Software Engineering for Engineers

Object Design

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Miscellaneous

- No exercise session today
- Last week lecture was canceled. Need to revise lecture schedule.
- Next Week, May 20
  - Lecture on Design Patterns
    - Preconditions: Object Design, UML Class Diagram
    - Postconditions: Adapter Pattern, Observer Pattern

New Schedule

Week 1 April 22, 2009	UML Class Diagrams
Week 2 April, 29 2009	Testing
Week 3 May 6, 2009	cancelled
Week 4 May 13, 2009	Object Design I: Reuse
Week 5 May 20, 2009	Object Design II: Interface Specification (Contracts) & Design Patterns I
Week 6 May 27, 2009	Design Patterns II
Week 7 June 6, 2009	Requirements Elicitation and Analysis

New Schedule (cont'd)

Week 8 June, 10 2009	System Design 1
Week 9 June 17, 2009	System Design 2
Week 10 June 24, 2009	Testing 2
Week 11 July 1, 2009	Guest Speaker
Week 12 July 8, 2009	Methodologies
Week 13 July 15, 2009	XP and Scrum
Week 14 July 22, 2009	Putting everything together

Outline of Today

- Definition: Object Design
- System Design vs Object Design
- Object Design Activities
- Reuse examples
  - Whitebox and Blackbox Reuse
- Object design leads also to new classes
- Implementation vs Specification Inheritance
- Inheritance vs Delegation
- Class Libraries and Frameworks
- Exercises: Documenting the Object Design
  - JavaDoc, Doxygen

Object Design

- Purpose of object design:
  - Prepare for the implementation of the analysis model based on system design decisions
  - Transform analysis and system design models
- Investigate alternative ways to implement the analysis model
  - Use design goals: minimize execution time, memory and other measures of cost.
- Object Design serves as the basis of implementation

Terminology: Naming of Design Activities

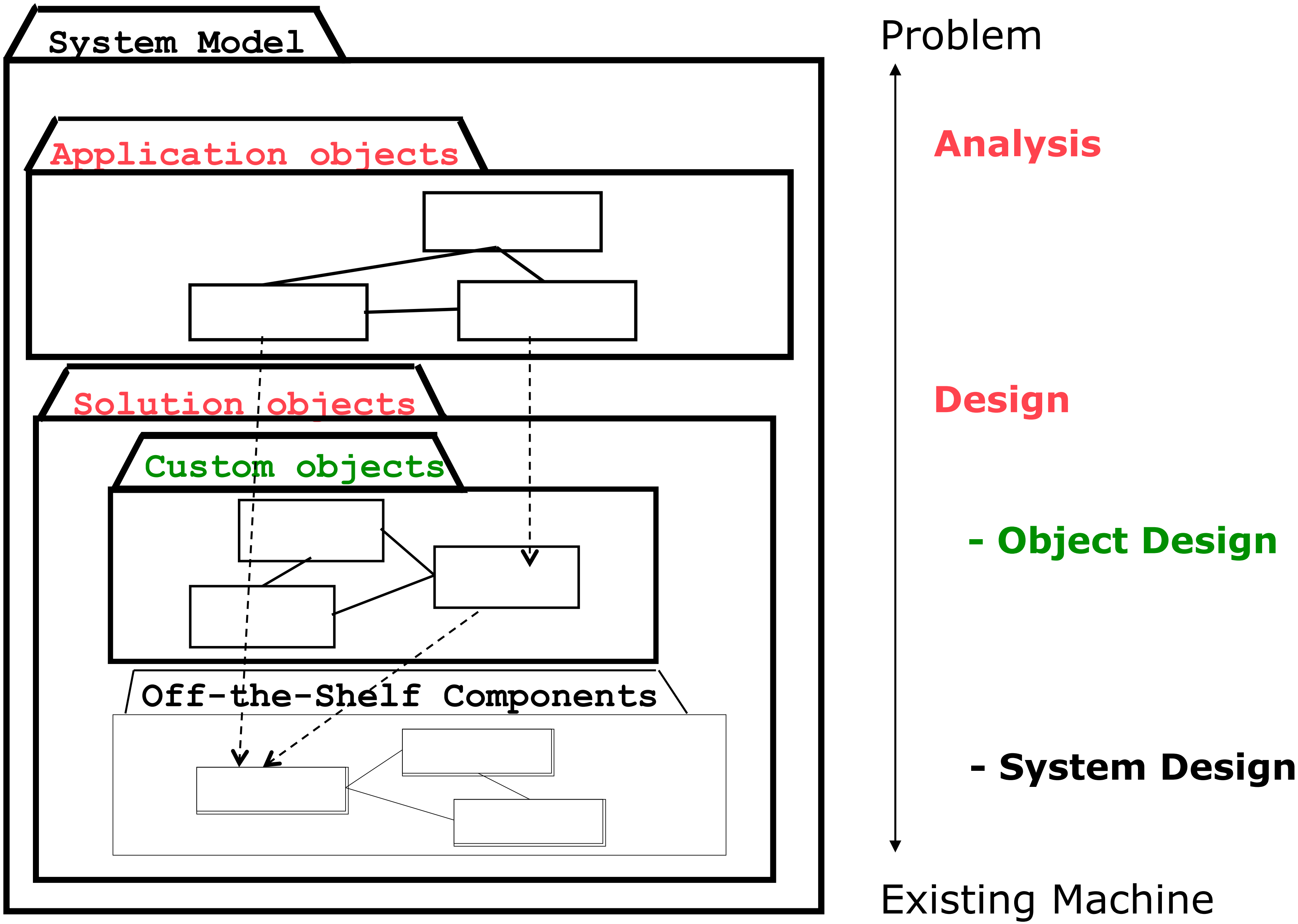
Methodology: Object-oriented software engineering (OOSE)

- *System Design*
  - Subsystem Decomposition, Concurrency, HW-SW mapping, Access Control
- *Object Design*
  - Data structures and algorithms chosen
- *Implementation*
  - Implementation language is chosen

