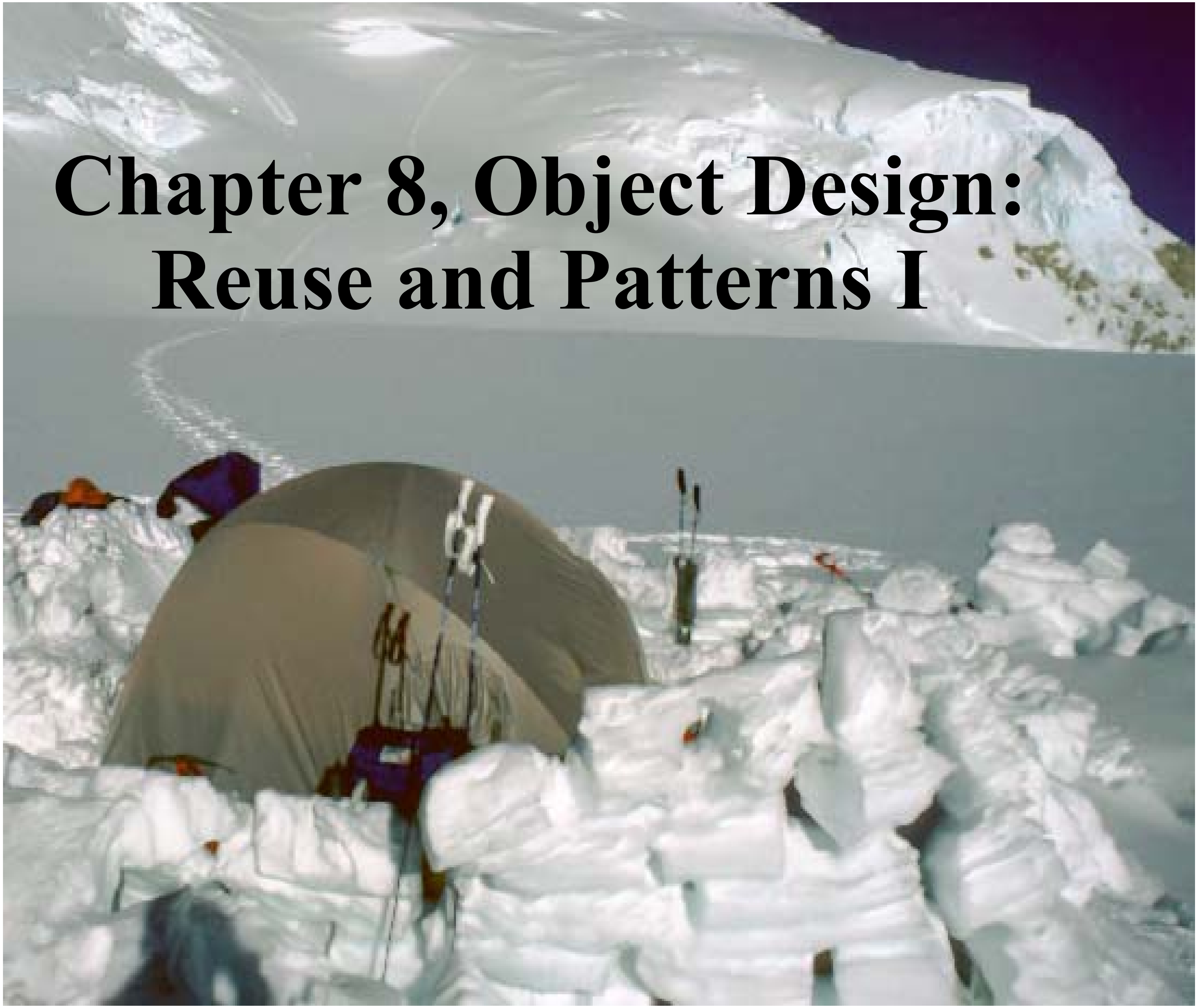
Object-Oriented Software Engineering
Using UML, Patterns, and Java

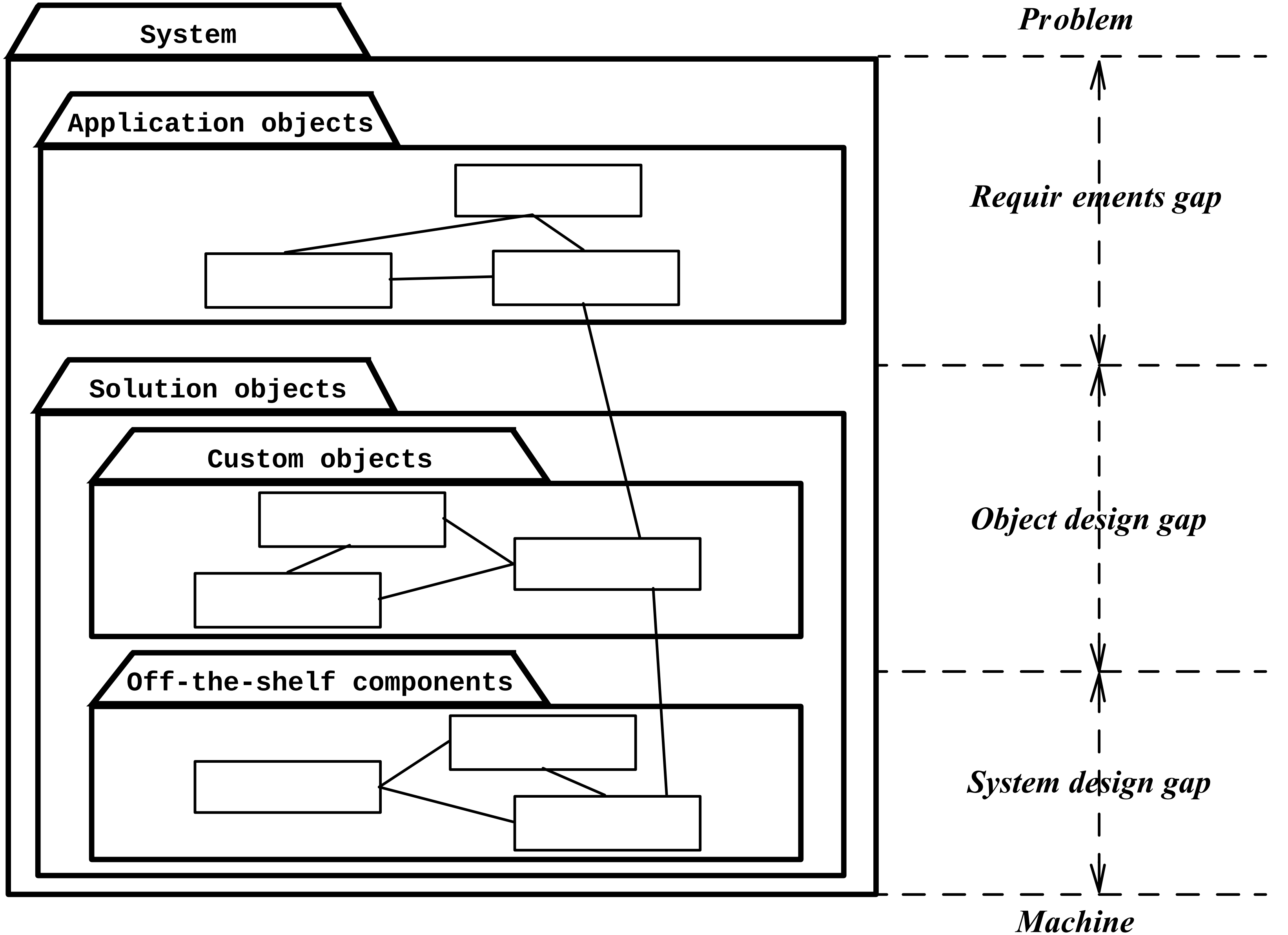
Chapter 8, Object Design: Reuse and Patterns I



Object Design

- Object design is the process of adding details to the requirements analysis and making implementation decisions
- The object designer must choose among different ways to implement the analysis model with the goal to minimize execution time, memory and other measures of cost.
- Requirements Analysis: Use cases, functional and dynamic model deliver operations for object model
- Object Design: Iterates on the models, in particular the object model and refine the models
- Object Design serves as the basis of implementation

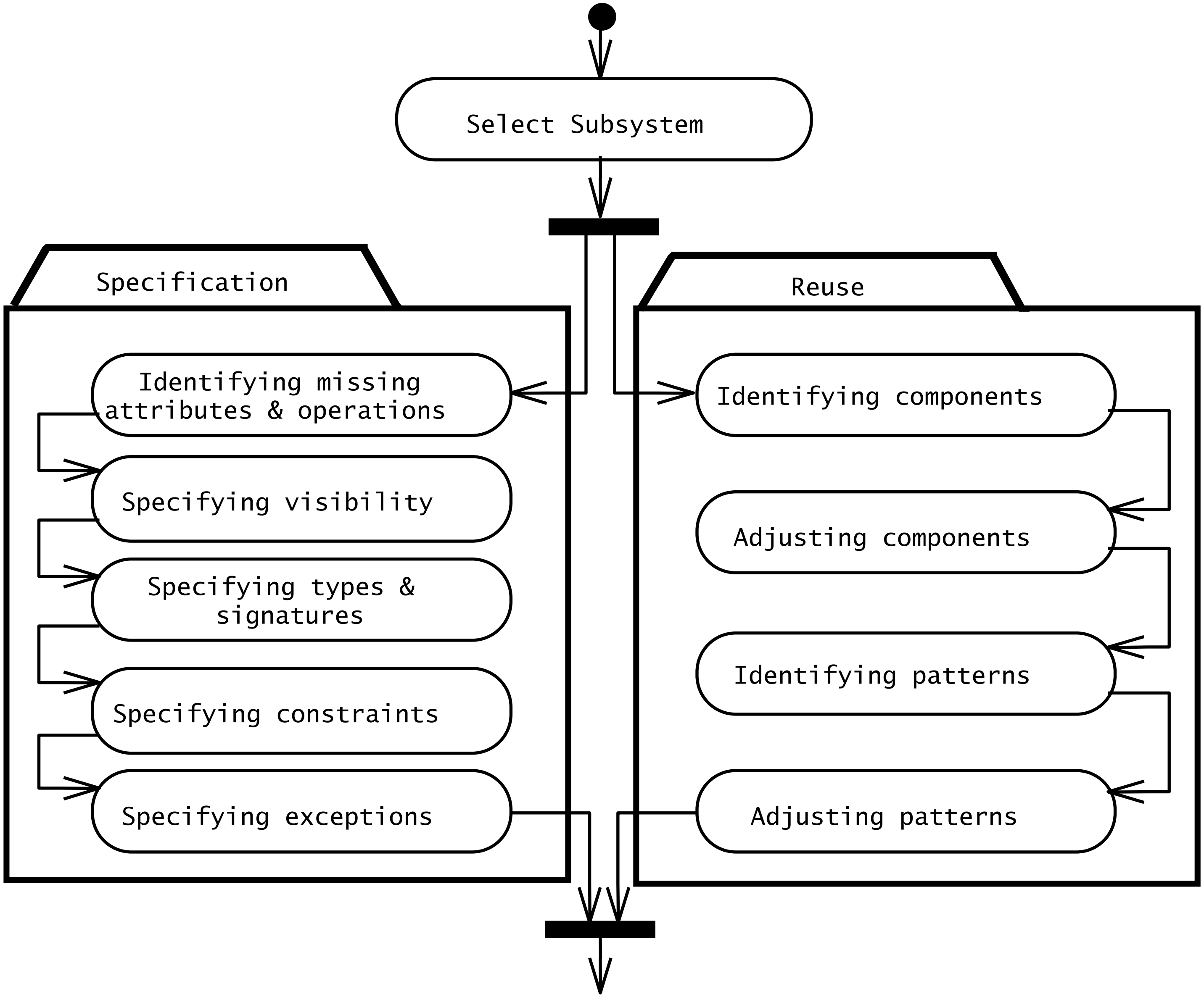
Object Design: Closing the Gap



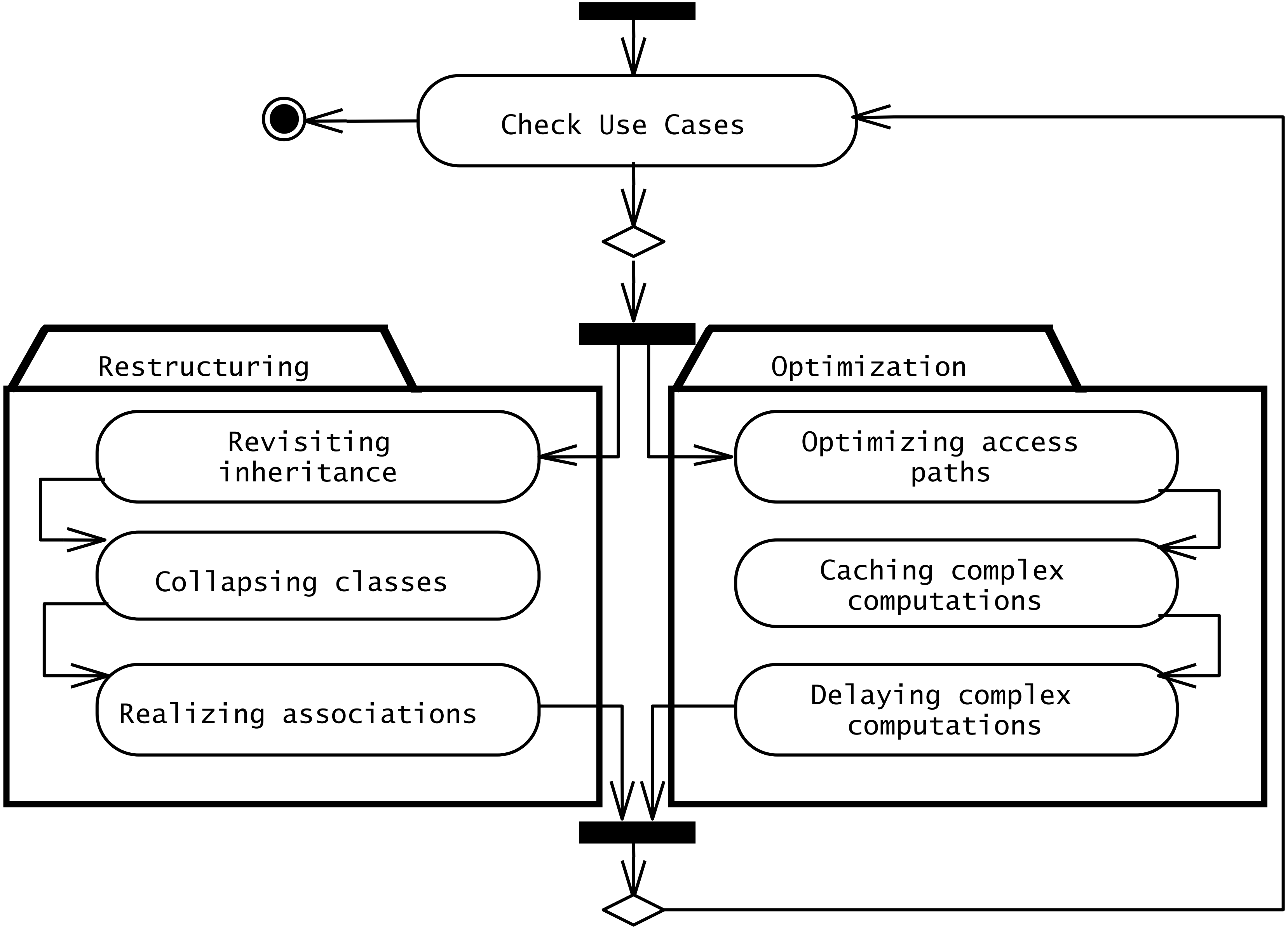
Examples of Object Design Activities

- Identification of existing components
- Full definition of associations
- Full definition of classes
  - **System Design => Service**
  - **Object Design => API**
- Specifying the contract for each component
- Choosing algorithms and data structures
- Identifying possibilities of reuse
- Detection of solution-domain classes
- Optimization
- Increase of inheritance
- Decision on control
- Packaging

A More Detailed View of Object Design Activities



Detailed View of Object Design Activities (ctd)



A Little Bit of Terminology: Activities

- Object-Oriented methodologies use these terms:
  - **System Design Activity**
    - Decomposition into subsystems
  - **Object Design Activity**
    - Implementation language chosen
    - Data structures and algorithms chosen
- Structured analysis/structured design uses these terms:
  - **Preliminary Design Activity**
    - Decomposition into subsystems
    - Data structures are chosen
  - **Detailed Design Activity**
    - Algorithms are chosen
    - Data structures are refined
    - Implementation language is chosen
    - Typically in parallel with preliminary design, not a separate activity

Outline of the Lecture

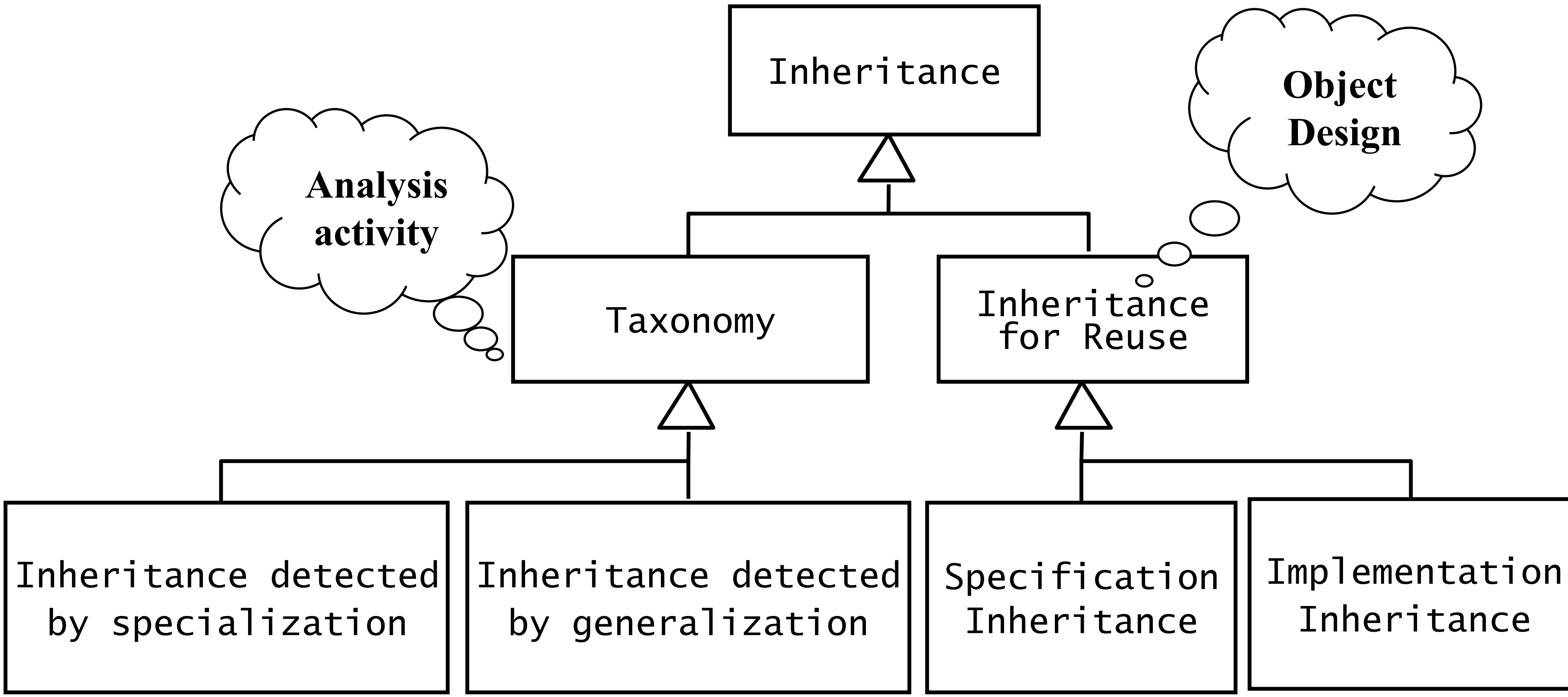
- Design Patterns
  - **Usefulness of design patterns**
  - **Design Pattern Categories**
- Patterns covered in this lecture
  - **Composite: Model dynamic aggregates**
  - **Facade: Interfacing to subsystems**
  - **Adapter: Interfacing to existing systems (legacy systems)**
  - **Bridge: Interfacing to existing and future systems**
- More patterns:
  - **Abstract Factory: Provide manufacturer independence**
  - **Builder: Hide a complex creation process**
  - **Proxy: Provide Location transparency**
  - **Command: Encapsulate control flow**
  - **Observer: Provide publisher/subscribe mechanism**
  - **Strategy: Support family of algorithms, separate of policy and mechanism**

