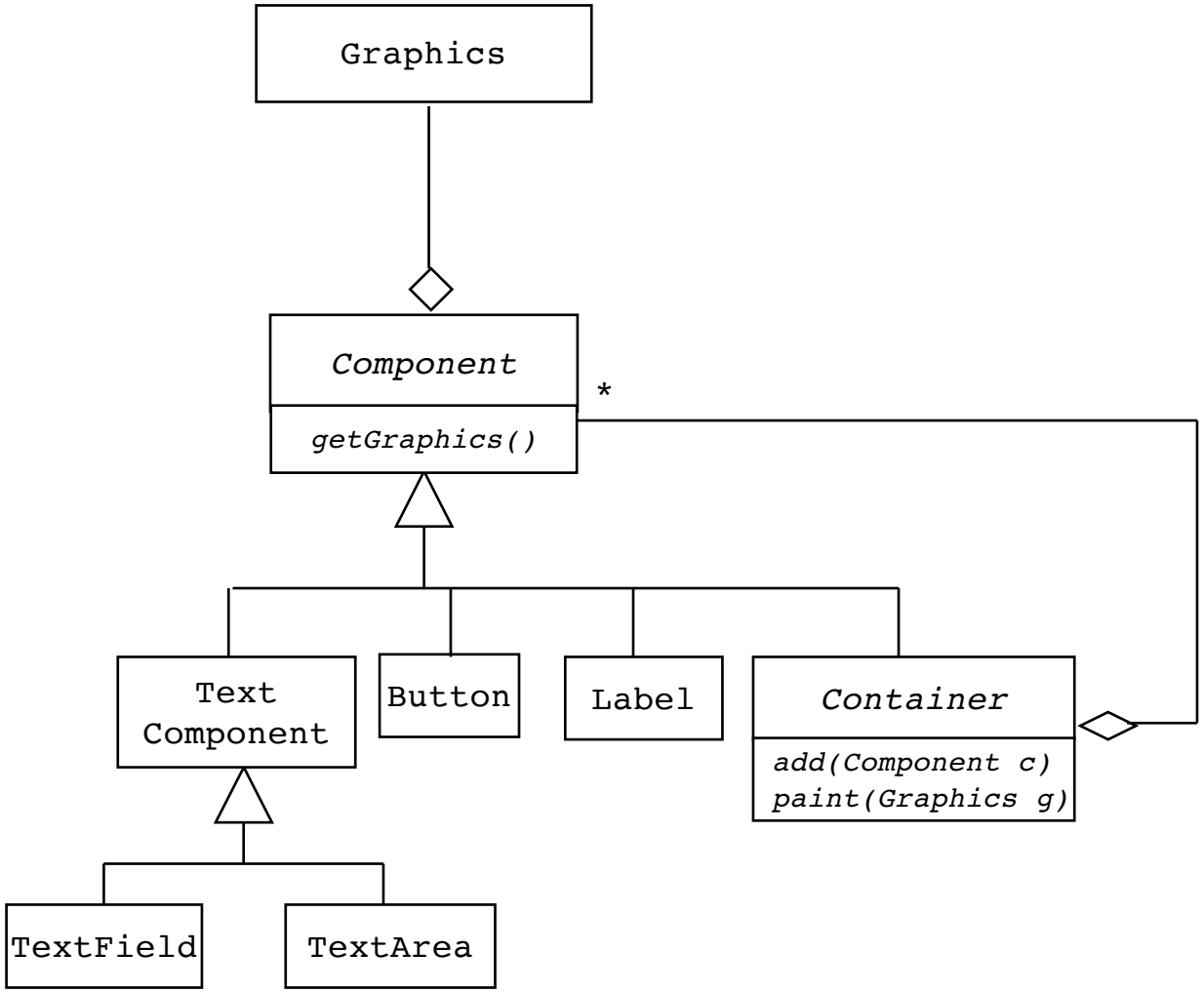




Example: grouping graphic

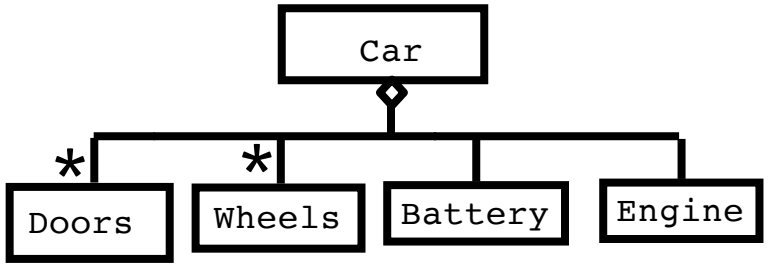


The java's AWT library can be modeled with the composite pattern



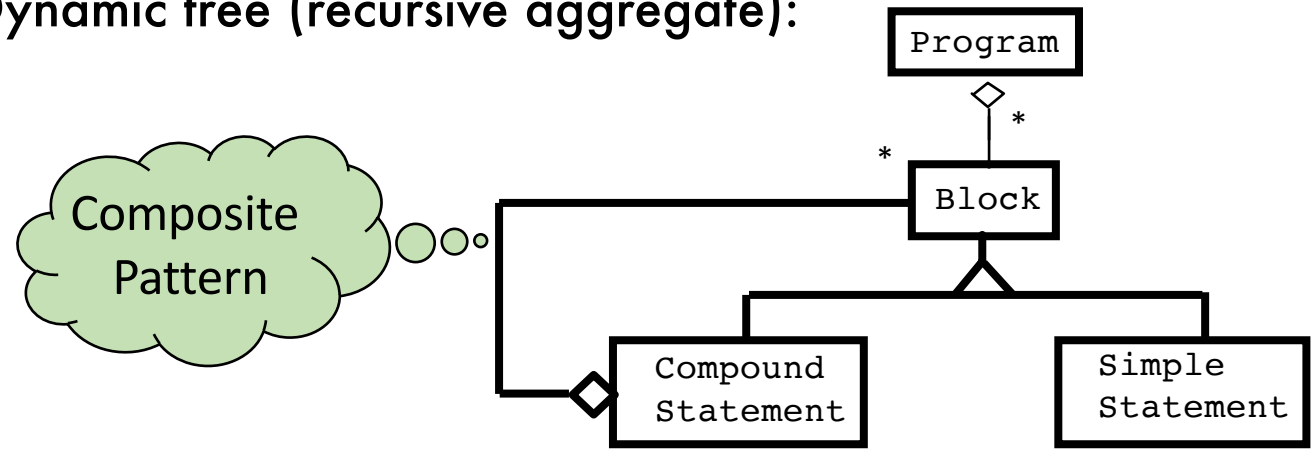
Composite patterns models dynamic aggregates

- Fixed Structure:



- Organization Chart (variable aggregate):

- Dynamic tree (recursive aggregate):



Design patterns taxonomy (23 patterns)