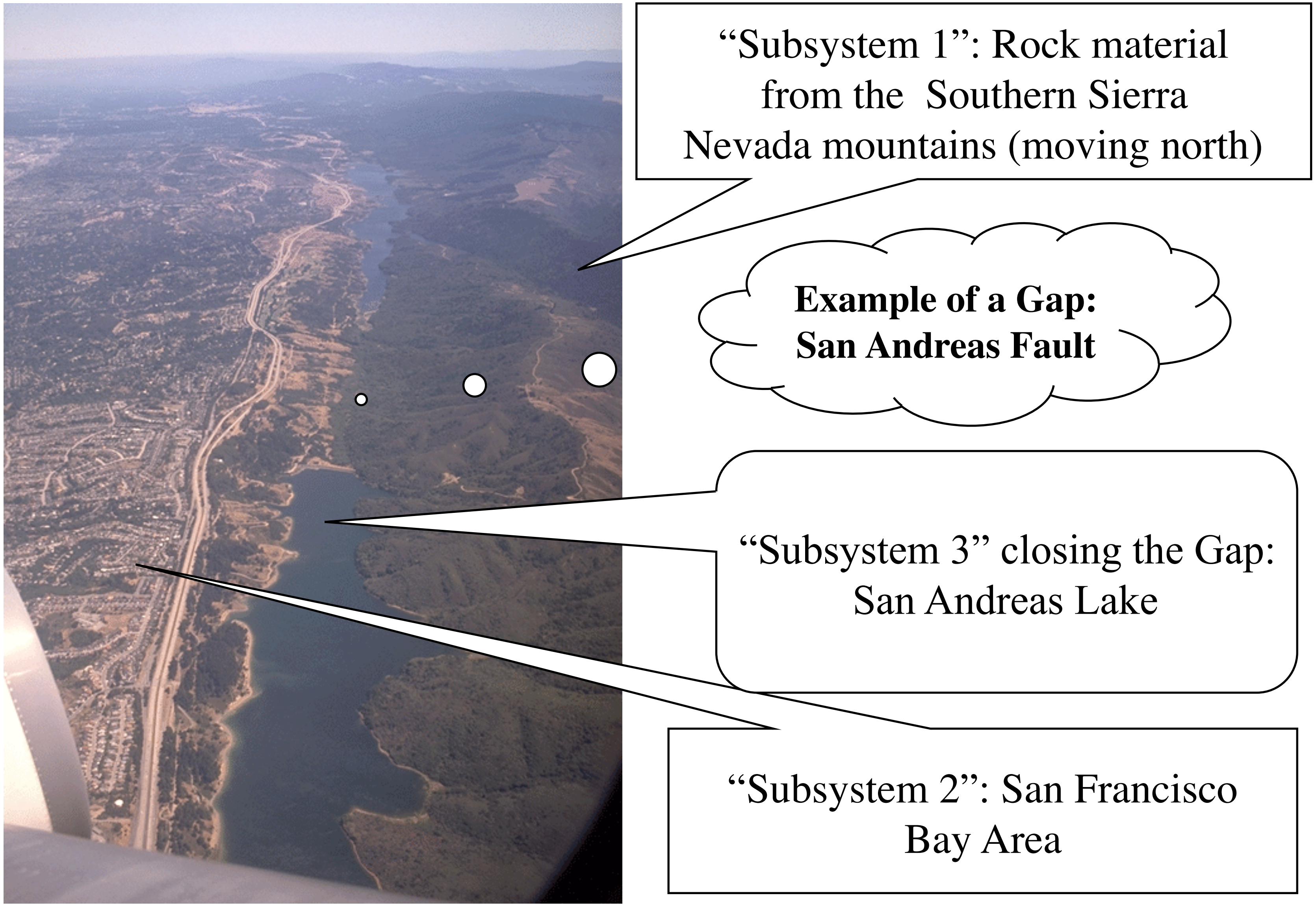
Methodology: Structured analysis/structured design (SA/SD)

- *Preliminary Design*
  - Decomposition into subsystems, etc
  - Data structures are chosen
- *Detailed Design*
  - Algorithms are chosen
  - Data structures are refined
  - Implementation language is chosen.

System Development as a Set of Activities



Design means “Closing the Gap”



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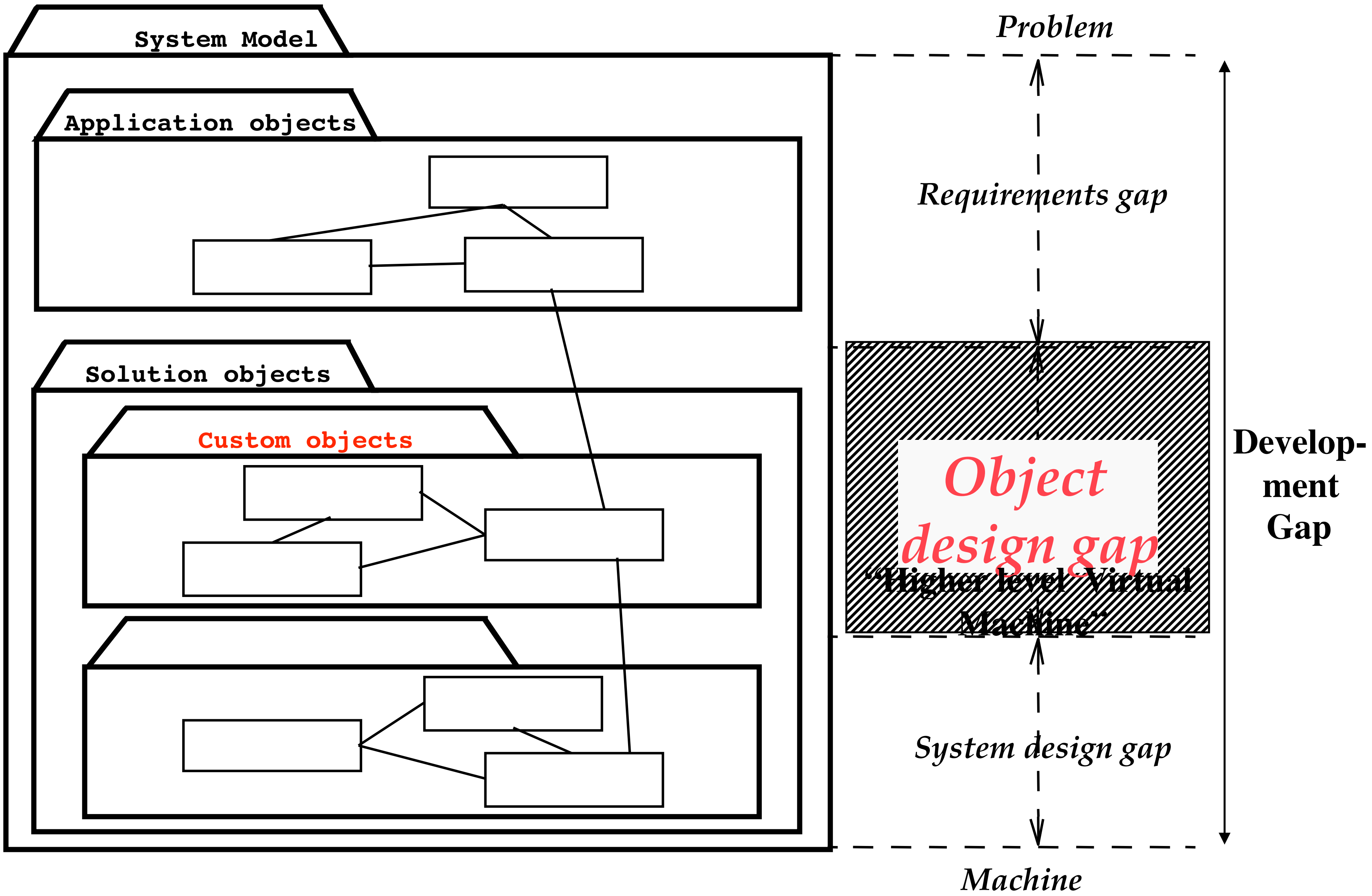


Object Design consists of 4 Activities

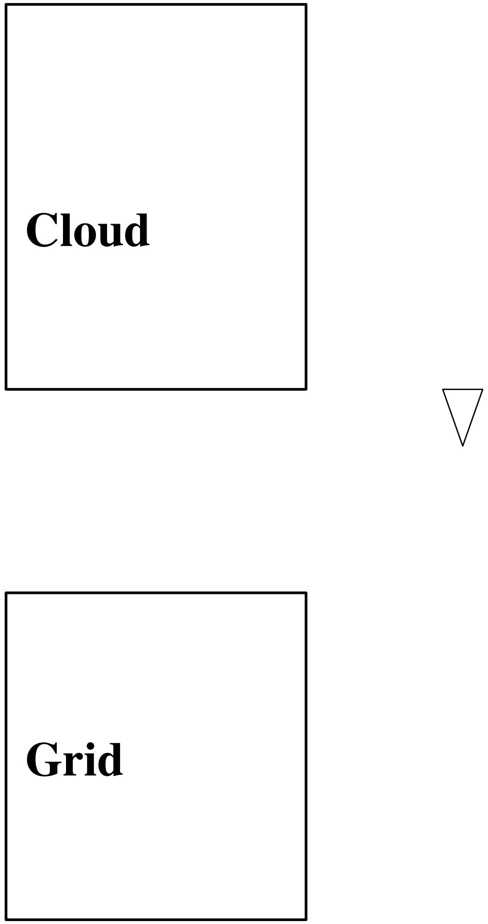
1. Reuse: Identification of existing solutions
   - Use of inheritance
   - Off-the-shelf components and additional solution objects
   - Design patterns (Adapter, etc)
2. Interface specification
   - Describes precisely each class interface
3. Object model restructuring
   - Transforms the object design model to improve its understandability and extensibility
4. Object model optimization
   - Transforms the object design model to address performance criteria such as response time or memory utilization.