The use of inheritance

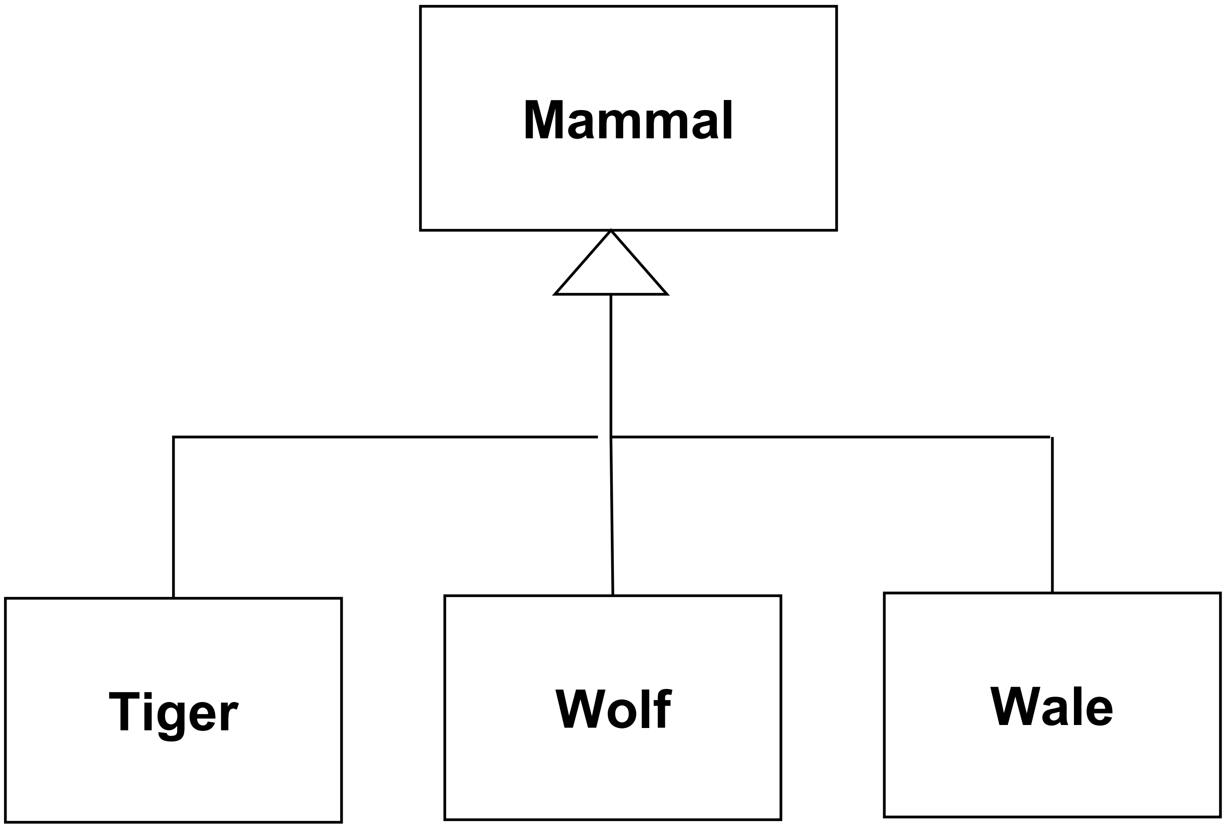
- Inheritance is used to achieve two different goals
  - **Description of Taxonomies**
  - **Interface Specification**
- Identification of taxonomies
  - **Used during requirements analysis.**
  - **Activity: identify application domain objects that are hierarchically related**
  - **Goal: make the analysis model more understandable**
- Service specification
  - **Used during object design**
  - **Activity:**
  - **Goal: increase reusability, enhance modifiability and extensibility**
- Inheritance is found either by specialization or generalization

Metamodel for Inheritance

- Inheritance is used during analysis and object design

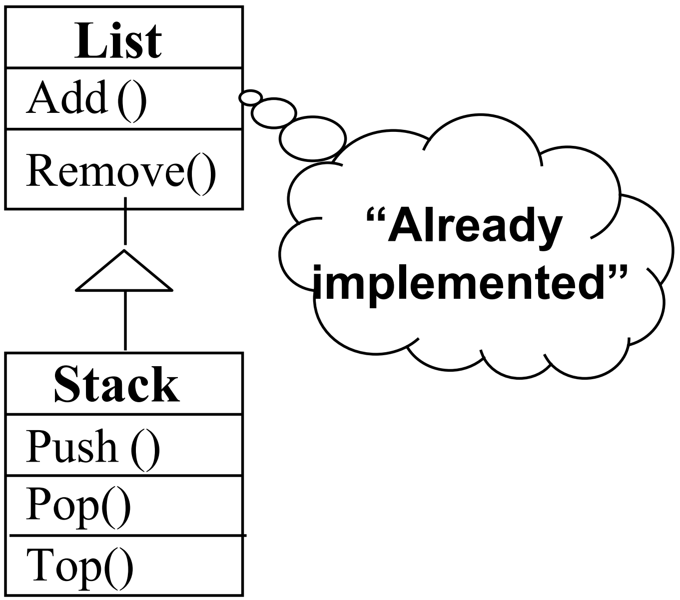


Taxonomy Example



Implementation Inheritance

- A very similar class is already implemented that does almost the same as the desired class implementation.
  - Example: I have a **List** class, I need a **Stack** class. How about subclassing the **Stack** class from the **List** class and providing three methods, **Push()** and **Pop(), Top()**?



- Problem with implementation inheritance:

  Some of the inherited operations might exhibit unwanted behavior. What happens if the Stack user calls Remove() instead of Pop()?

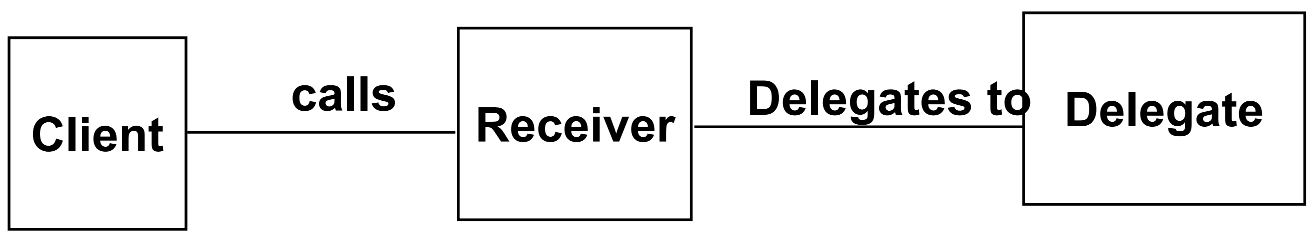
Implementation Inheritance vs Interface Inheritance

- Implementation inheritance
  - **Also called class inheritance**
  - **Goal: Extend an applications' functionality by reusing functionality in parent class**
  - **Inherit from an existing class with some or all operations already implemented**

- Interface inheritance
  - **Also called subtyping**
  - **Inherit from an abstract class with all operations specified, but not yet implemented**

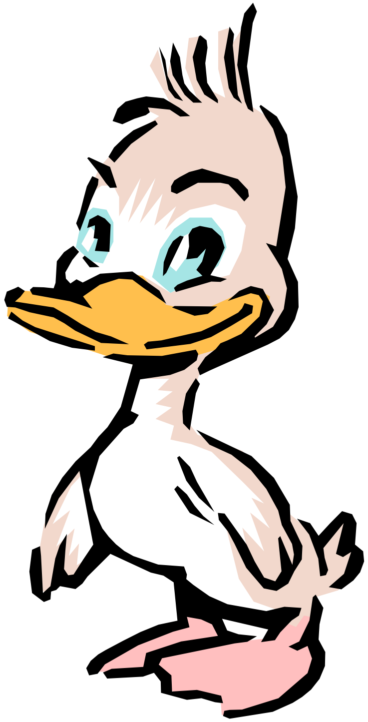
Delegation as alternative to Implementation Inheritance

- Delegation is a way of making composition (for example aggregation) as powerful for reuse as inheritance
- In Delegation two objects are involved in handling a request
  - **A receiving object delegates operations to its delegate.**
  - **The developer can make sure that the receiving object does not allow the client to misuse the delegate object**



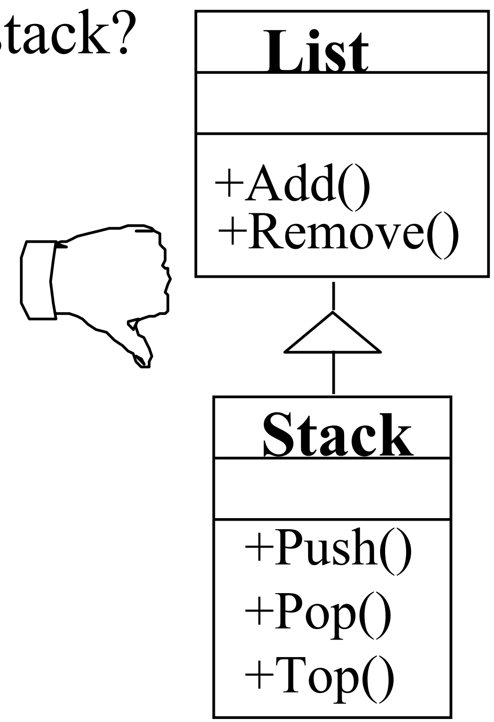
Duck: Delegation vs. Inheritance

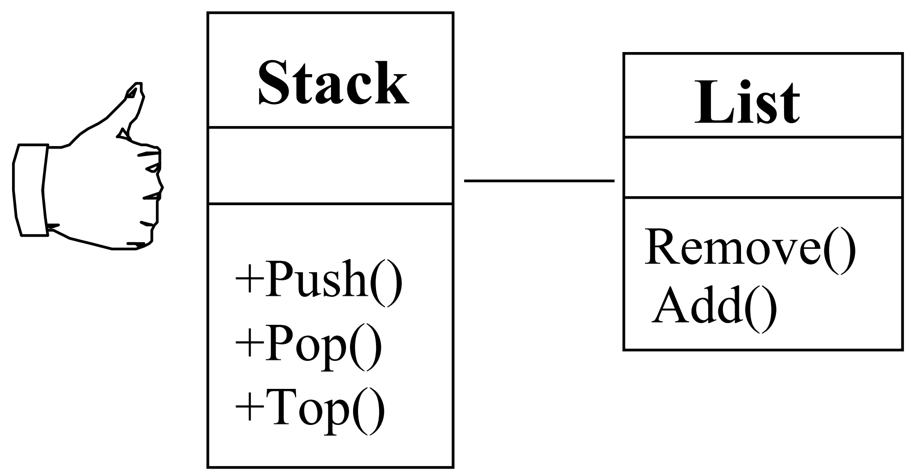
- Description: Decide whether to use delegation or inheritance for designing the following classes. Specify the attributes and methods for each class. Draw the UML diagram for the whole thing.
    - Array
    - Queue
    - Stack
    - Tree
    - Linked list
- Process:
    - Work in pairs
    - You have about 10 minutes.



Delegation instead of Implementation Inheritance

- **Inheritance**: Extending a Base class by a new operation or overwriting an operation.
- **Delegation**: Catching an operation and sending it to another object.
- Which of the following models is better for implementing a stack?





Comparison: Delegation vs Implementation Inheritance

- Delegation
  - **Pro:**
    - **Flexibility: Any object can be replaced at run time by another one (as long as it has the same type)**
  - **Con:**
    - **Inefficiency: Objects are encapsulated.**
- Inheritance
  - **Pro:**
    - **Straightforward to use**
    - **Supported by many programming languages**
    - **Easy to implement new functionality**
  - **Con:**
    - **Inheritance exposes a subclass to the details of its parent class**
    - **Any change in the parent class implementation forces the subclass to change (which requires recompilation of both)**

Component Selection

- Select existing
  - **off-the-shelf class libraries**
  - **frameworks or**
  - **components**
- Adjust the class libraries, framework or components
  - **Change the API if you have the source code.**
  - **Use the adapter or bridge pattern if you don’t have access**
- Architecture Driven Design

Reuse...

- **Look for existing classes in class libraries**
  - **JSAPI, JTAPI, ...**
- Select data structures appropriate to the algorithms
  - **Container classes**
  - **Arrays, lists, queues, stacks, sets, trees, ...**
- It might be necessary to define new internal classes and operations
  - **Complex operations defined in terms of lower-level operations might need new classes and operations**

Frameworks

- A framework is a reusable partial application that can be specialized to produce custom applications.
- Frameworks are targeted to particular technologies, such as data processing or cellular communications, or to application domains, such as user interfaces or real-time avionics.
- The key benefits of frameworks are reusability and extensibility.
  - **Reusability leverages of the application domain knowledge and prior effort of experienced developers**
  - **Extensibility is provided by hook methods, which are overwritten by the application to extend the framework.**
    - **Hook methods systematically decouple the interfaces and behaviors of an application domain from the variations required by an application in a particular context.**

Classification of Frameworks

- Frameworks can be classified by their position in the software development process.

- Frameworks can also be classified by the techniques used to extend them.
  - **Whitebox frameworks**
  - **Blackbox frameworks**

Frameworks in the Development Process

- Infrastructure frameworks aim to simplify the software development process
  - **System infrastructure frameworks are used internally within a software project and are usually not delivered to a client.**
- Middleware frameworks are used to integrate existing distributed applications and components.
  - **Examples: MFC, DCOM, Java RMI, WebObjects, WebSphere, WebLogic Enterprise Application [BEA].**
- Enterprise application frameworks are application specific and focus on domains
  - **Example domains: telecommunications, avionics, environmental modeling, manufacturing, financial engineering, enterprise business activities.**

White-box and Black-Box Frameworks

- **Whitebox frameworks:**
  - **Extensibility achieved through inheritance and dynamic binding.**
  - **Existing functionality is extended by subclassing framework base classes and overriding predefined hook methods**
  - **Often design patterns such as the template method pattern are used to override the hook methods.**
- **Blackbox frameworks**
  - **Extensibility achieved by defining interfaces for components that can be plugged into the framework.**
  - **Existing functionality is reused by defining components that conform to a particular interface**
  - **These components are integrated with the framework via delegation.**

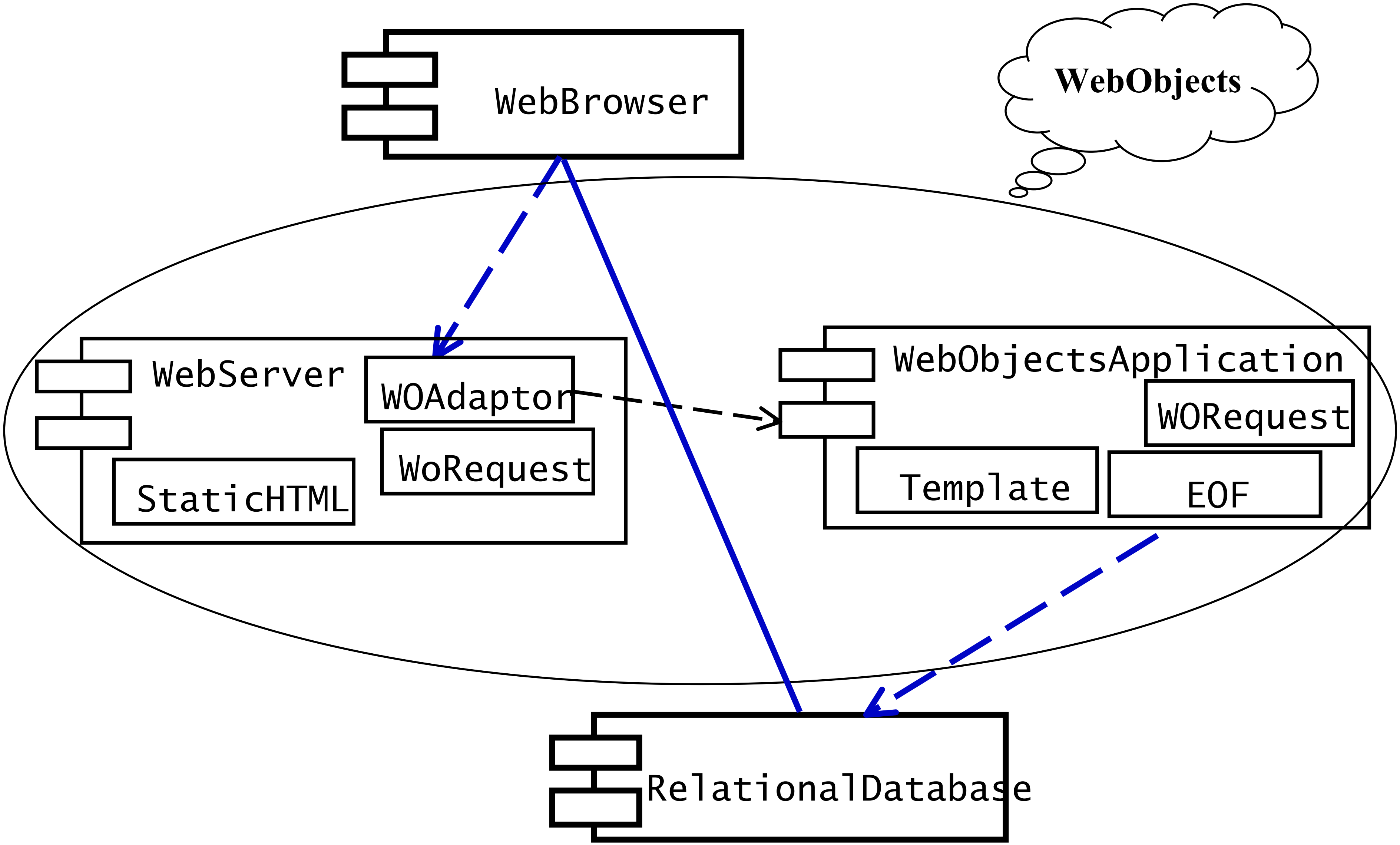
Class libraries and Frameworks

- Class Libraries:
  - **Less domain specific**
  - **Provide a smaller scope of reuse.**
  - **Class libraries are passive; no constraint on control flow.**
- Framework:
  - **Classes cooperate for a family of related applications.**
  - **Frameworks are active; affect the flow of control.**
- In practice, developers often use both:
  - **Frameworks often use class libraries internally to simplify the development of the framework.**
  - **Framework event handlers use class libraries to perform basic tasks (e.g. string processing, file management, numerical analysis….)**

Components and Frameworks

- Components
  - **Self-contained instances of classes**
  - **Plugged together to form complete applications.**
  - **Blackbox that defines a cohesive set of operations,**
  - **Can be used based on the syntax and semantics of the interface.**
  - **Components can even be reused on the binary code level.**
    - **The advantage is that applications do not always have to be recompiled when components change.**
- Frameworks:
  - **Often used to develop components**
  - **Components are often plugged into blackbox frameworks.**

Example: Framework for Building Web Applications



Finding Objects

- The hardest problems in object-oriented system development are:
  - **Identifying objects**
  - **Decomposing the system into objects**
- Requirements Analysis focuses on application domain:
  - **Object identification**
- System Design addresses both, application and implementation domain:
  - **Subsystem Identification**
- Object Design focuses on implementation domain:
  - **Additional solution objects**

Techniques for Finding Objects

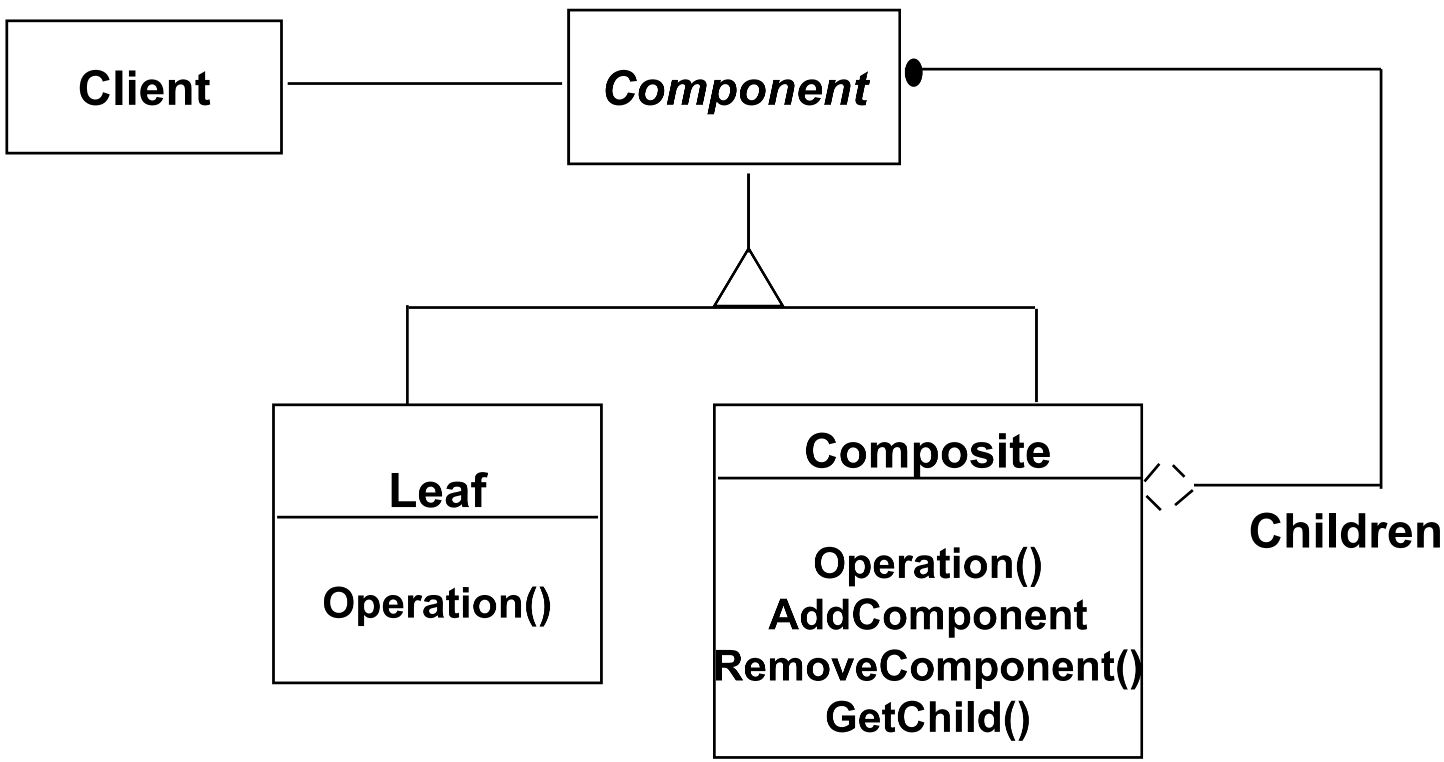
- Requirements Analysis
  - **Start with Use Cases. Identify participating objects**
  - **Textual analysis of flow of events (find nouns, verbs, ...)**
  - **Extract application domain objects by interviewing client (application domain knowledge)**
  - **Find objects by using general knowledge**
- System Design
  - **Subsystem decomposition**
  - **Try to identify layers and partitions**
- Object Design
  - **Find additional objects by applying implementation domain knowledge**

Another Source for Finding Objects : Design Patterns

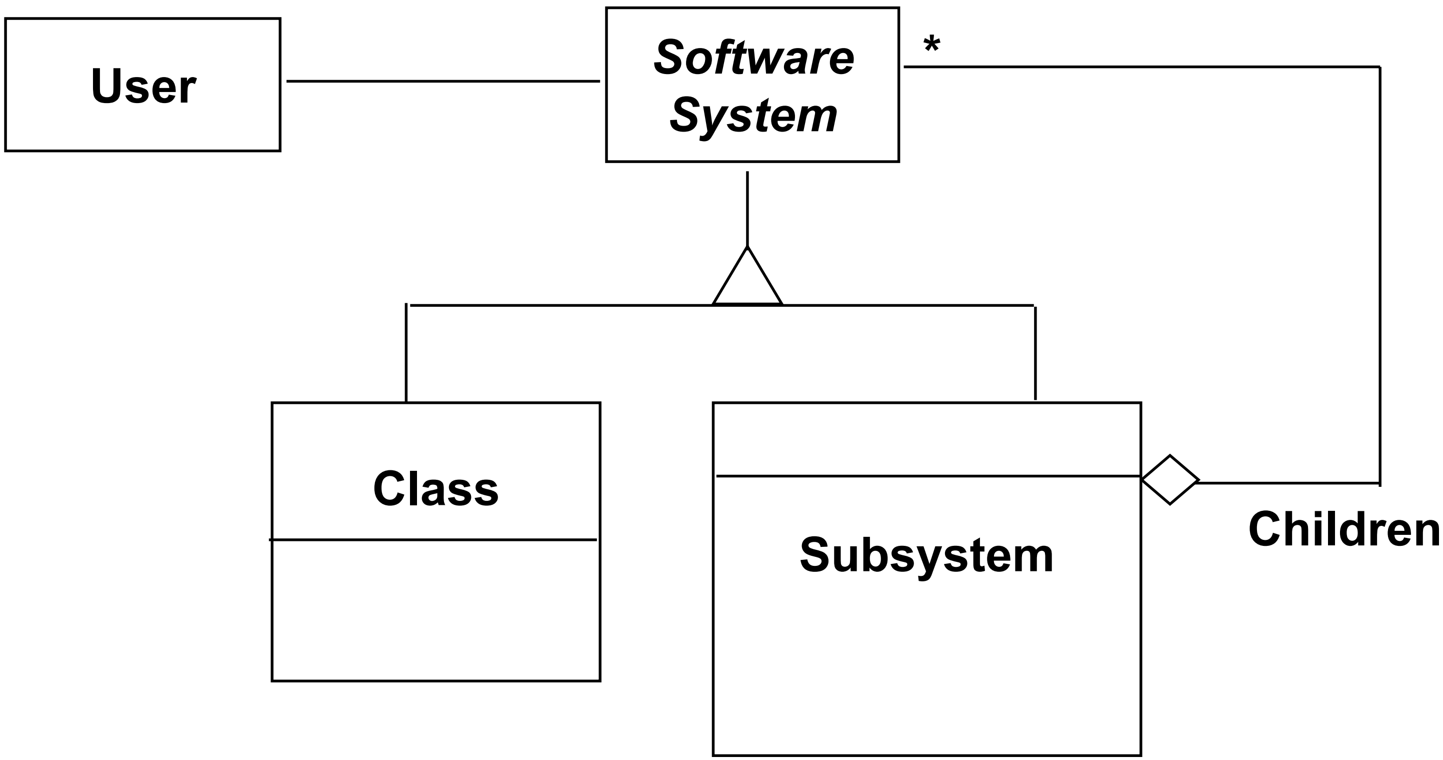
- What are Design Patterns?
  - **A design pattern describes a problem which occurs over and over again in our environment**
  - **Then it describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same twice**

Introducing the Composite Pattern

- Models tree structures that represent part-whole hierarchies with arbitrary depth and width.
- The Composite Pattern lets client treat individual objects and compositions of these objects uniformly

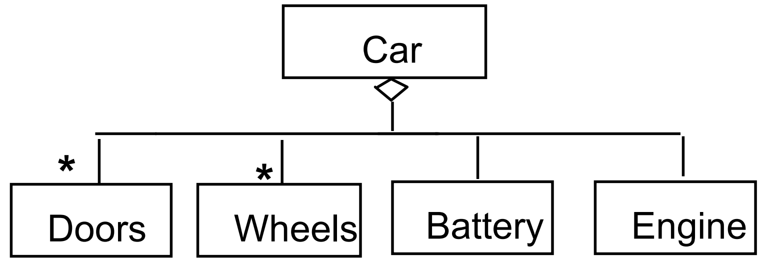


Modeling a Software System with a Composite Pattern



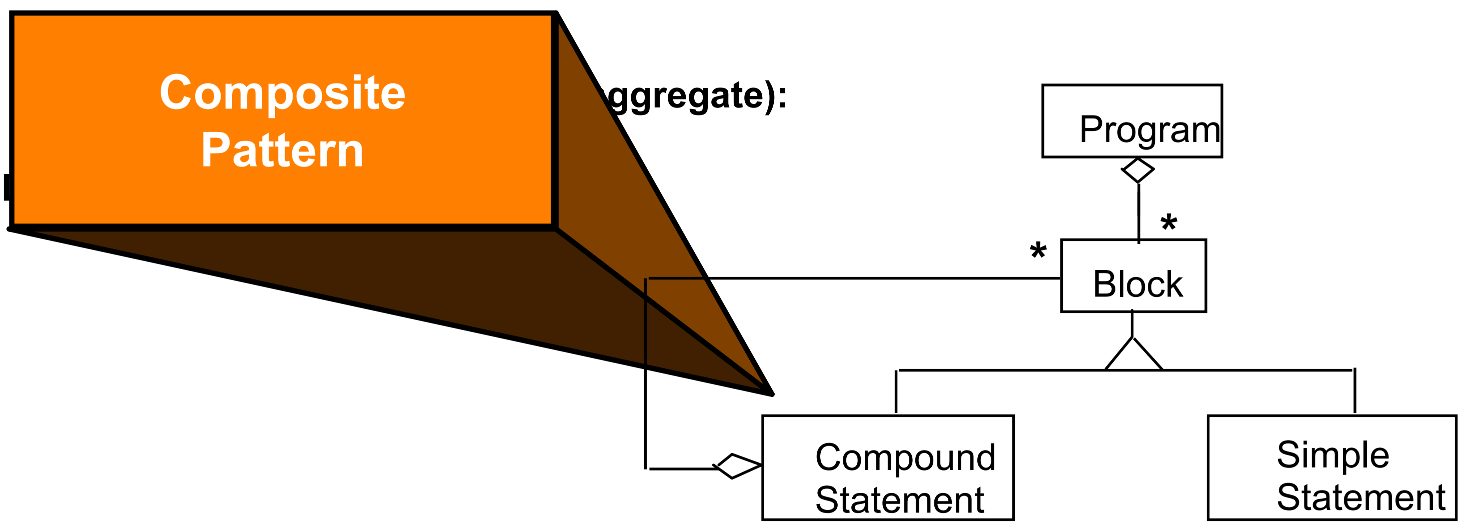
The Composite Patterns models dynamic aggregates

Fixed Structure:



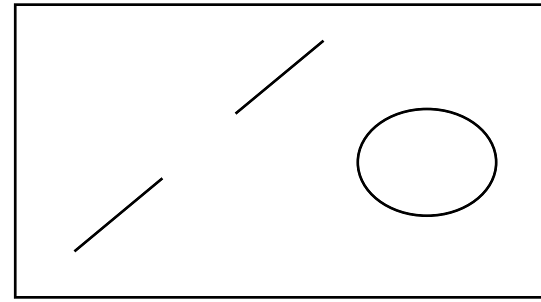
Organization Chart (variable aggregate):

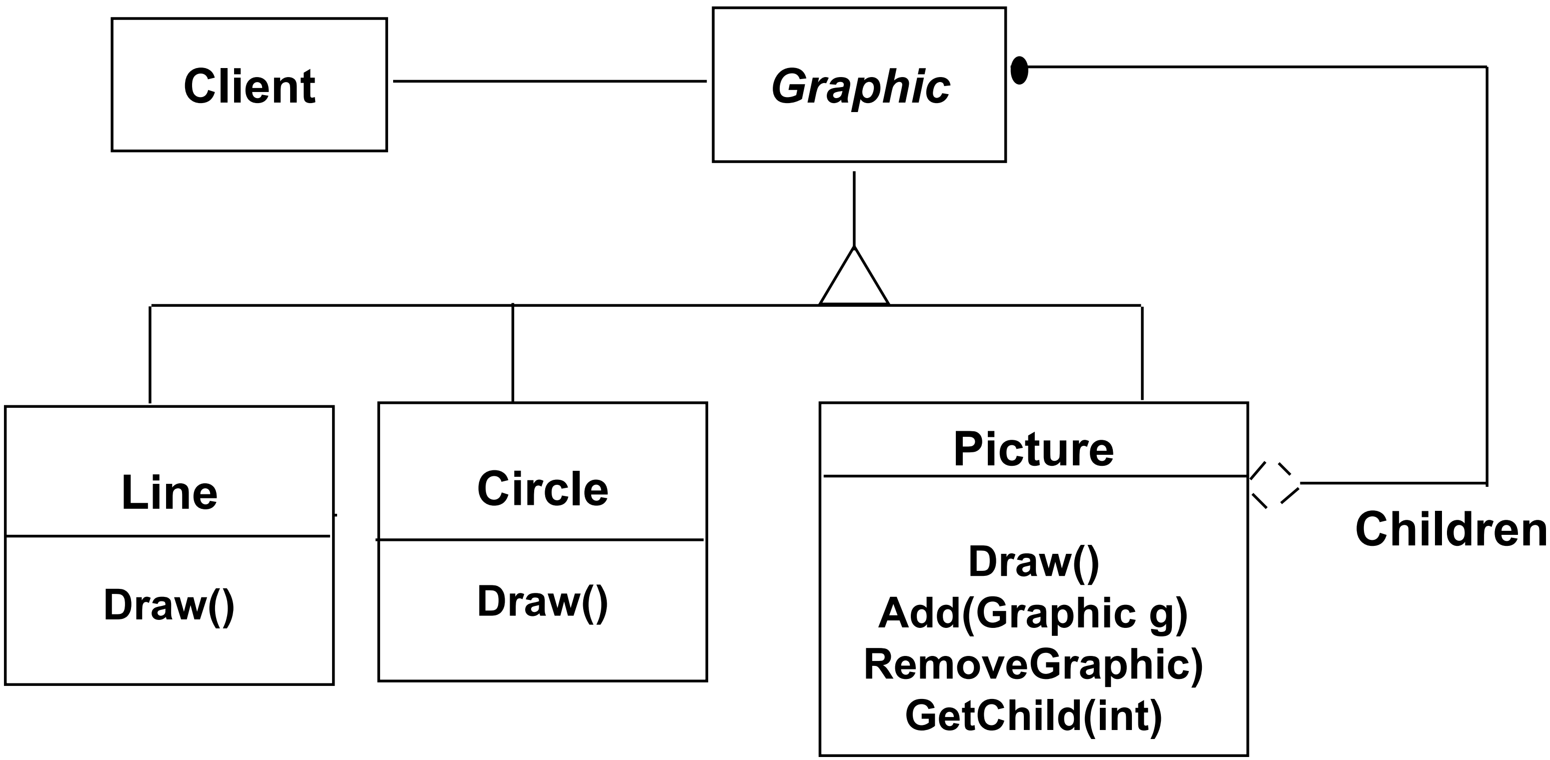
ggregate):



Graphic Applications also use Composite Patterns

- The *Graphic* Class represents both primitives (Line, Circle) and their containers (Picture)