Today's Lecture

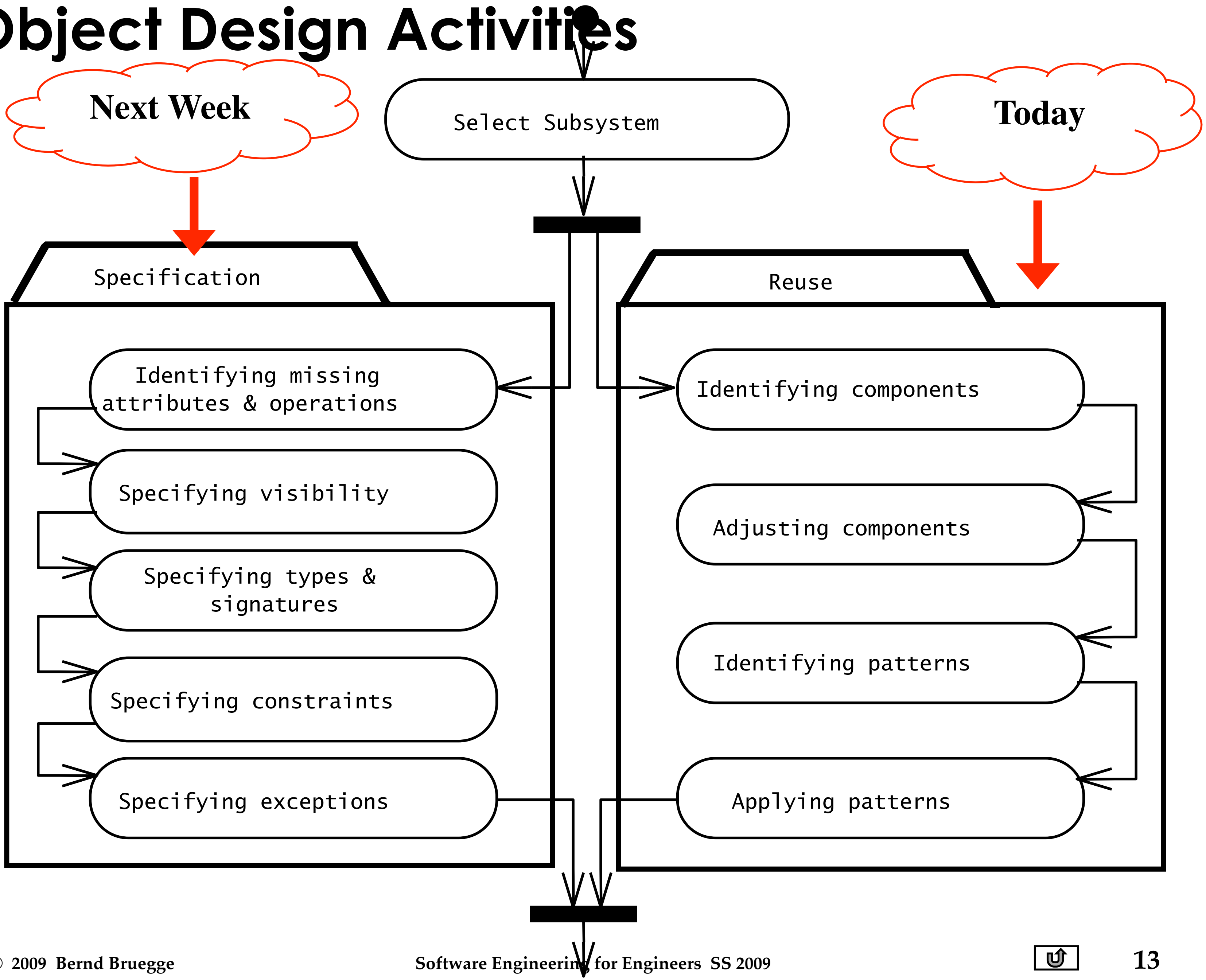
Next week Lecture

Ch 10

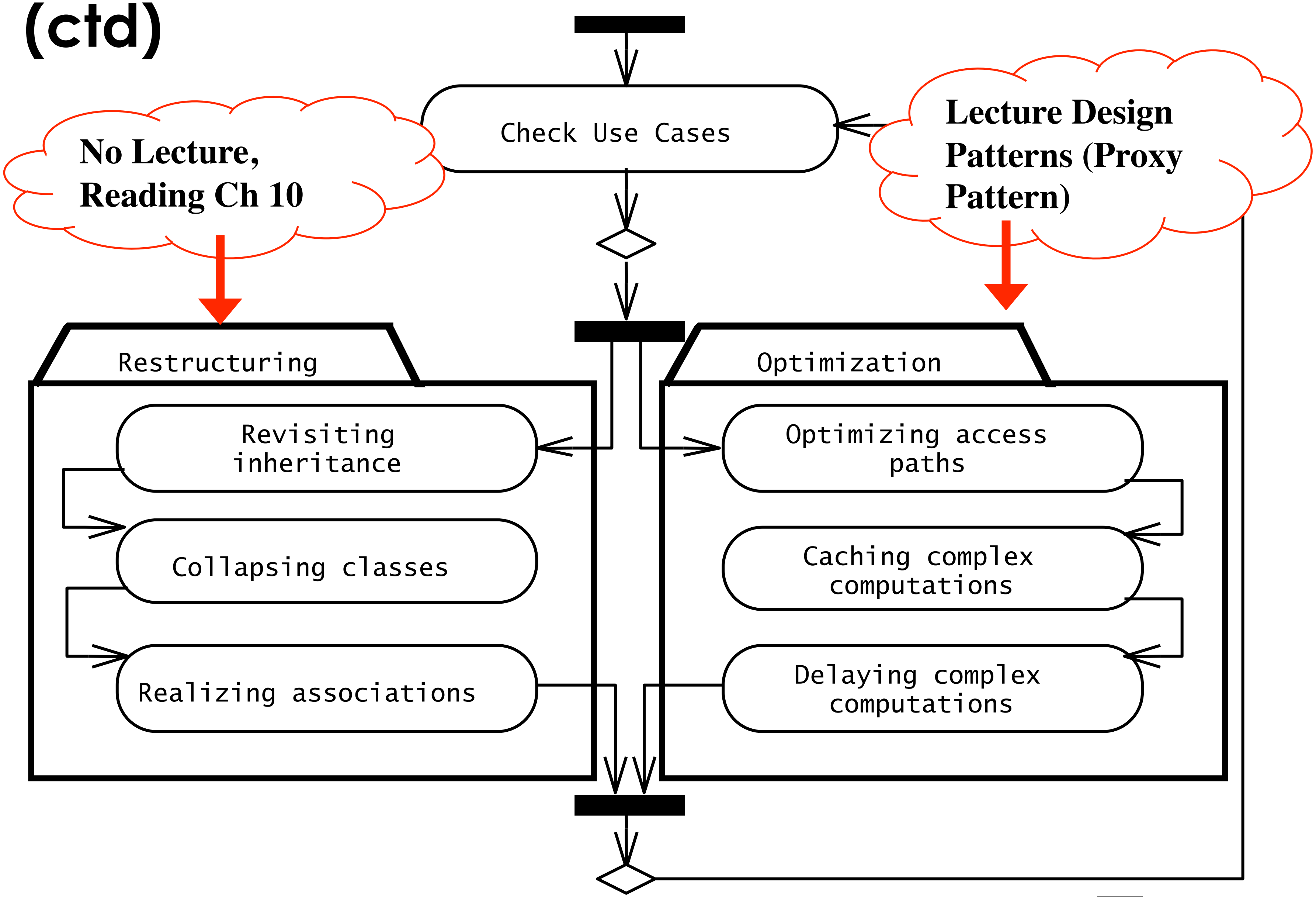
More Design Patterns


Cloud
Grid

Object Design Activities



Detailed View of Object Design Activities (ctd)