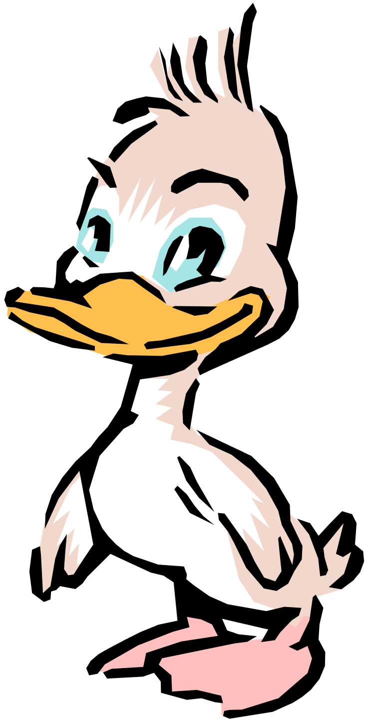


Design Patterns reduce the Complexity of Models

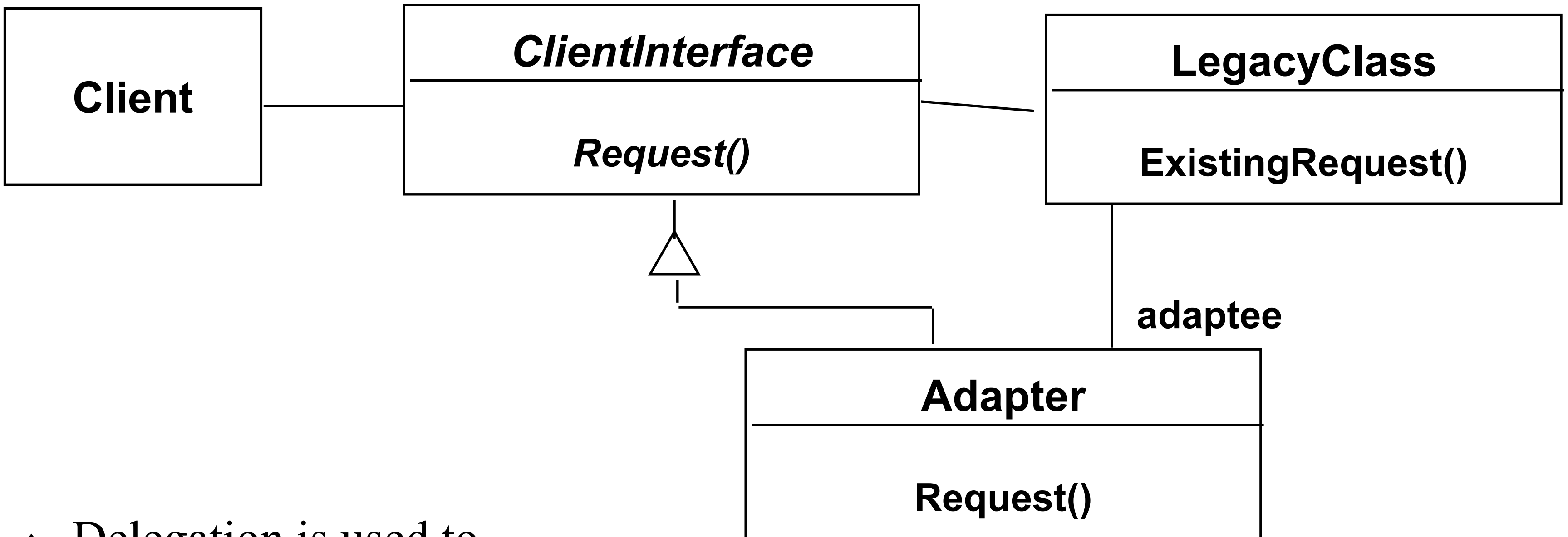
- To communicate a complex model we use navigation and reduction of complexity
  - **We do not simply use a picture from the CASE tool and dump it in front of the user**
  - **The key is navigate through the model so the user can follow it.**
- We start with a very simple model and then decorate it incrementally
  - **Start with key abstractions (use animation)**
  - **Then decorate the model with the additional classes**
- To reduce the complexity of the model even further, we
  - **Apply the use of inheritance (for taxonomies, and for design patterns)**
    - **If the model is still too complex, we show the subclasses on a separate slide**
  - **Then identify (or introduced) patterns in the model**
    - **We make sure to use the name of the patterns**

Duck: Studying your object design

- Description:
  - **Review your current object design.**
  - **Identify any objects that are missing.**
  - **Does the composite pattern fit any part of your design?**
  - **Review all the attributes and methods, including their types and visibility, of your objects. Fill in the missing attributes and methods.**
- Process:
  - Work in teams
  - You have about 10 minutes.



Adapter pattern



- Delegation is used to bind an **Adapter** and an **Adaptee**
- Interface inheritance is use to specify the interface of the **Adapter** class.
- *Target* and **Adaptee** (usually called legacy system) pre-exist the **Adapter.**
- **Target** may be realized as an interface in Java.

Adapter Pattern

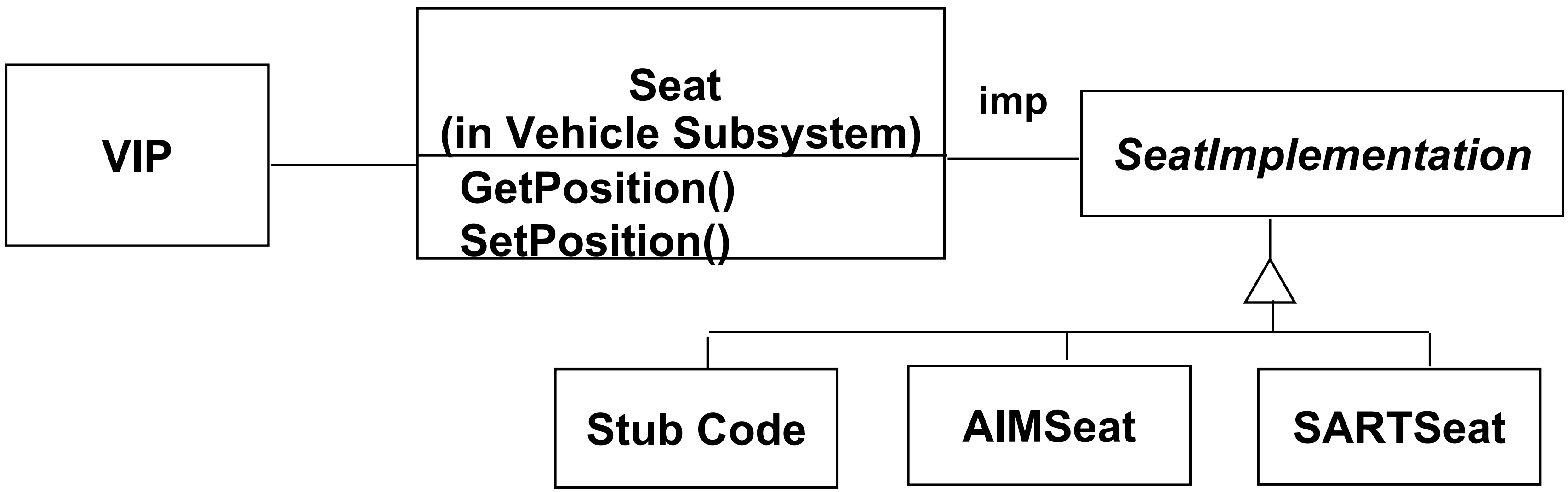
- "Convert the interface of a class into another interface clients expect."
- The adapter pattern lets classes work together that couldn't otherwise because of incompatible interfaces
- Used to provide a new interface to existing legacy components (Interface engineering, reengineering).
- Also known as a wrapper
- Two adapter patterns:
  - **Class adapter:**
    - **Uses multiple inheritance to adapt one interface to another**
  - **Object adapter:**
    - **Uses single inheritance and delegation**
- Object adapters are much more frequent. We will only cover object adapters (and call them therefore simply adapters)

Bridge Pattern

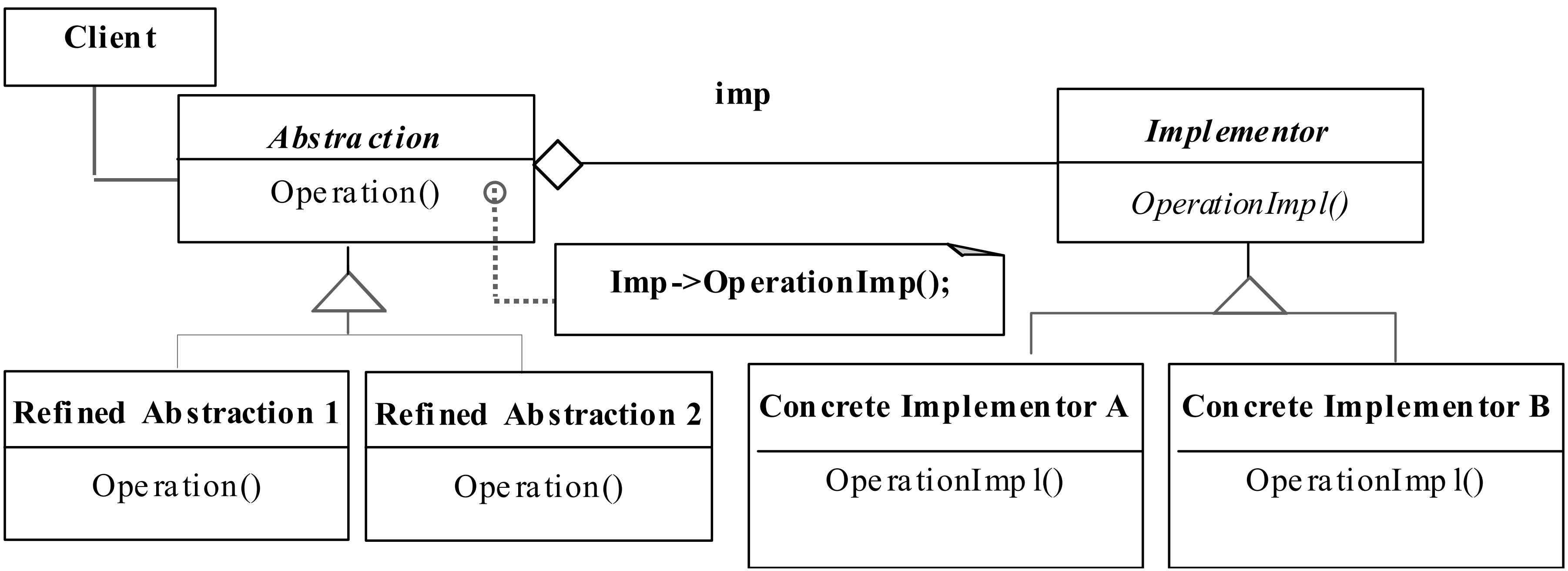
- Use a bridge to “decouple an abstraction from its implementation so that the two can vary independently”. (From [Gamma et al 1995])
- Also know as a Handle/Body pattern.
- Allows different implementations of an interface to be decided upon dynamically.

Using a Bridge

- The bridge pattern is used to provide multiple implementations under the same interface.
- Examples: Interface to a component that is incomplete, not yet known or unavailable during testing
- JAMES Project: if seat data is required to be read, but the seat is not yet implemented, known, or only available by a simulation, provide a bridge:



Bridge Pattern

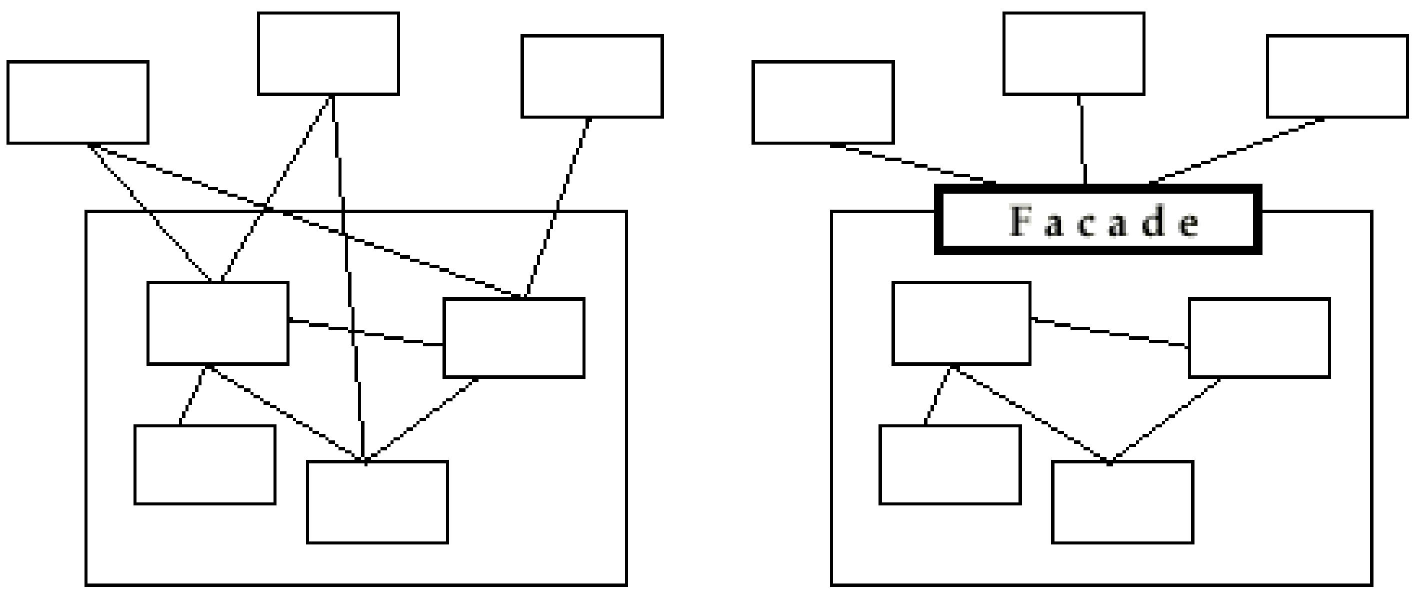


Adapter vs Bridge

- Similarities:
  - **Both are used to hide the details of the underlying implementation.**
- Difference:
  - **The adapter pattern is geared towards making unrelated components work together**
    - **Applied to systems after they're designed (reengineering, interface engineering).**
  - **A bridge, on the other hand, 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 "object zoo", even if these are not known at analysis or system design time.**

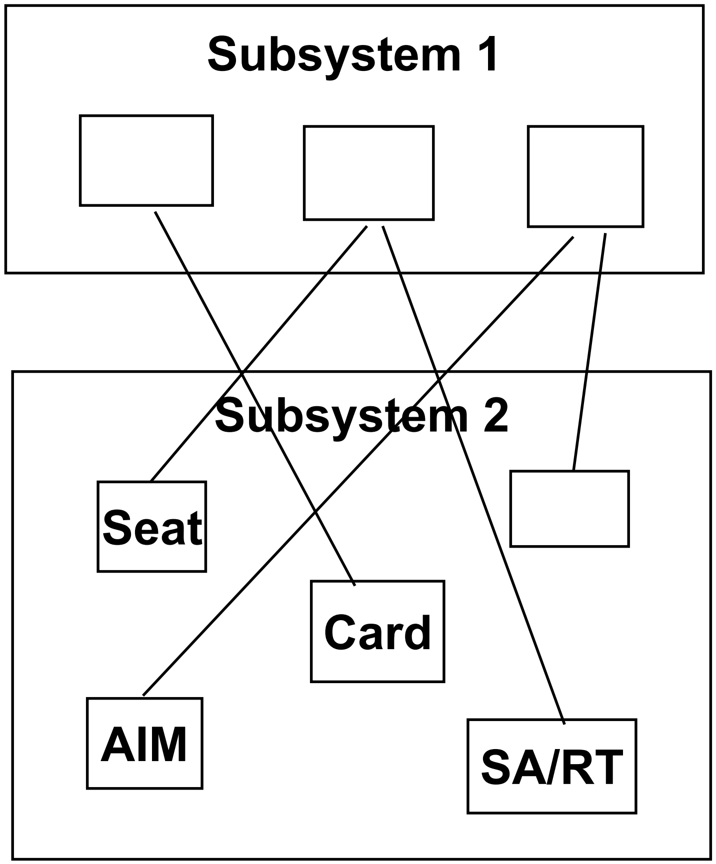
Facade Pattern

- Provides a unified interface to a set of objects in a subsystem.
- A facade defines a higher-level interface that makes the subsystem easier to use (i.e. it abstracts out the gory details)
- Facades allow us to provide a closed architecture



Design Example

- Subsystem 1 can look into the Subsystem 2 (vehicle subsystem) and call on any component or class operation at will.
- This is “Ravioli Design”
- Why is this good?
  - **Efficiency**
- Why is this bad?
  - **Can’t expect the caller to understand how the subsystem works or the complex relationships within the subsystem.**
  - **We can be assured that the subsystem will be misused, leading to non-portable code**



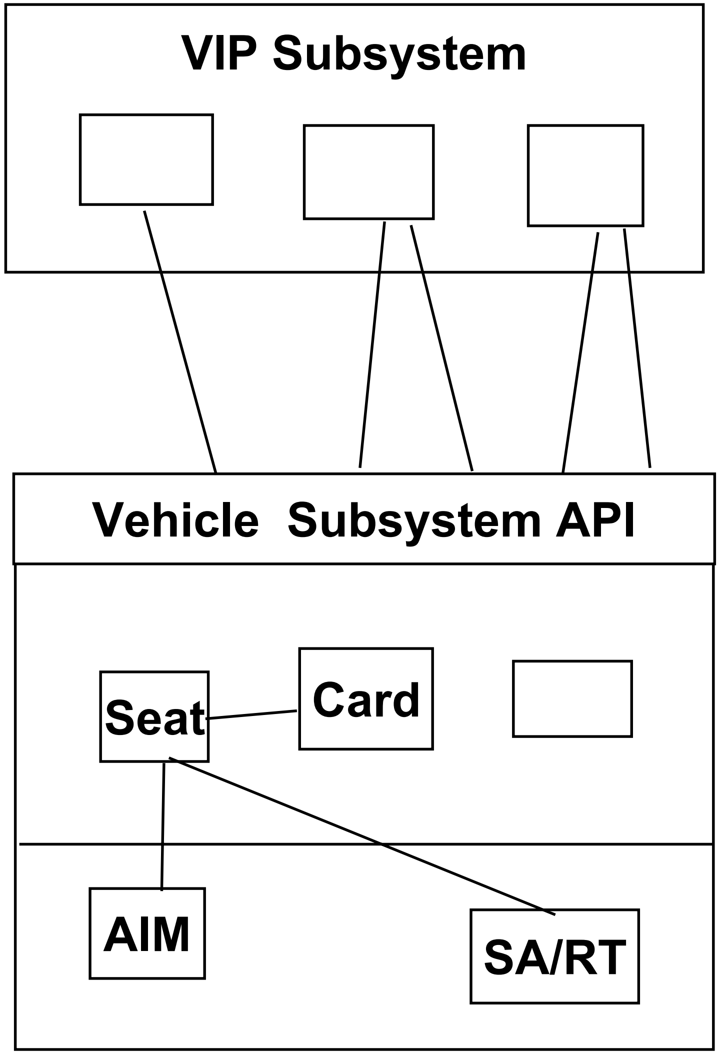
Subsystem Design with Façade, Adapter, Bridge

- The ideal structure of a subsystem consists of
  - **an interface object**
  - **a set of application domain objects (entity objects) modeling real entities or existing systems**
    - **Some of the application domain objects are interfaces to existing systems**
  - **one or more control objects**

- We can use design patterns to realize this subsystem structure
- Realization of the Interface Object: Facade
  - **Provides the interface to the subsystem**
- Interface to existing systems: Adapter or Bridge
  - **Provides the interface to existing system (legacy system)**
  - **The existing system is not necessarily object-oriented!**

Realizing an Opaque Architecture with a Facade

- The subsystem decides exactly how it is accessed.
- No need to worry about misuse by callers
- If a façade is used the subsystem can be used in an early integration test
  - **We need to write only a driver**



Design Patterns encourage reusable Designs

- A facade pattern should be used by all subsystems in a software system. The façade defines all the services of the subsystem.
  - **The facade will delegate requests to the appropriate components within the subsystem. Most of the time the façade does not need to be changed, when the component is changed,**
- Adapters should be used to interface to existing components.
  - **For example, a smart card software system should provide an adapter for a particular smart card reader and other hardware that it controls and queries.**
- Bridges should be used to interface to a set of objects
  - **where the full set is not completely known at analysis or design time.**
  - **when the subsystem must be extended later after the system has been deployed and client programs are in the field(dynamic extension).**
- Model/View/Controller should be used
  - **when the interface changes much more rapidly than the application domain.**

Review: Design pattern

A design pattern is…

…a template solution to a recurring design problem

- **Look before re-inventing the wheel just one more time**

…reusable design knowledge

- **Higher level than classes or datastructures (link lists,binary trees...)**
- **Lower level than application frameworks**

…an example of *modifiable* design

- **Learning to design starts by studying other designs**

Why are modifiable designs important?

A modifiable design enables…

…an iterative and incremental development cycle

- **concurrent development**
- **risk management**
- **flexibility to change**

…to minimize the introduction of new problems when fixing old ones

…to deliver more functionality after initial delivery

What makes a design modifiable?

- Low coupling and high cohesion
- Clear dependencies
- Explicit assumptions

How do design patterns help?

- They are generalized from existing systems
- They provide a shared vocabulary to designers
- They provide examples of modifiable designs
  - **Abstract classes**
  - **Delegation**

On to More Patterns!

- Structural pattern
  - **Proxy**

- Creational Patterns
  - **Abstract Factory**
  - **Builder**

- Behavioral pattern
  - **Command**
  - **Observer**
  - **Strategy**

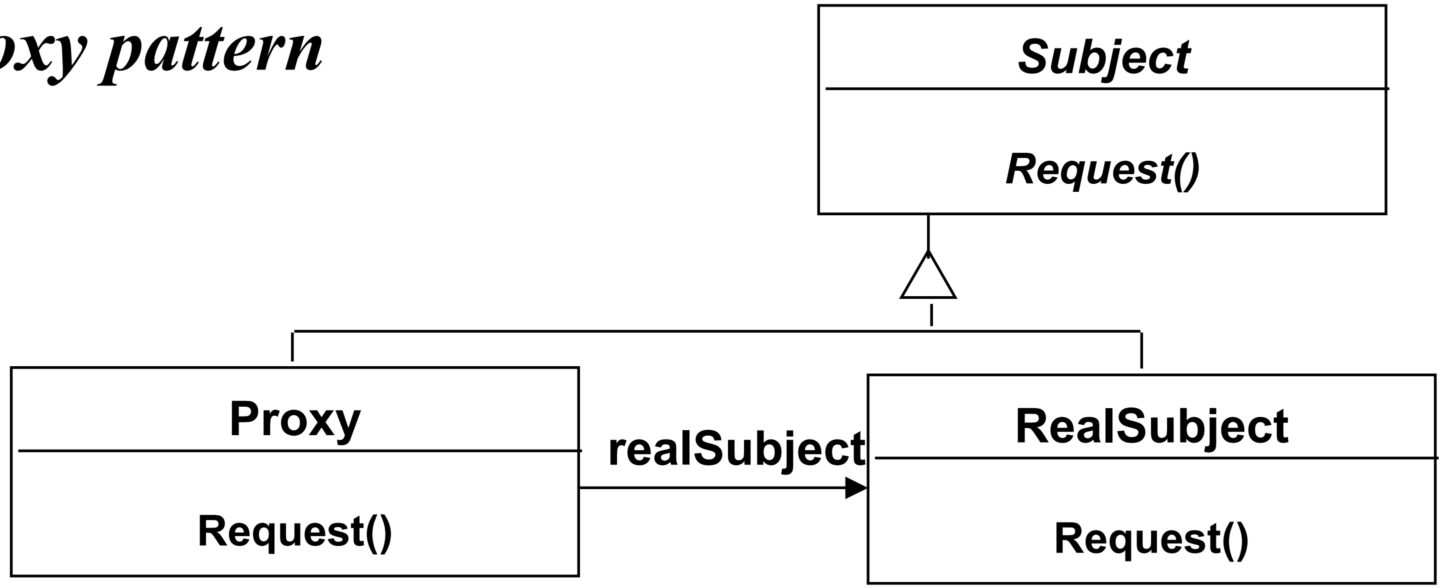
Proxy Pattern: Motivation

- It is 15:00pm. I am sitting at my 14.4 baud modem connection and retrieve a fancy web site from the US, This is prime web time all over the US. So I am getting 10 bits/sec.
- What can I do?

Proxy Pattern

- What is expensive?
  - **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**
  - **Uses another object ("the proxy") that acts as a stand-in for the real object**
  - **The proxy creates the real object only if the user asks for it**

Proxy pattern

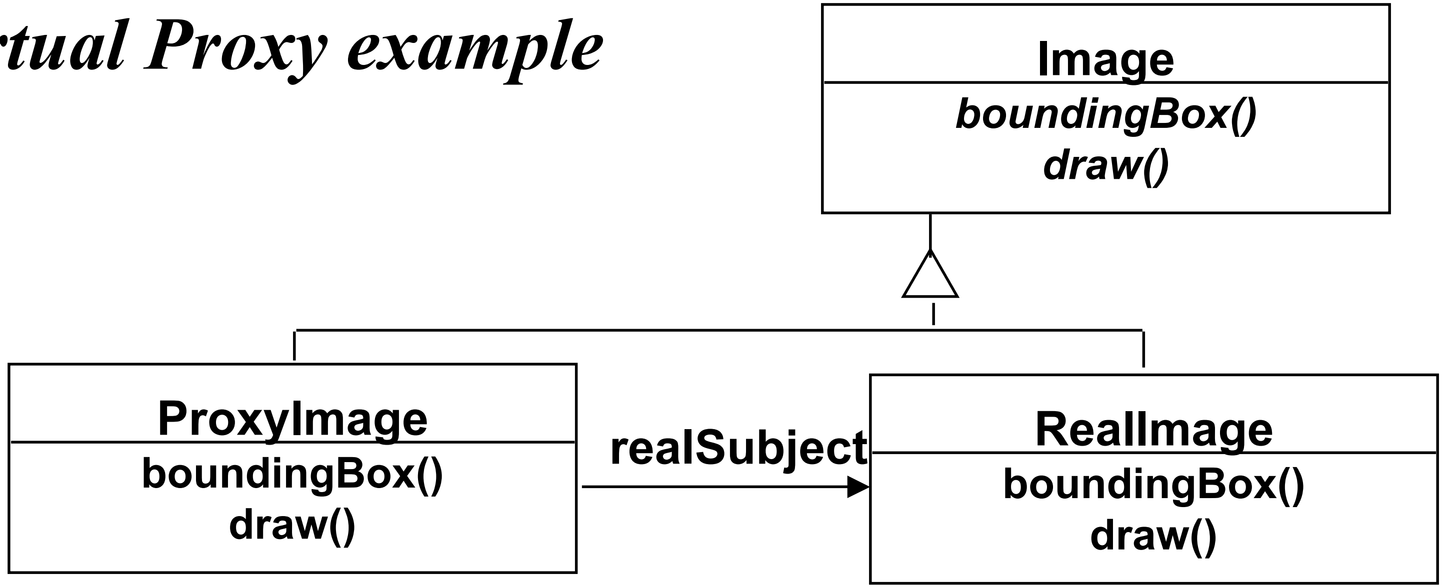


- Interface inheritance is used to specify the interface shared by **Proxy** and **RealSubject.**
- Delegation is used to catch and forward any accesses to the **RealSubject** (if desired)
- Proxy patterns can be used for lazy evaluation and for remote invocation.
- Proxy patterns can be implemented with a Java interface.

Proxy Applicability

- Remote Proxy
  - **Local representative for an object in a different address space**
  - **Caching of information: Good if information does not change too often**
- Virtual Proxy
  - **Object is too expensive to create or too expensive to download**
  - **Proxy is a stand-in**
- Protection Proxy
  - **Proxy provides access control to the real object**
  - **Useful 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.**

Virtual Proxy example



- **Images** are stored and loaded separately from text
- If a **RealImage** is not loaded a **ProxyImage** displays a grey rectangle in place of the image
- The client cannot tell that it is dealing with a **ProxyImage** instead of a **RealImage**
- A proxy pattern can be easily combined with a **Bridge**

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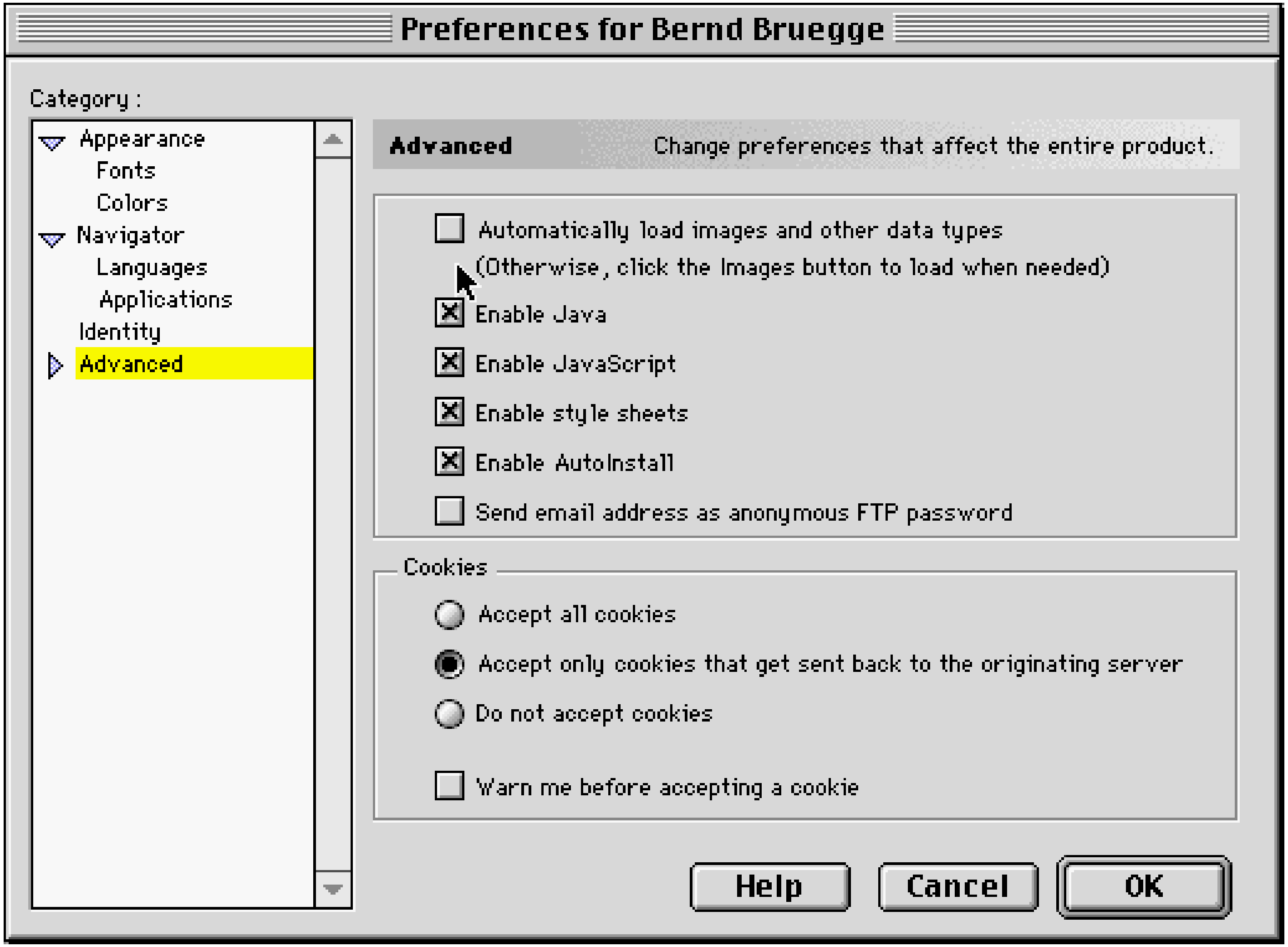

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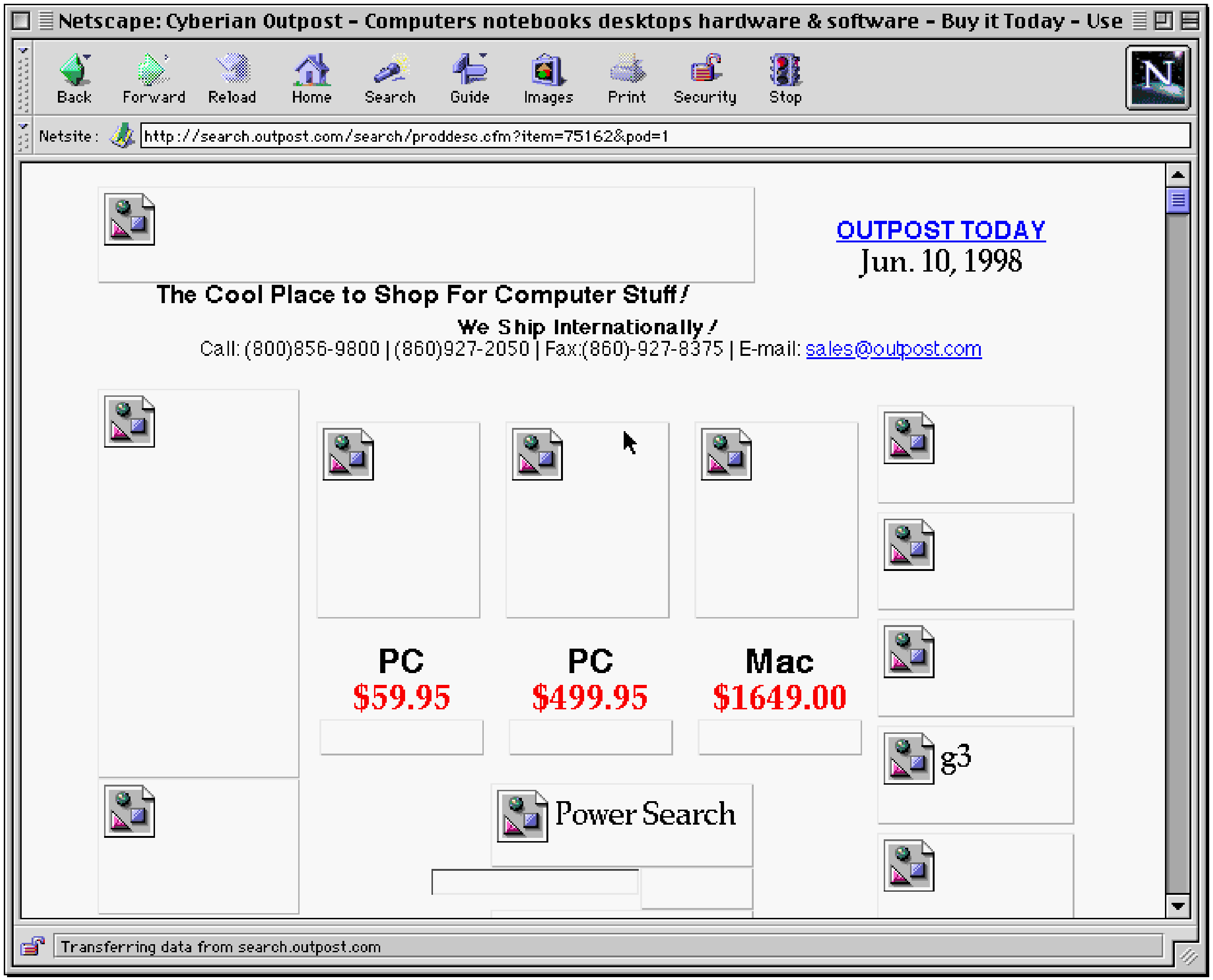
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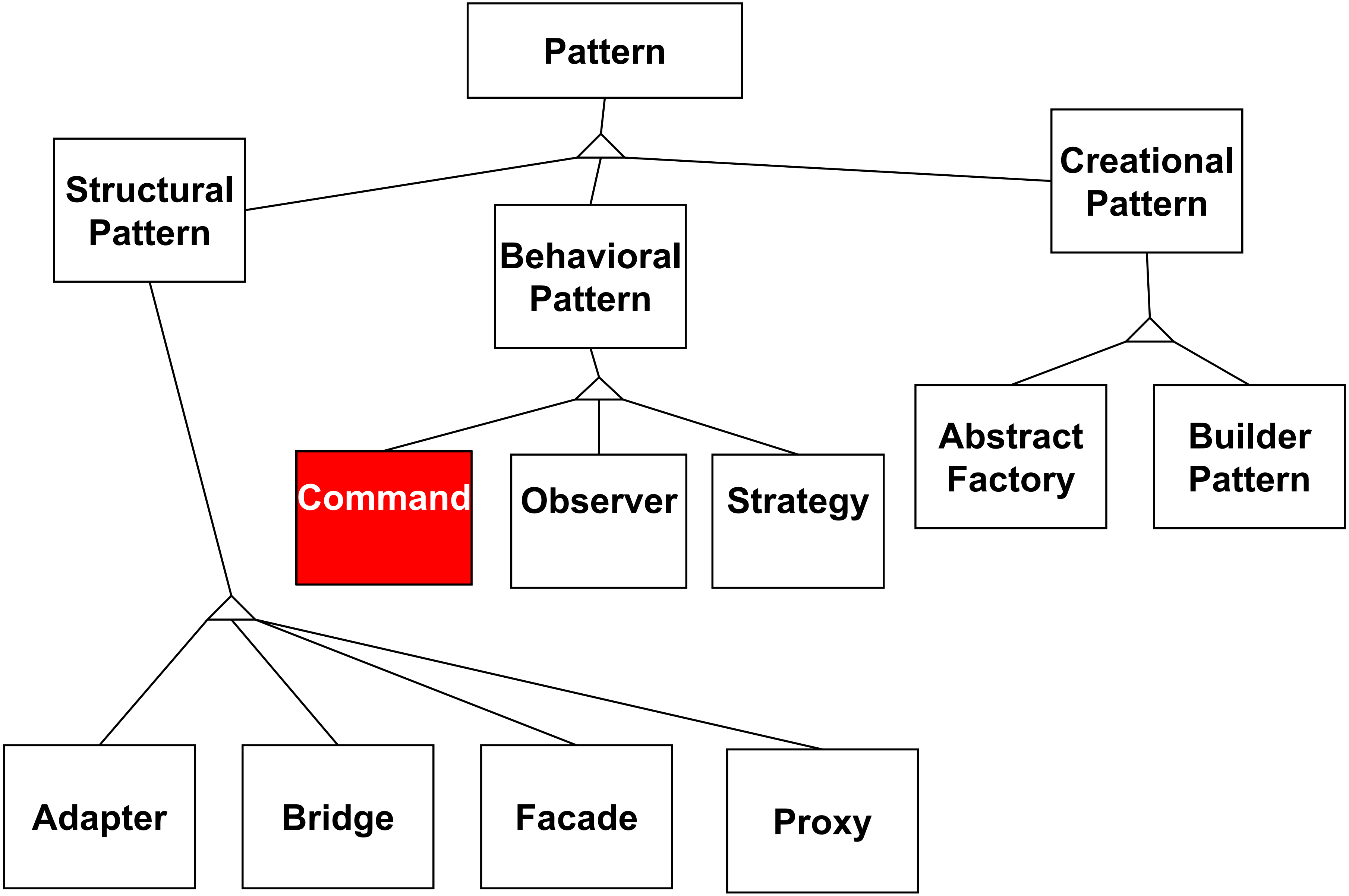
Towards a Pattern Taxonomy