One Way to do Object Design

1. Identify the missing components in the design gap
2. Make a build or buy decision to obtain the missing component

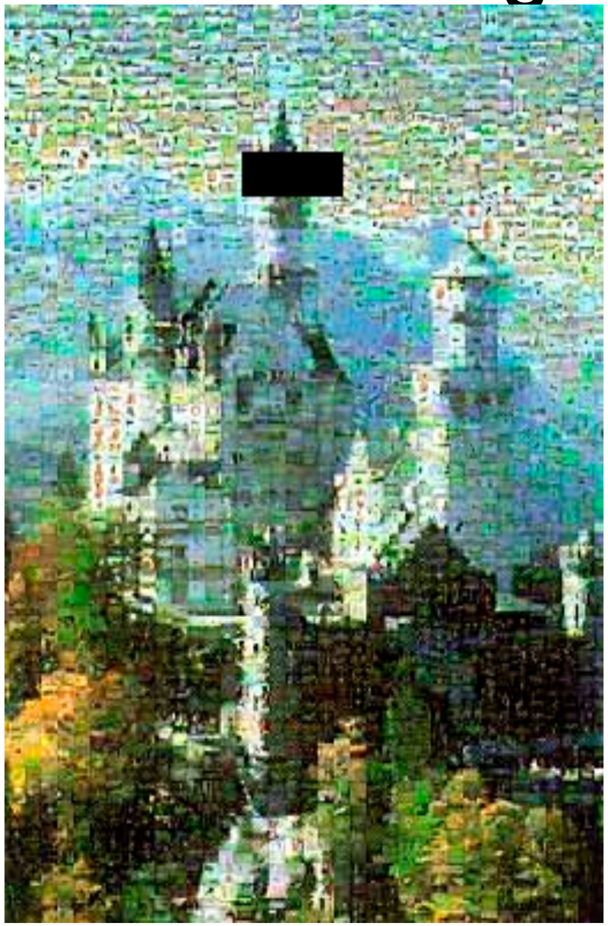
=> Component-Based Software Engineering:

The design gap is filled with available components ("0 % coding").

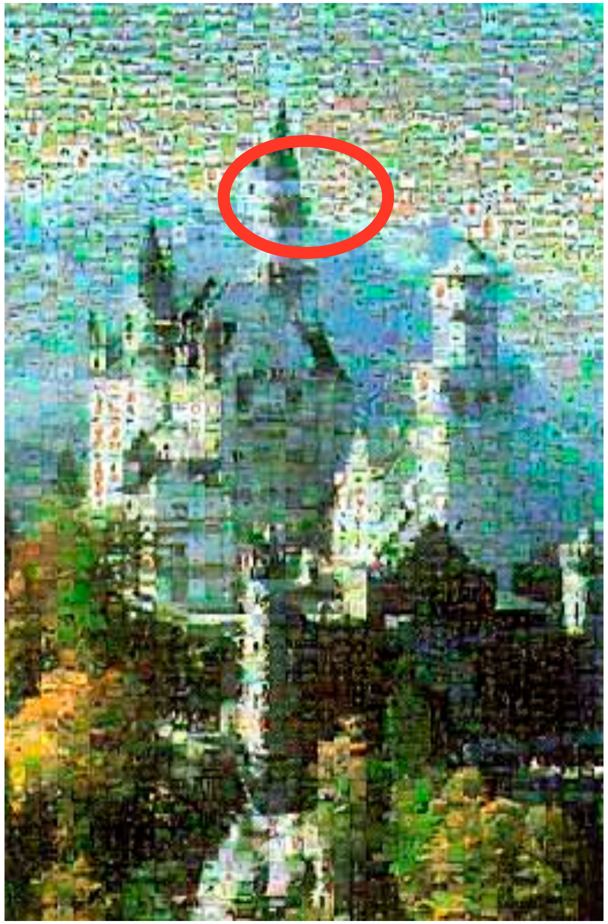
- Special Case: COTS-Development
  - COTS: Commercial-off-the-Shelf
  - The design gap is completely filled with commercial-off-the-shelf-components.

=> Design with standard components.

Design with Standard Components is like solving a Traditional Jigsaw Puzzle



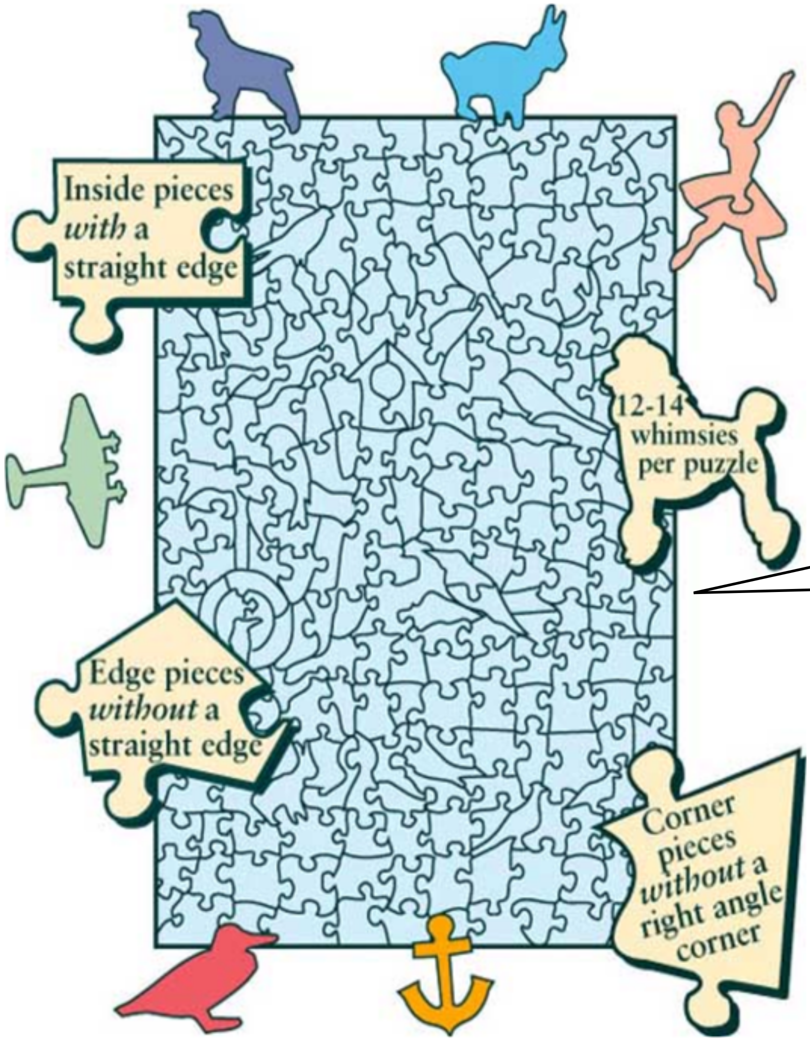
Remaining puzzle piece ("component")



Design Activities:

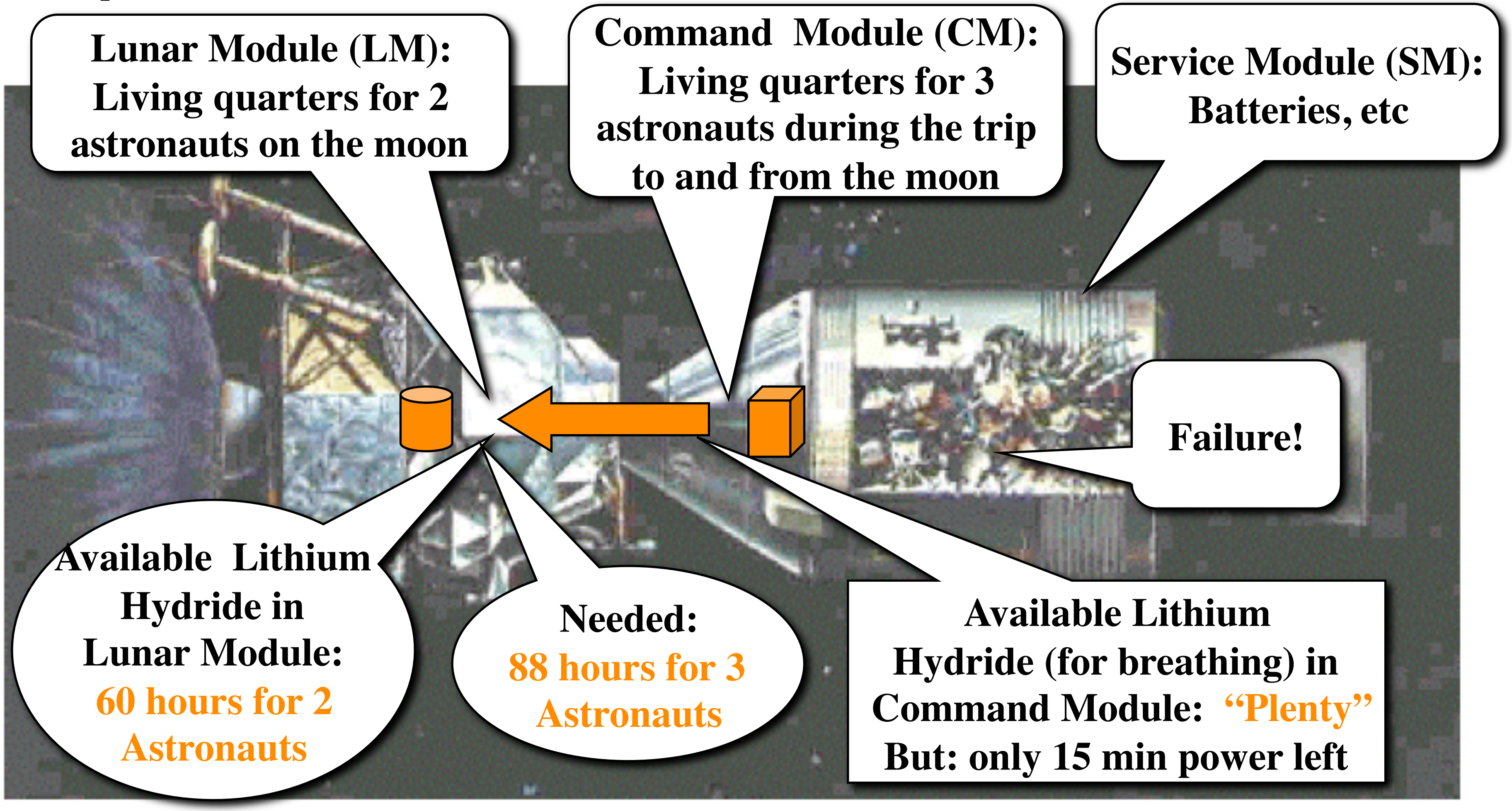
1. Identify the missing components
2. Make a build or buy decision to get the missing component.

What do we do if we have non-Standard Components?



Advanced
Jigsaw Puzzles

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



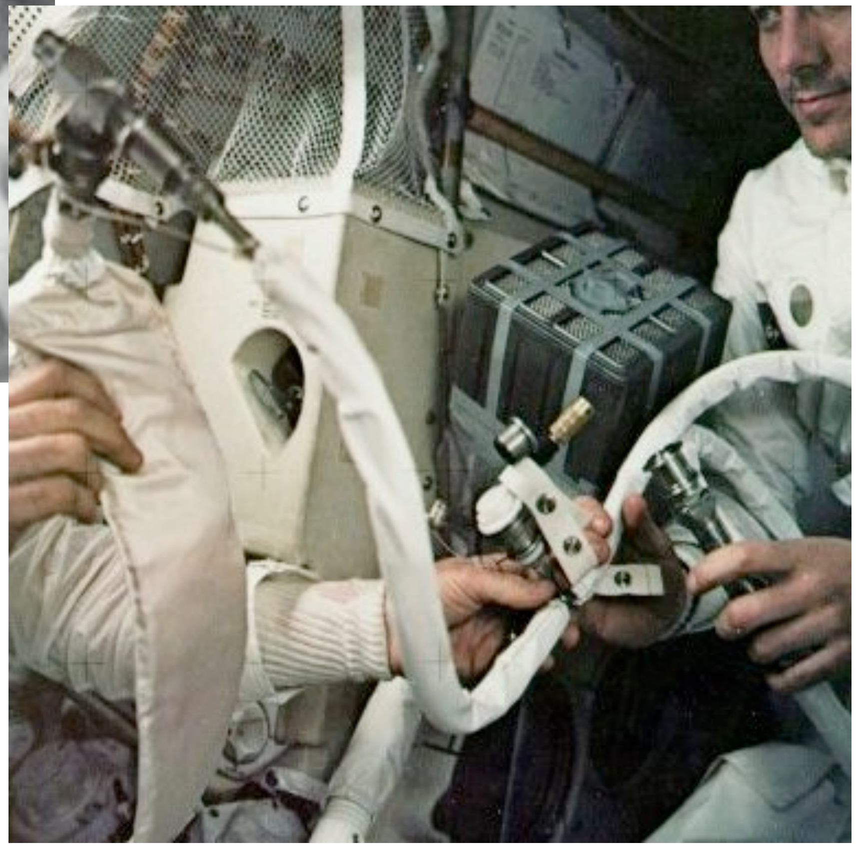
The LM was designed for 60 hours for 2 astronauts staying 2 days on the moon

Redesign challenge: Can the LM be used for 12 man-days (2 1/2 days until reentry into Earth)?