- Structural Patterns
  - **Adapters, Bridges, Facades, and Proxies are variations on a single theme:**
    - **They reduce the coupling between two or more classes**
    - **They introduce an abstract class to enable future extensions**
    - **They encapsulate complex structures**
- Behavioral Patterns
  - **Here we are concerned with algorithms and the assignment of responsibilies between objects: Who does what?**
  - **Behavioral patterns allow us to characterize complex control flows that are difficult to follow at runtime.**
- Creational Patterns
  - **Here our goal is to provide a simple abstraction for a complex instantiation process.**
  - **We want to make the system independent from the way its objects are created, composed and represented.**

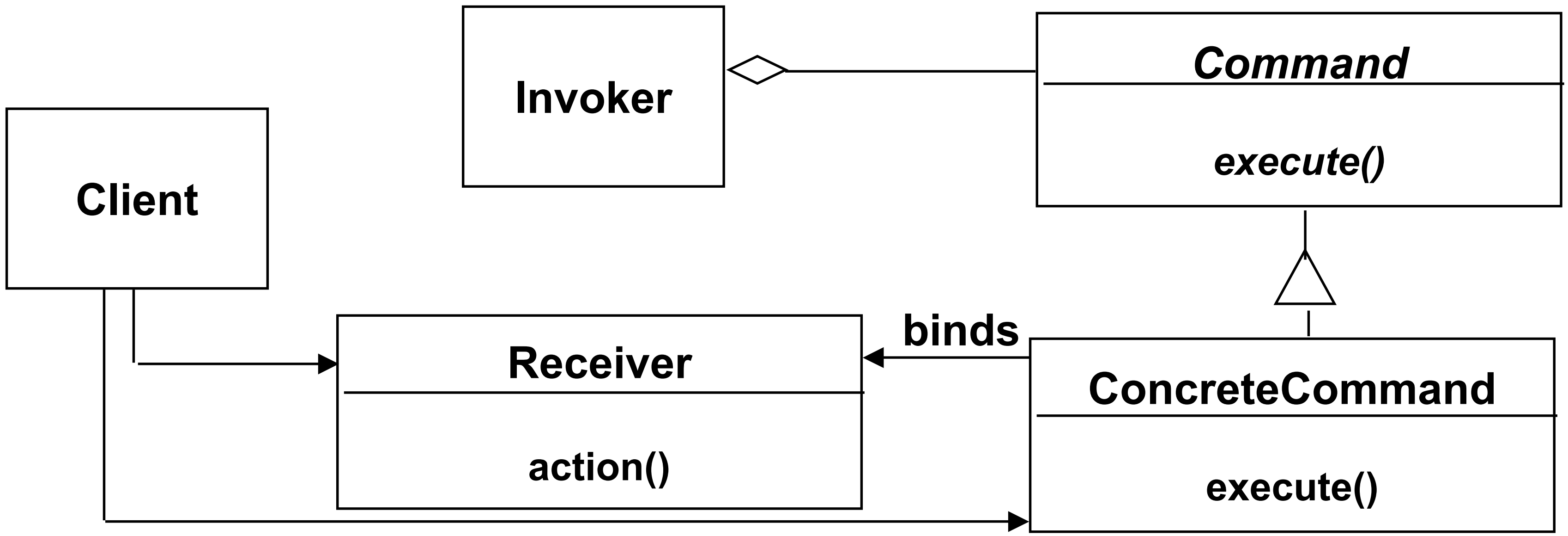
A Pattern Taxonomy



Command Pattern: Motivation

- You want to build a user interface
- You want to provide menus
- You want to make the user interface reusable across many applications
  - **You cannot hardcode the meanings of the menus for the various applications**
  - **The applications only know what has to be done when a menu is selected.**
- Such a menu can easily be implemented with the Command Pattern

Command pattern



- **Client** creates a **ConcreteCommand** and binds it with a **Receiver.**
- **Client** hands the **ConcreteCommand** over to the **Invoker** which stores it.
- The **Invoker** has the responsibility to do the command (“execute” or “undo”)**.**

Command pattern Applicability

- "Encapsulate a request as an object, thereby letting you
  - **parameterize clients with different requests,**
  - **queue or log requests, and**
  - **support undoable operations."**
- Uses:
  - **Undo queues**
  - **Database transaction buffering**

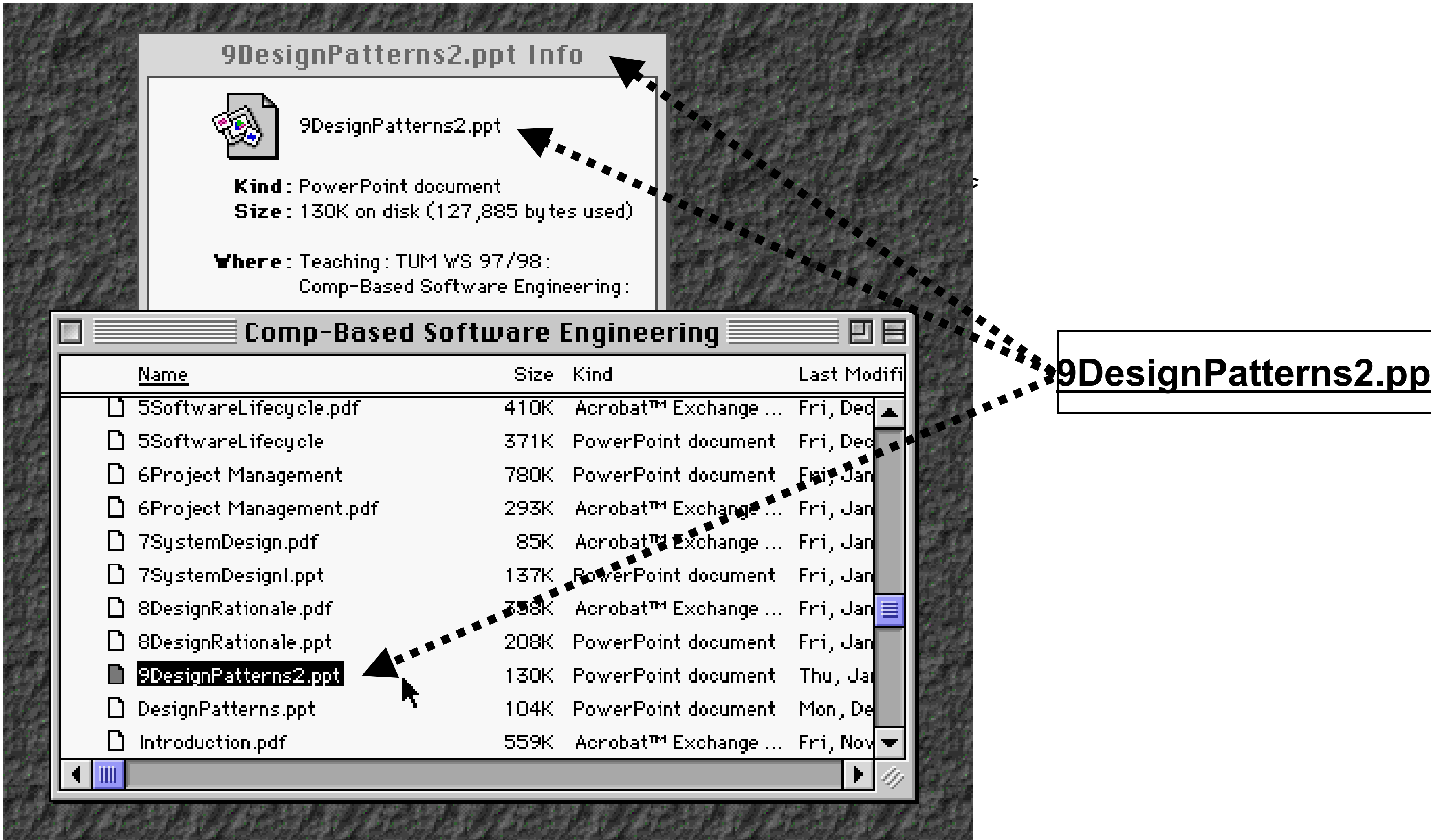
Observer pattern

- "Define a one-to-many dependency between objects so that when one object changes state, all its dependents are notified and updated automatically."
- Also called "Publish and Subscribe"
- Uses:
  - **Maintaining consistency across redundant state**
  - **Optimizing batch changes to maintain consistency**

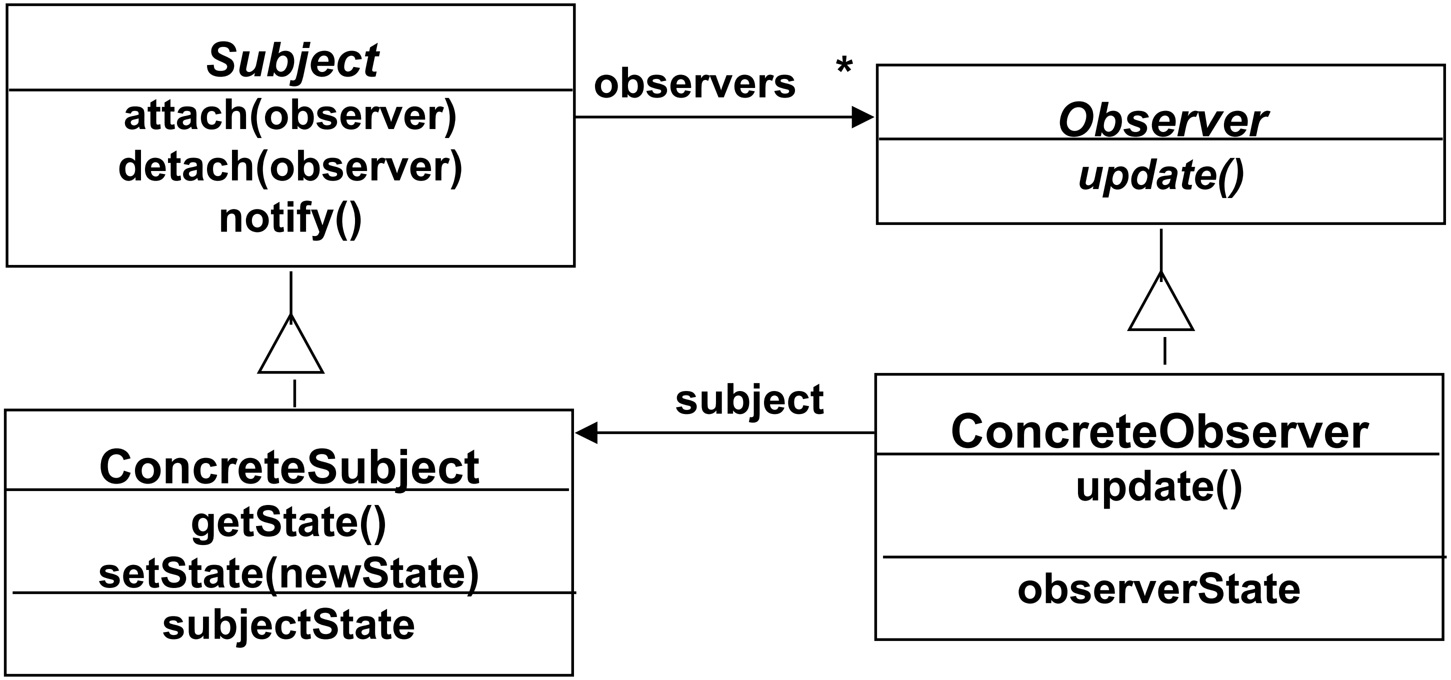
Observer pattern (continued)

Observers

Subject

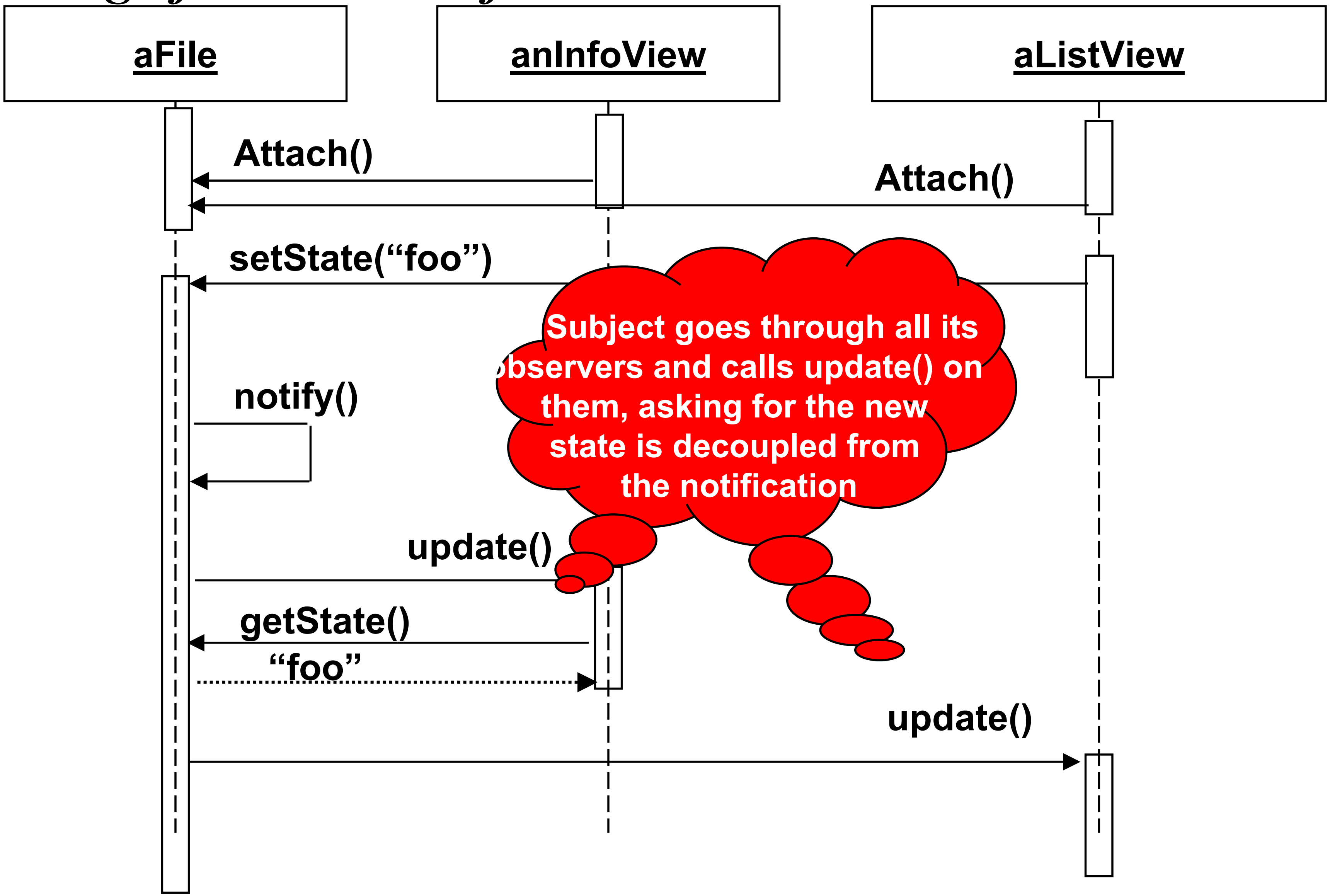


Observer pattern (cont'd)

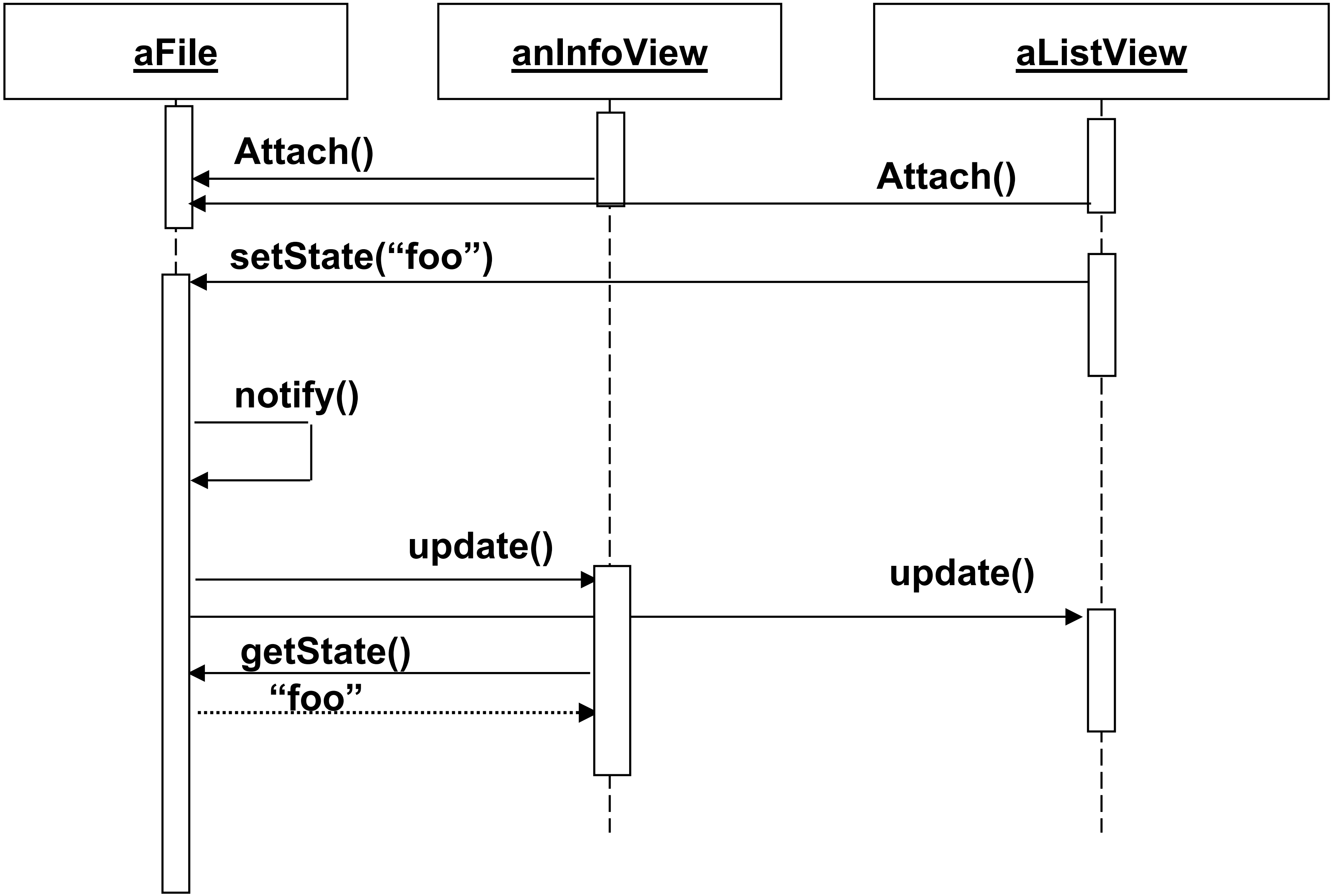


- The **Subject** represents the actual state, the **Observers** represent different views of the state.
- **Observer** can be implemented as a Java interface.
- **Subject** is a super class (needs to store the observers vector) ***not*** an interface.

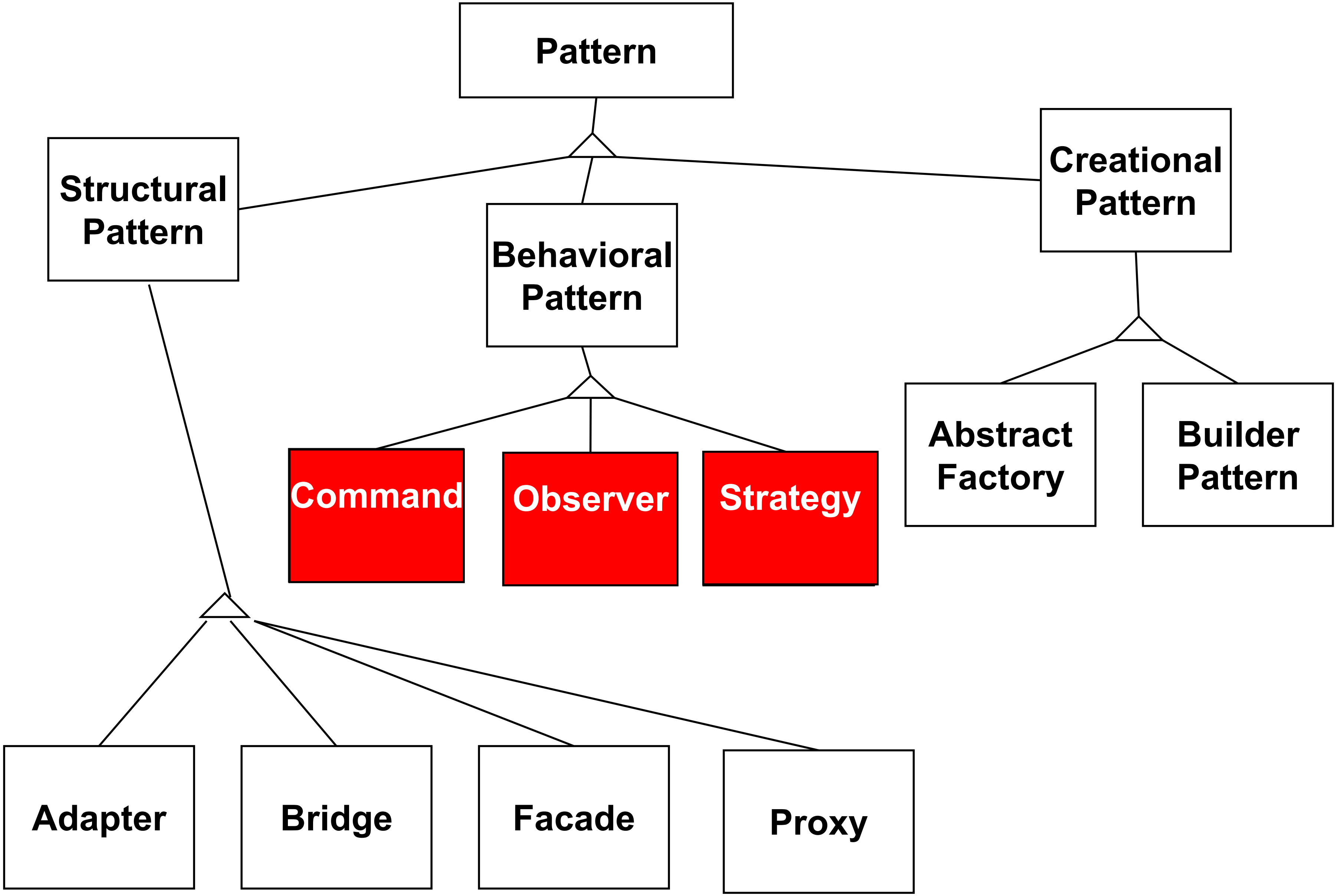
Sequence diagram for scenario: Change filename to "foo"



Animated Sequence diagram



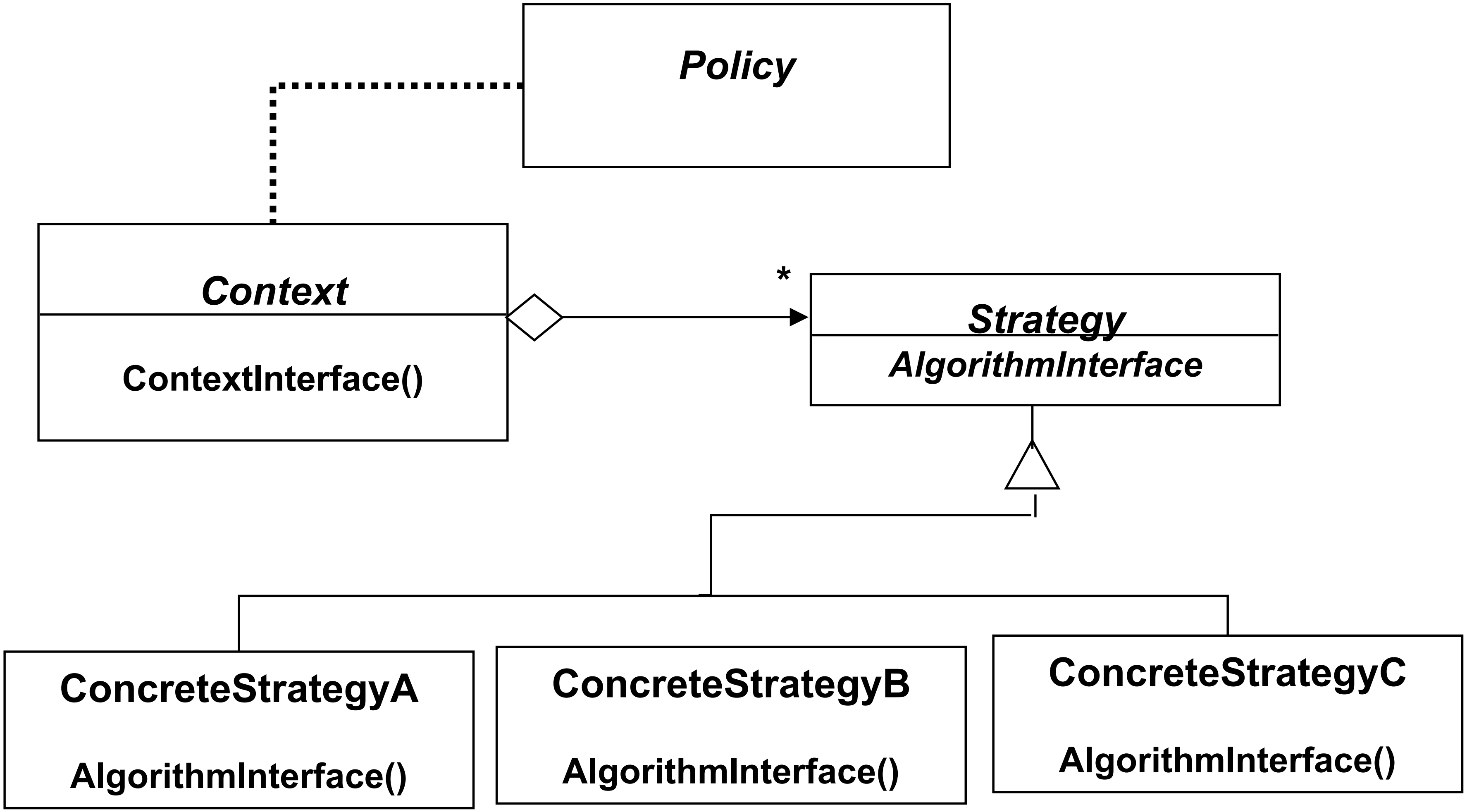
A Pattern Taxonomy



Strategy Pattern

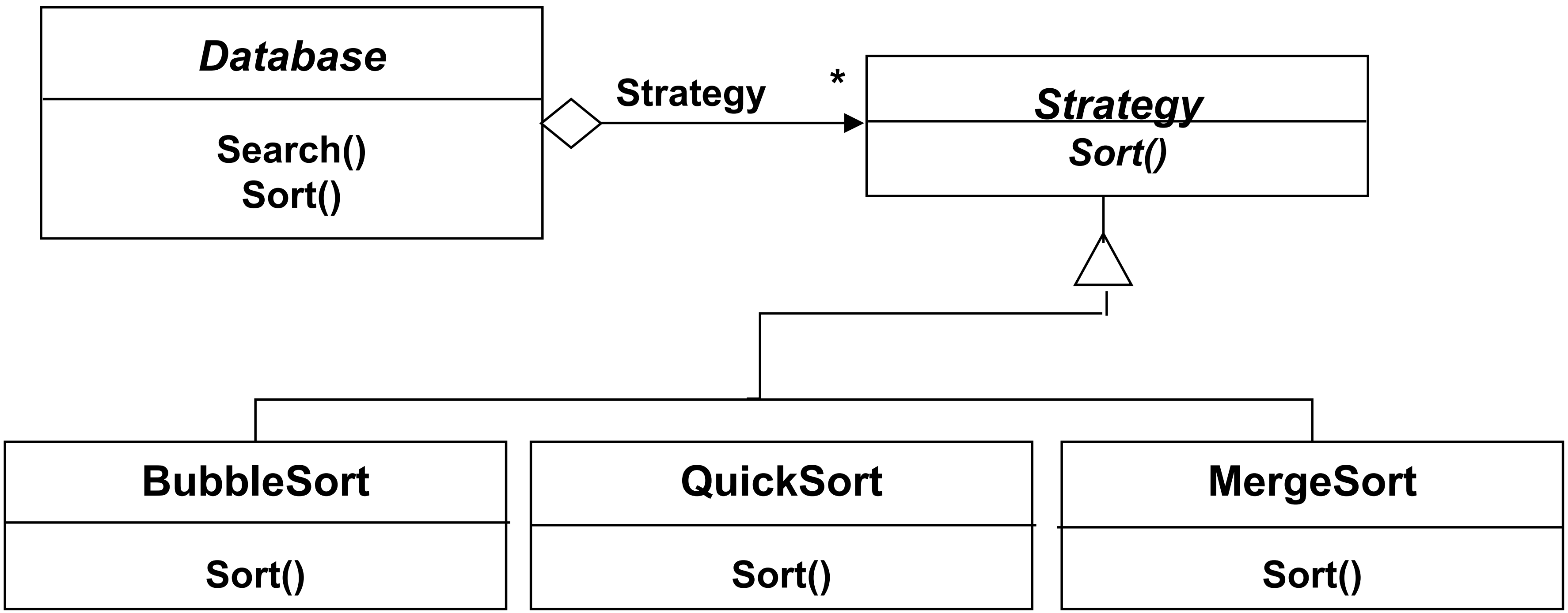
- Many different algorithms exists for the same task
- Examples:
  - **Breaking a stream of text into lines**
  - **Parsing a set of tokens into an abstract syntax tree**
  - **Sorting a list of customers**
- The different algorithms will be appropriate at different times
  - **Rapid prototyping vs delivery of final product**
- We don't want to support all the algorithms if we don't need them
- If we need a new algorithm, we want to add it easily without disturbing the application using the algorithm

Strategy Pattern



Policy decides which Strategy is best given the current Context

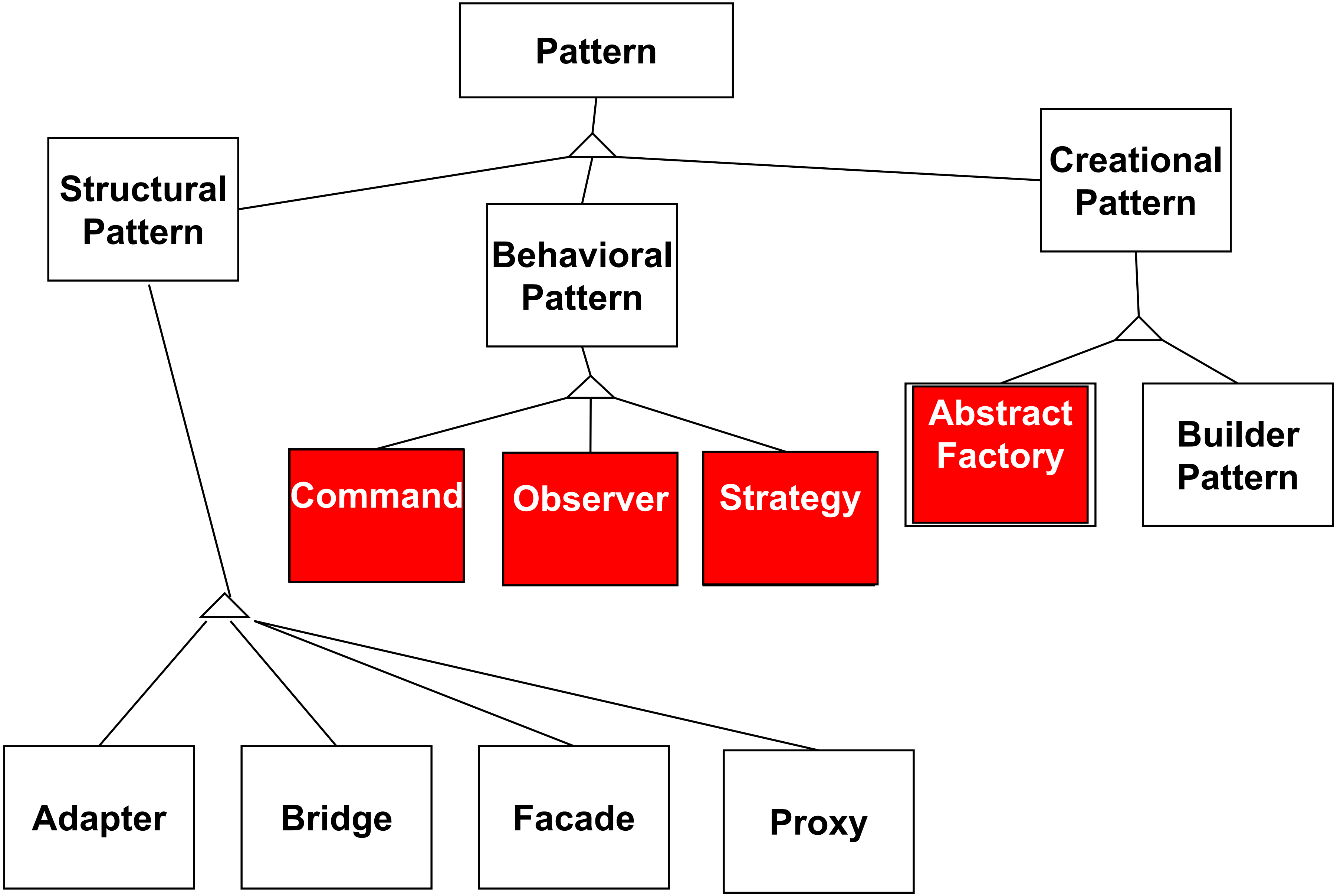
Applying a Strategy Pattern in a Database Application



Applicability of Strategy Pattern

- Many related classes differ only in their behavior. Strategy allows to configure a single class with one of many behaviors
- Different variants of an algorithm are needed that trade-off space against time. All these variants can be implemented as a class hierarchy of algorithms