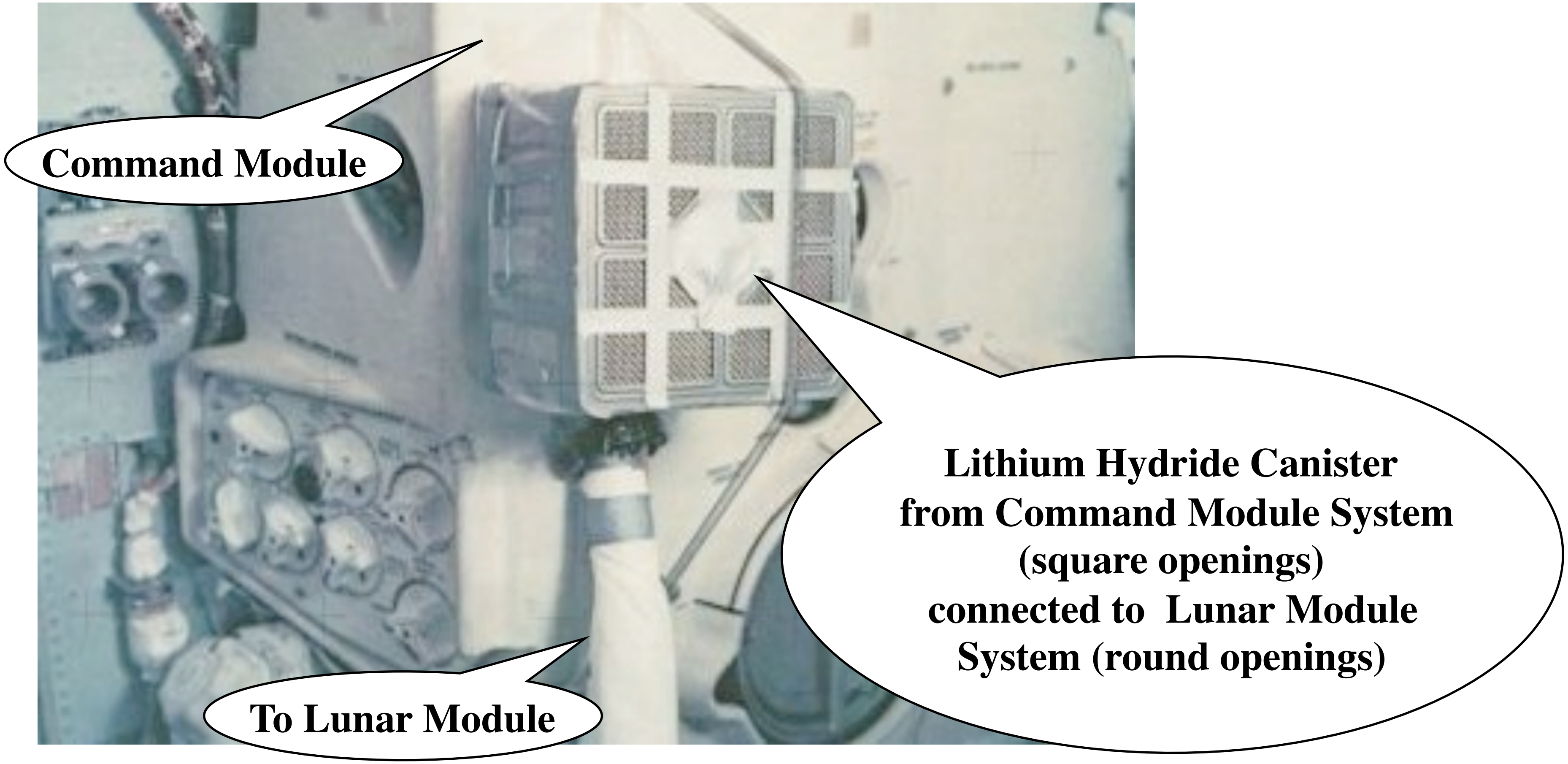
Proposal: Reuse Lithium Hydride Canisters from CM in LM

Problem: Incompatible openings in Lithium Hydride Canisters

Apollo 13: "Fitting a square peg in a round hole"