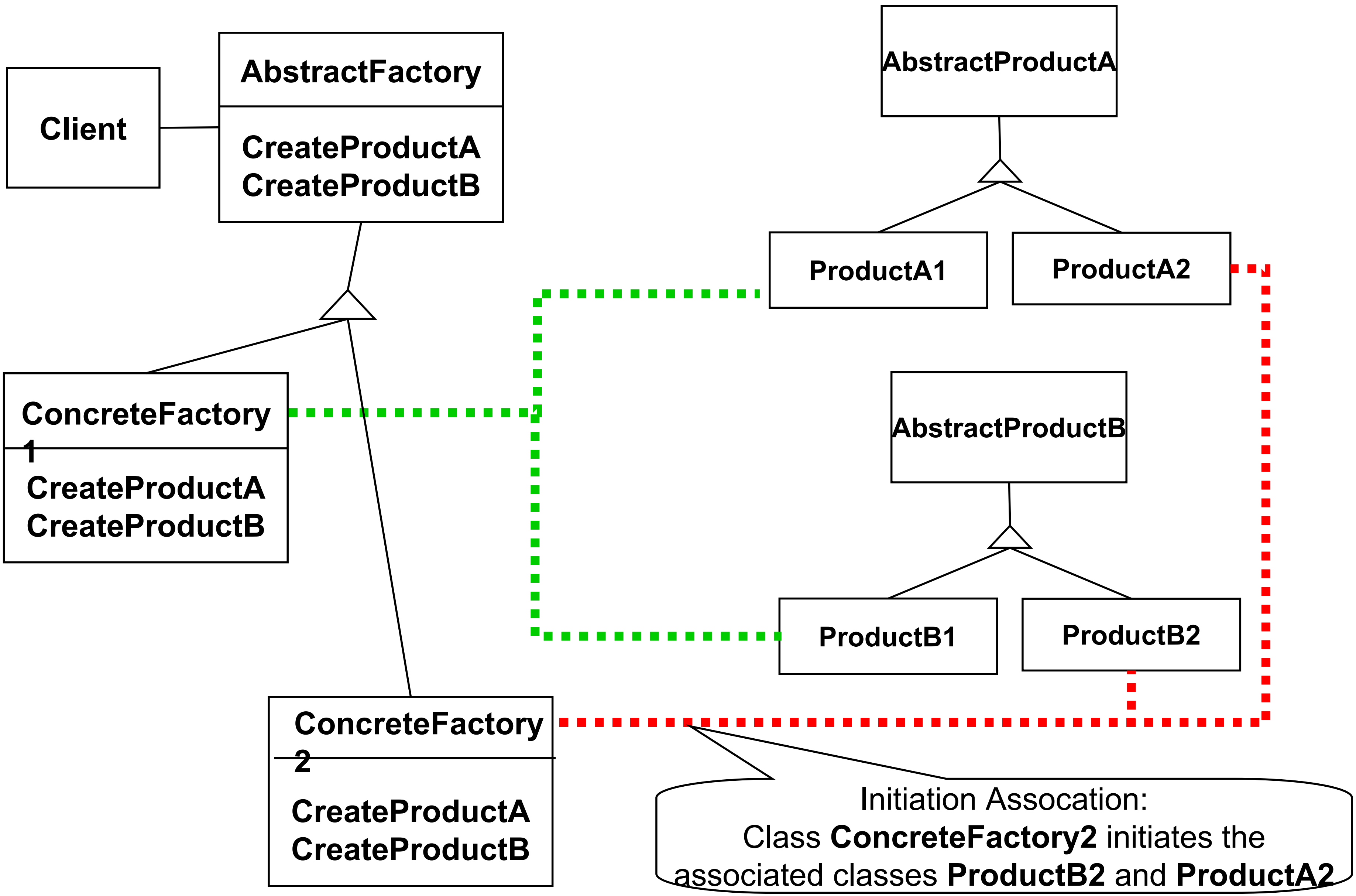
A Pattern Taxonomy



Abstract Factory Motivation

- 2 Examples
- Consider a user interface toolkit that supports multiple looks and feel standards such as Motif, Windows 95 or the finder in MacOS.
  - **How can you write a single user interface and make it portable across the different look and feel standards for these window managers?**
- Consider a facility management system for an intelligent house that supports different control systems such as Siemens' Instabus, Johnson & Control Metasys or Zumtobe's proprietary standard.
  - **How can you write a single control system that is independent from the manufacturer?**

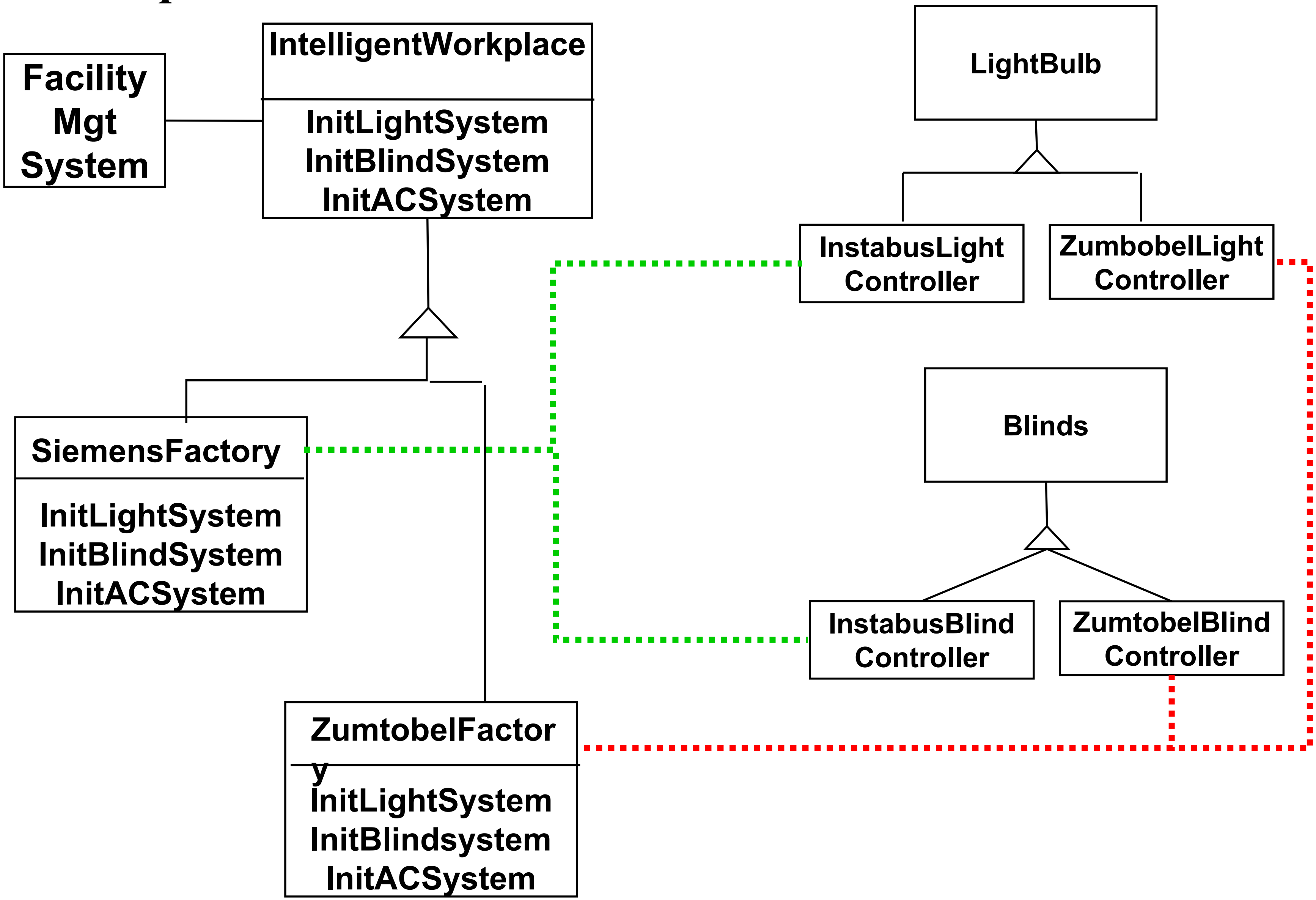
Abstract Factory



Applicability for Abstract Factory Pattern

- Independence from Initialization or Representation:
  - **The system should be independent of how its products are created, composed or represented**
- Manufacturer Independence:
  - **A system should be configured with one family of products, where one has a choice from many different families.**
  - **You want to provide a class library for a customer (“facility management library”), but you don’t want to reveal what particular product you are using.**
- Constraints on related products
  - **A family of related products is designed to be used together and you need to enforce this constraint**
- Cope with upcoming change:
  - **You use one particular product family, but you expect that the underlying technology is changing very soon, and new products will appear on the market.**

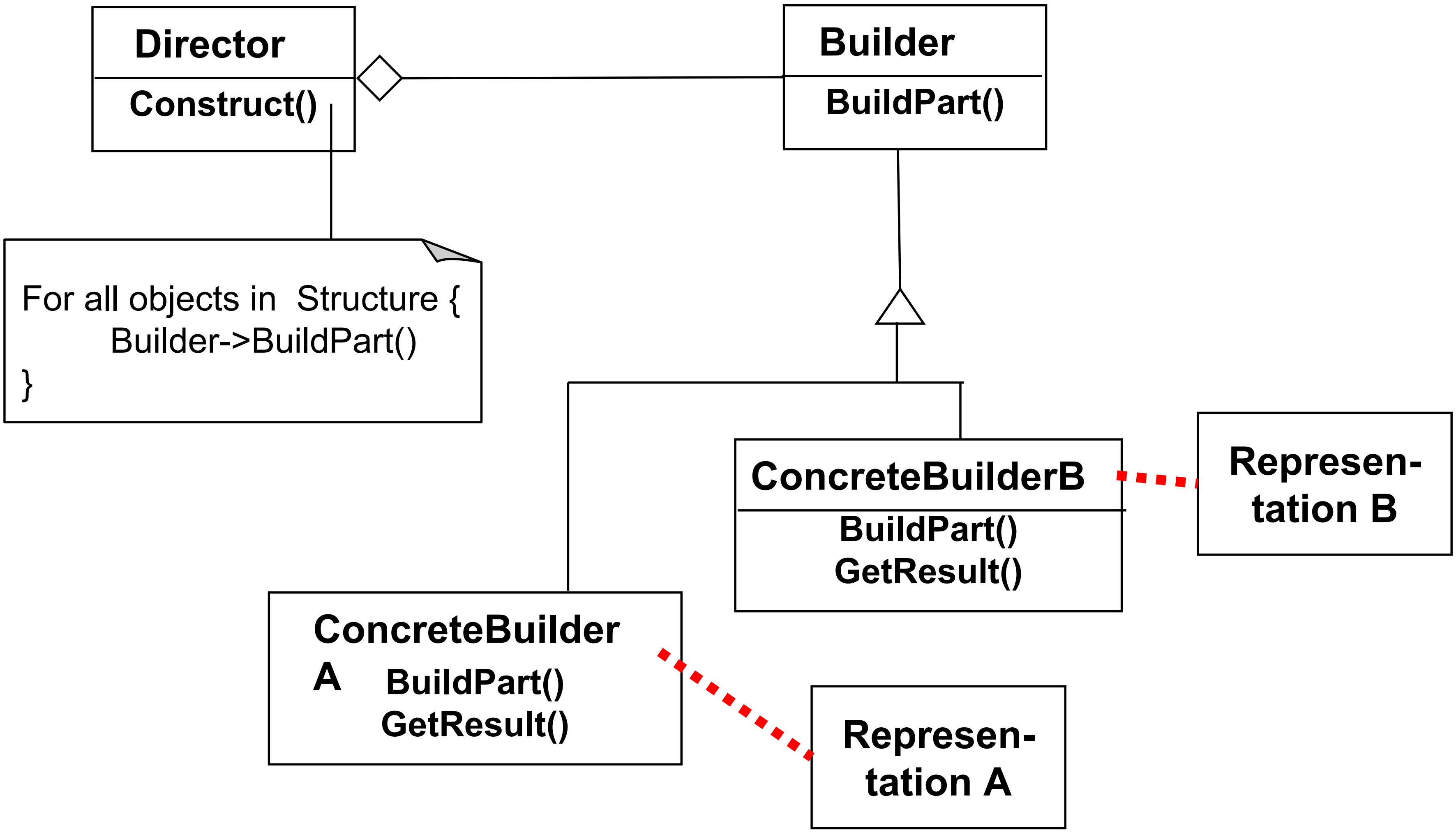
Example: A Facility Management System for the Intelligent Workplace



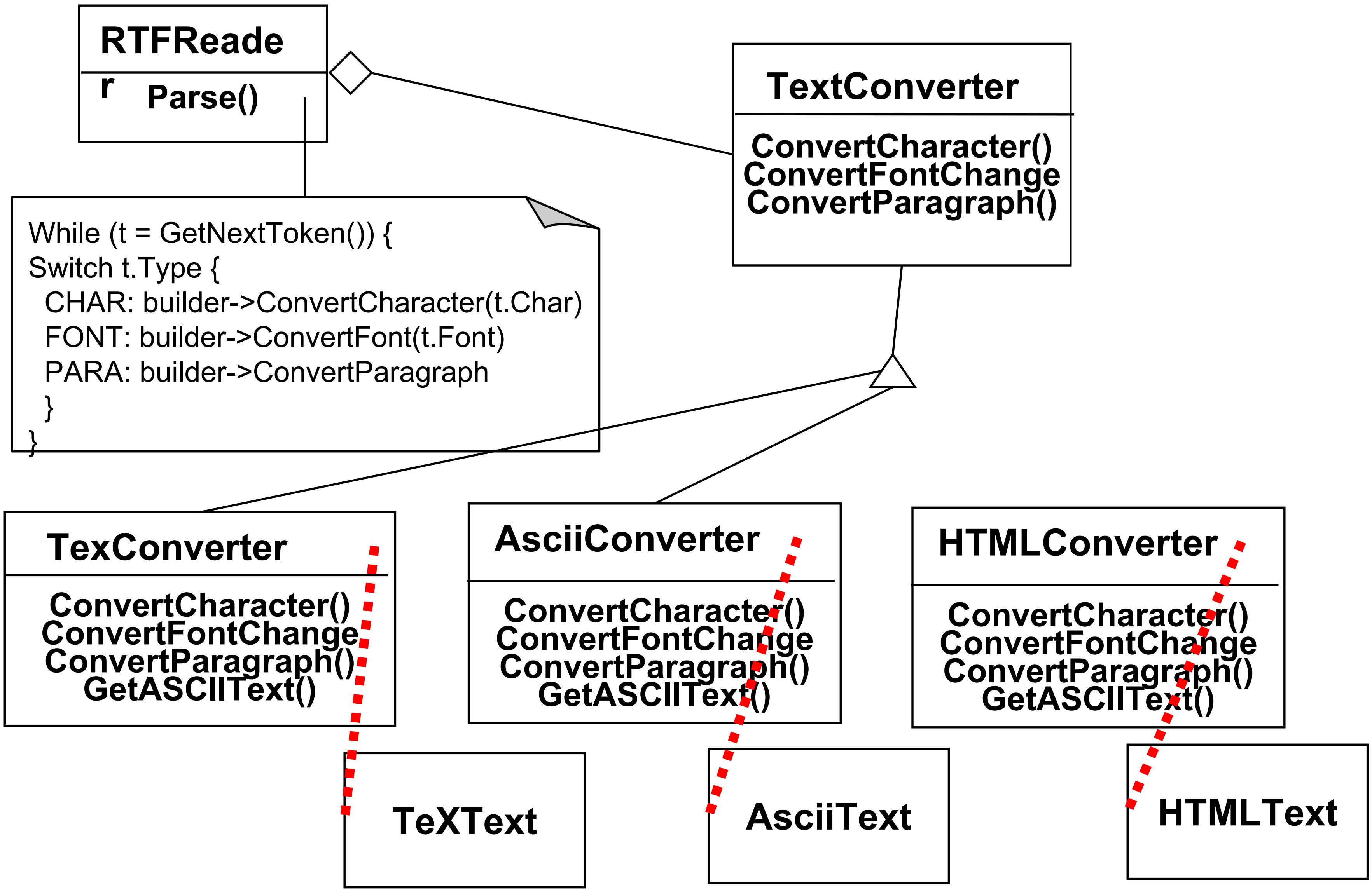
Builder Pattern Motivation

- Conversion of documents
- Software companies make their money by introducing new formats, forcing users to upgrades
  - **But you don’t want to upgrade your software every time there is an update of the format for Word documents**
- Idea: A reader for RTF format
  - **Convert RTF to many text formats (EMACS, Framemaker 4.0, Framemaker 5.0, Framemaker 5.5, HTML, SGML, WordPerfect 3.5, WordPerfect 7.0, ….)**
    - ***Problem: The number of conversions is open-ended.***
- Solution
  - **Configure the RTF Reader with a “builder” object that specializes in conversions to any known format and can easily be extended to deal with any new format appearing on the market**

Builder Pattern



Example


RTFReader
Parse()
TextConverter
ConvertCharacter()
ConvertFontChange
ConvertParagraph()
While (t = GetNextToken()) {
Switch t.Type {
CHAR: builder->ConvertCharacter(t.Char)
FONT: builder->ConvertFont(t.Font)
PARA: builder->ConvertParagraph
}
}
TexConverter
ConvertCharacter()
ConvertFontChange
ConvertParagraph()
GetASCIIText()
AsciiConverter
ConvertCharacter()
ConvertFontChange
ConvertParagraph()
GetASCIIText()
HTMLConverter
ConvertCharacter()
ConvertFontChange
ConvertParagraph()
GetASCIIText()
TeXText
AsciiText
HTMLText

When do you use the Builder Pattern?

- The creation of a complex product must be independent of the particular parts that make up the product
  - **In particular, the creation process should not know about the assembly process (how the parts are put together to make up the product)**
- The creation process must allow different representations for the object that is constructed. Examples:
  - **A house with one floor, 3 rooms, 2 hallways, 1 garage and three doors.**
  - **A skyscraper with 50 floors, 15 offices and 5 hallways on each floor. The office layout varies for each floor.**

Comparison: Abstract Factory vs Builder

- Abstract Factory
  - **Focuses on product family**
    - **The products can be simple ("light bulb") or complex ("engine")**
  - **Does not hide the creation process**
    - **The product is immediately returned**
- Builder
  - **The underlying product needs to be constructed as part of the system, but the creation is very complex**
  - **The construction of the complex product changes from time to time**
  - **The builder patterns hides the creation process from the user:**
    - **The product is returned after creation as a final step**
- Abstract Factory and Builder work well together for a family of multiple complex products

Summary I

- Object design closes the gap between the requirements and the machine.
- Object design is the process of adding details to the requirements analysis and making implementation decisions
- Object design activities include:
  - ✓ **Identification of Reuse**
  - ✓ **Identification of Inheritance and Delegation opportunities**
  - ✓ **Component selection**
- Object design is documented in the Object Design Document, which can be automatically generated from a specification using tools such as JavaDoc.

Summary II

- Design patterns are partial solutions to common problems such as
  - **such as separating an interface from a number of alternate implementations**
  - **wrapping around a set of legacy classes**
  - **protecting a caller from changes associated with specific platforms.**
- A design pattern is composed of a small number of classes
  - **use delegation and inheritance**
  - **provide a robust and modifiable solution.**
- These classes can be adapted and refined for the specific system under construction.
  - **Customization of the system**
  - **Reuse of existing solutions**

Summary III

- Composite Pattern:
  - **Models trees with dynamic width and dynamic depth**
- Facade Pattern:
  - **Interface to a subsystem**
  - **closed vs open architecture**
- Adapter Pattern:
  - **Interface to reality**
- Bridge Pattern:
  - **Interface to reality and prepare for future**

Summary IV

- Structural Patterns
  - **Focus: How objects are composed to form larger structures**
  - **Problems solved:**
    - **Realize new functionality from old functionality,**
    - **Provide flexibility and extensibility**
- Behavioral Patterns
  - **Focus: Algorithms and the assignment of responsibilities to objects**
  - **Problem solved:**
    - **Too tight coupling to a particular algorithm**
- Creational Patterns
  - **Focus: Creation of complex objects**
  - **Problems solved:**
    - **Hide how complex objects are created and put together**
- Design patterns
  - **Provide solutions to common problems.**
  - **Lead to extensible models and code.**
  - **Can be used as is or as examples of interface inheritance and delegation.**
  - **Apply the same principles to structure and to behavior.**