A Typical Object Design Challenge: Connecting Incompatible Components

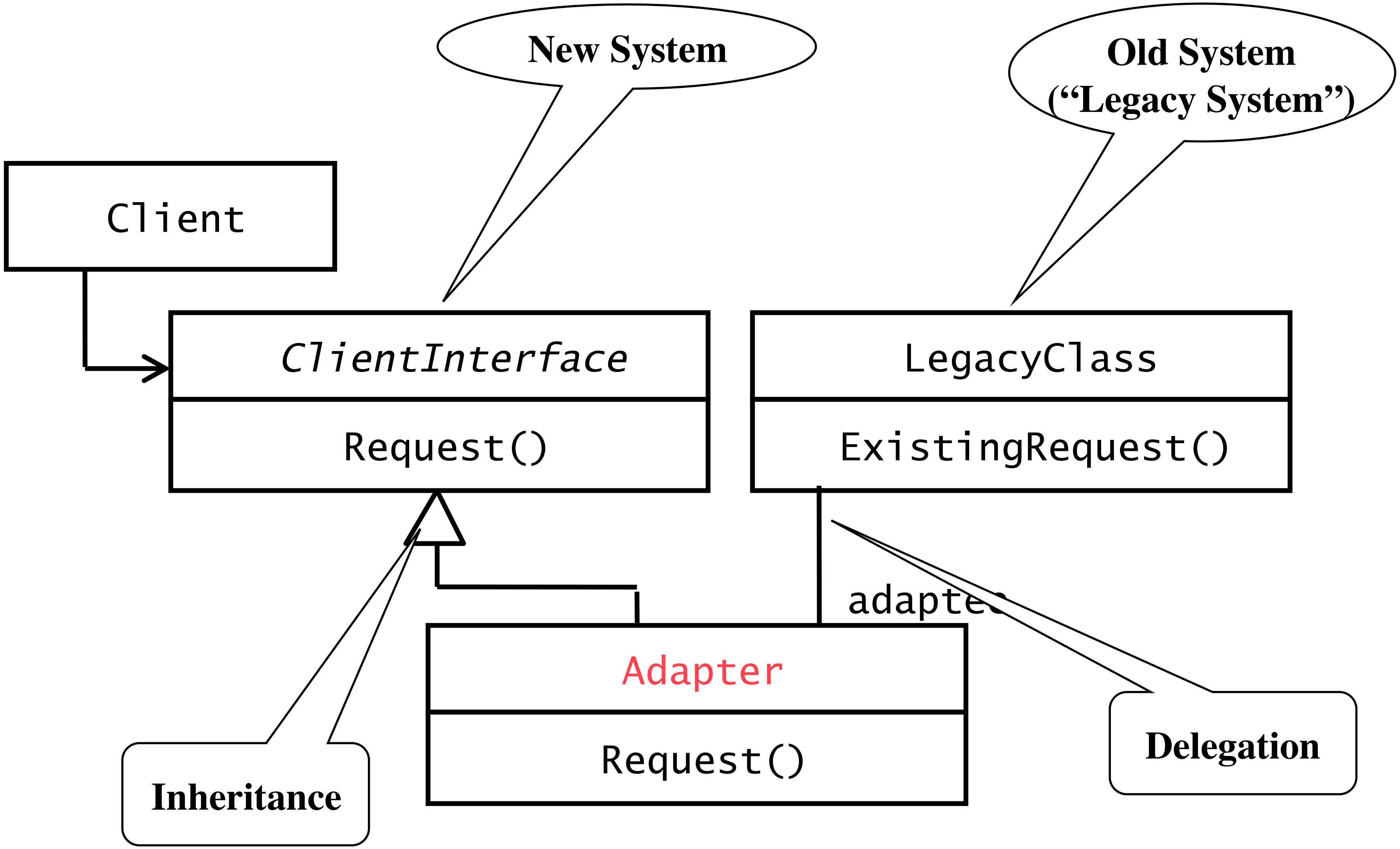


Source: http://www.hq.nasa.gov/office/pao/History/SP-350/ch-13-4.html

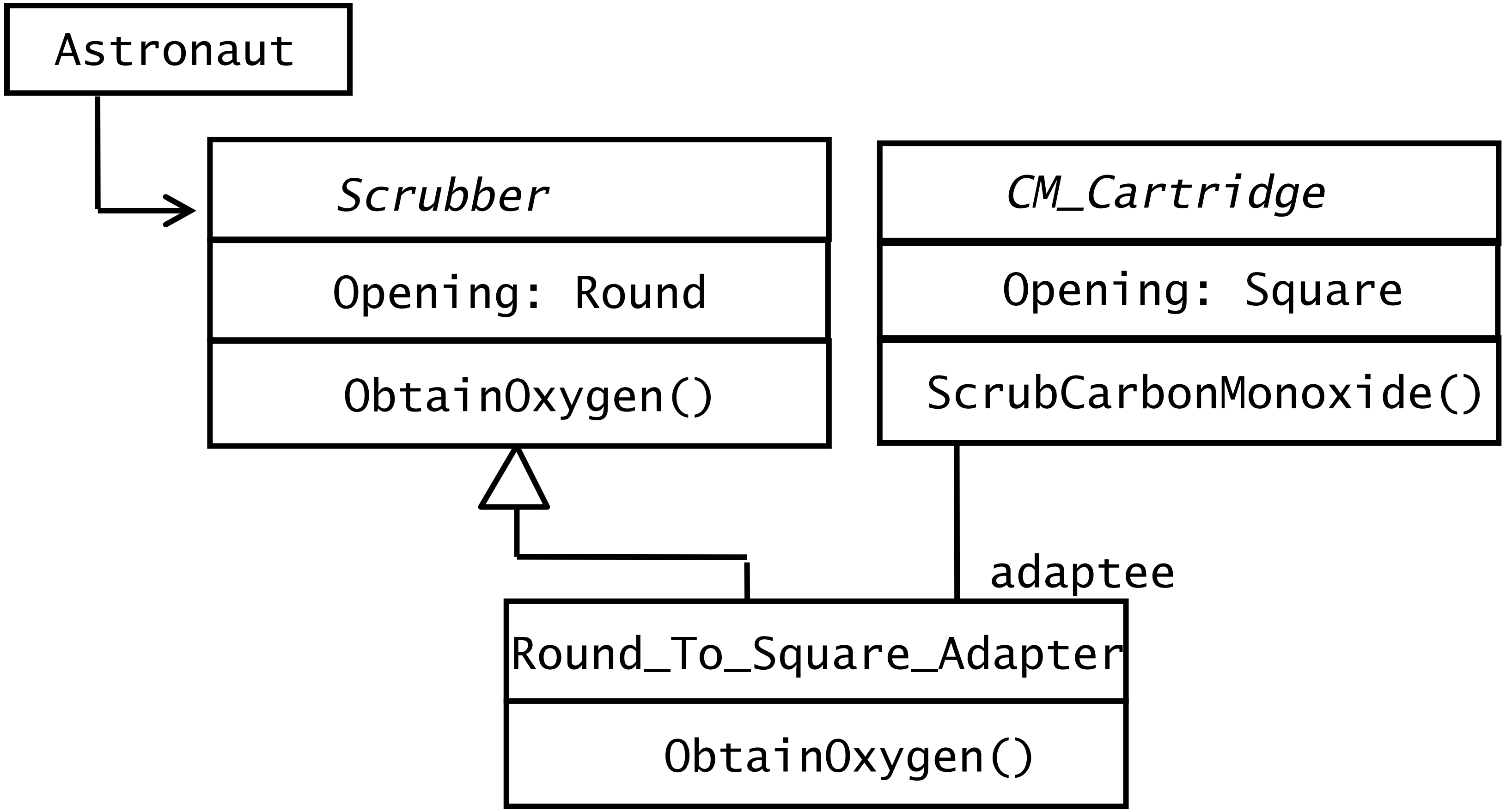
Adapter Pattern

- Adapter Pattern: Converts the interface of a component into another interface expected by the calling component
- 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
    - Introduced in this lecture.

Adapter Pattern



Adapter for Scrubber in Lunar Module



- Using a carbon monoxide scrubber (round opening) in the lunar module with square cartridges from the command module (square opening)

Modeling of the Real World

- Modeling of the real world leads to a system that reflects today's realities but not necessarily tomorrow's.
- There is a need for *reusable* and flexible designs
- Design knowledge such as the adapter pattern complements application domain knowledge and solution domain knowledge.

Typical of Object Design Activities

- Identifying possibilities of reuse
  - Identification of existing components
- Full definition of associations
- Full definition of classes
  - System Design => Service, Object Design => API
- Specifying contracts for each component
  - OCL (Object Constraint Language)
- Choosing algorithms and data structures
- Detection of solution-domain classes
- Optimization
- Increase of inheritance
- Decision on control
- Packaging

Reuse of Code

- I have a list, but my customer would like to have a stack
  - The list offers the operations Insert(), Find(), Delete()
  - The stack needs the operations Push(), Pop() and Top()
  - Can I reuse the existing list?
- I am an employee in a company that builds cars with expensive car stereo systems. Can I reuse the existing car software in a home stero system?

Reuse of interfaces

- I am an off-shore programmer in Hawaii. I have a contract to implement an electronic parts catalog for DaimlerChrysler
  - How can I and my contractor be sure that I implement it correctly?
- I would like to develop a window system for Linux that behaves the same way as in Windows
  - How can I make sure that I follow the conventions for Windows XP windows and not those of MacOS X?
- I have to develop a new service for cars, that automatically call a help center when the car is used the wrong way.
  - Can I reuse the help desk software that I developed for a company in the telecommuniction industry?

Reuse of existing classes

- I have an implementation for a list of elements vom Typ int
- How can I reuse this list without major effort to build a list of customers, or a spare parts catalog or a flight reservation schedule?
- Can I reuse a class “Addressbook”, which I have developed in another project, as a subsystem in my commercially obtained proprietary e-mail program?
  - Can I reuse this class also in the billing software of my dealer management system?

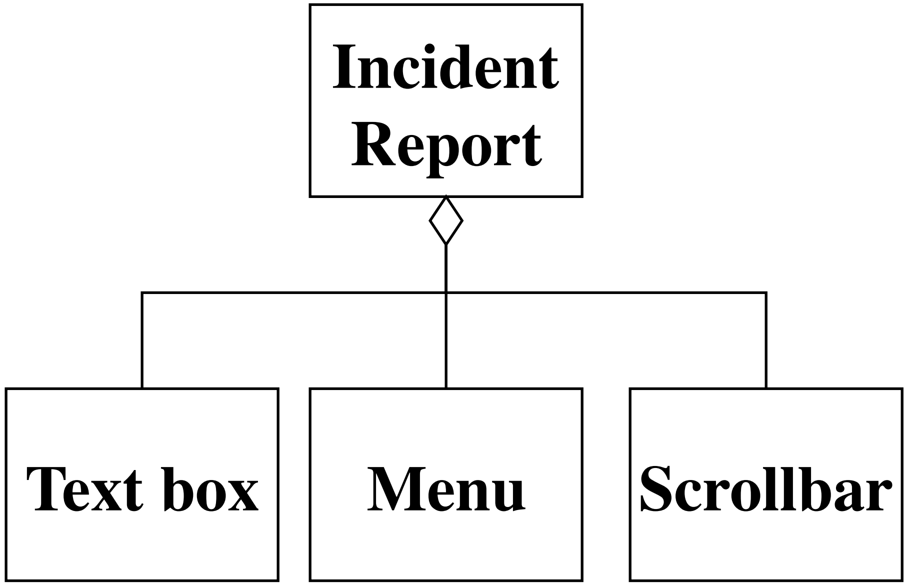
Reuse

- Problem: Close the object design gap to develop new functionality
- Design goal:
  - Reuse knowledge from previous experience
  - Reuse functionality already available
- Composition (also called Black Box Reuse)
  - New functionality is obtained by aggregation
  - The new object with more functionality is an aggregation of existing objects
- Inheritance (also called White-box Reuse)
  - New functionality is obtained by inheritance
- In both cases: Identification of new classes

Identification of new Classes during Object Design

Requirements Analysis (Language of Application Domain)

Object Design (Language of Solution Domain)



Other Reasons for new Classes

- The implementation of algorithms may necessitate objects to hold values
- New low-level operations may be needed during the decomposition of high-level operations
- Example: `EraseArea()` in a drawing program
  - Conceptually very simple
  - Implementation is complicated:
    - `Area` represented by pixels
    - We need a `Repair()` operation to clean up objects partially covered by the erased area
    - We need a `Redraw()` operation to draw objects uncovered by the erasure
    - We need a `Draw()` operation to erase pixels in background color not covered by other objects.

White Box and Black Box Reuse

- White box reuse
  - Access to the development products (models, system design, object design, source code) must be available
- Black box reuse
  - Access to models and designs is not avaliable, or models do not exist
    - Worst case: Only executables (binary code) are available
    - Better case: A specification of the system interface is available.

Types of Whitebox Reuse

1. Implementation inheritance
    - Reuse of Implementations
2. Specification Inheritance
    - Reuse of Interfaces

- Programming concepts to achieve reuse
    - ➢ Inheritance
    - Delegation
    - Abstract classes and Method Overriding
    - Interfaces

Why Inheritance?

1. Organization (during analysis):
   - Inheritance helps us with the construction of taxonomies to deal with the application domain
     - when talking the customer and application domain experts we usually find already existing taxonomies
2. Reuse (during object design):
   - Inheritance helps us to reuse models and code to deal with the solution domain
     - when talking to developers

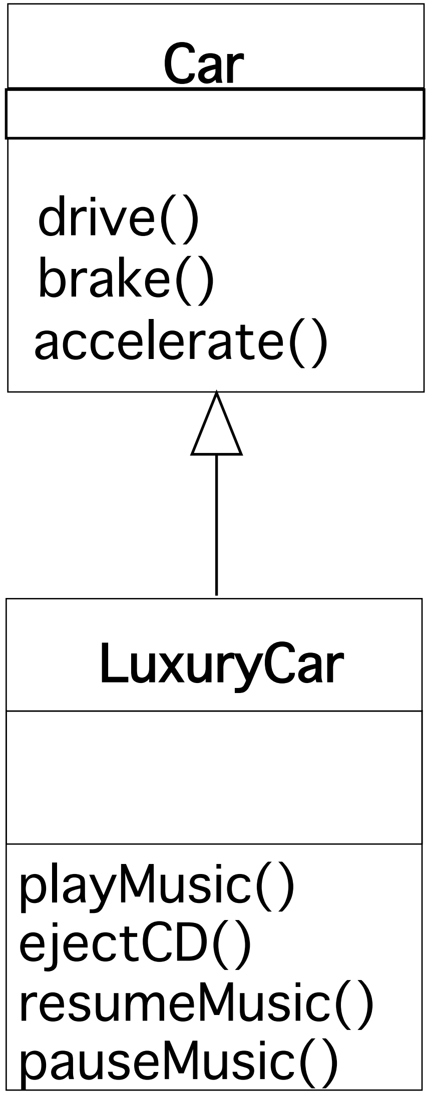
The use of Inheritance

- Inheritance is used to achieve two different goals
  - Description of Taxonomies
  - Interface Specification
- Description of taxonomies
  - Used during *requirements analysis*
  - Activity: identify application domain objects that are hierarchically related
  - Goal: make the analysis model more understandable
- Interface specification
  - Used during *object design*
  - Activity: identify the signatures of all identified objects
  - Goal: increase reusability, enhance modifiability and extensibility

Inheritance can be used during Modeling as well as during Implementation

- Starting Point is always the requirements analysis phase:
  - We start with use cases
  - We identify existing objects (“class identification“)
  - We investigate the relationship between these objects; “Identification of associations“:
    - general associations
    - aggregations
    - inheritance associations.

Example of Inheritance in a Taxonomy



Superclass:

```
public class Car {
    public void drive() {…}
    public void brake() {…}
    public void accelerate() {…}
}
```

Subclass:

```
public class LuxuryCar extends Car
{
    public void playMusic() {…}
    public void ejectCD() {…}
    public void resumeMusic() {…}
    public void pauseMusic() {…}
}
```

Inheritance comes in many Flavors

The term Inheritance is used in four different ways:

- Specialization
- Generalization
- Specification Inheritance
- Implementation Inheritance.

Discovering Inheritance

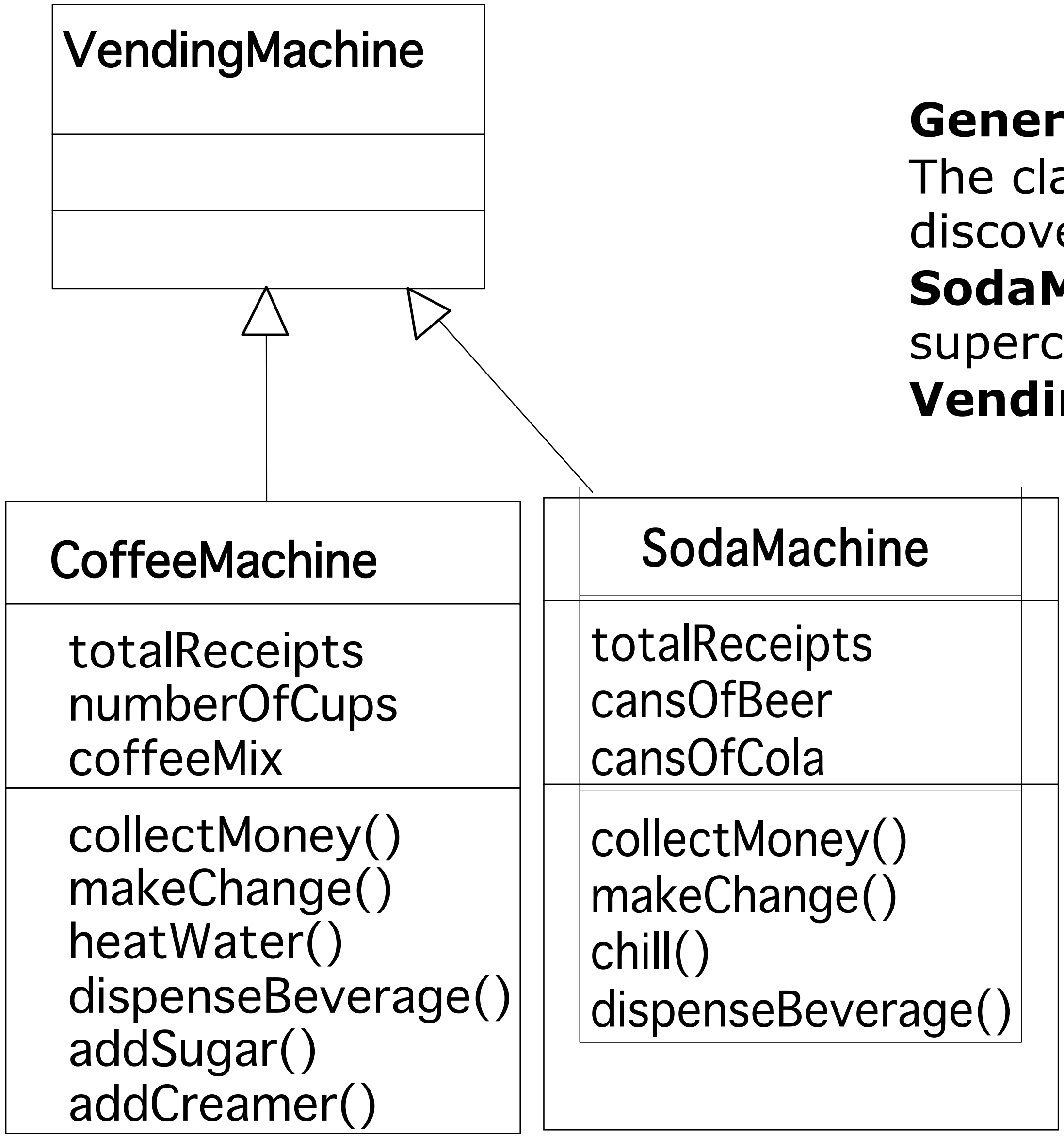
- To "discover" inheritance associations, we can proceed in two ways, which we call specialization and generalization

- Generalization: the discovery of an inheritance relationship between two classes, where the sub class is discovered first.
- Specialization: the discovery of an inheritance relationship between two classes, where the super class is discovered first.

Generalization

- First we find the subclass, then the super class
- This type of discovery occurs often in science

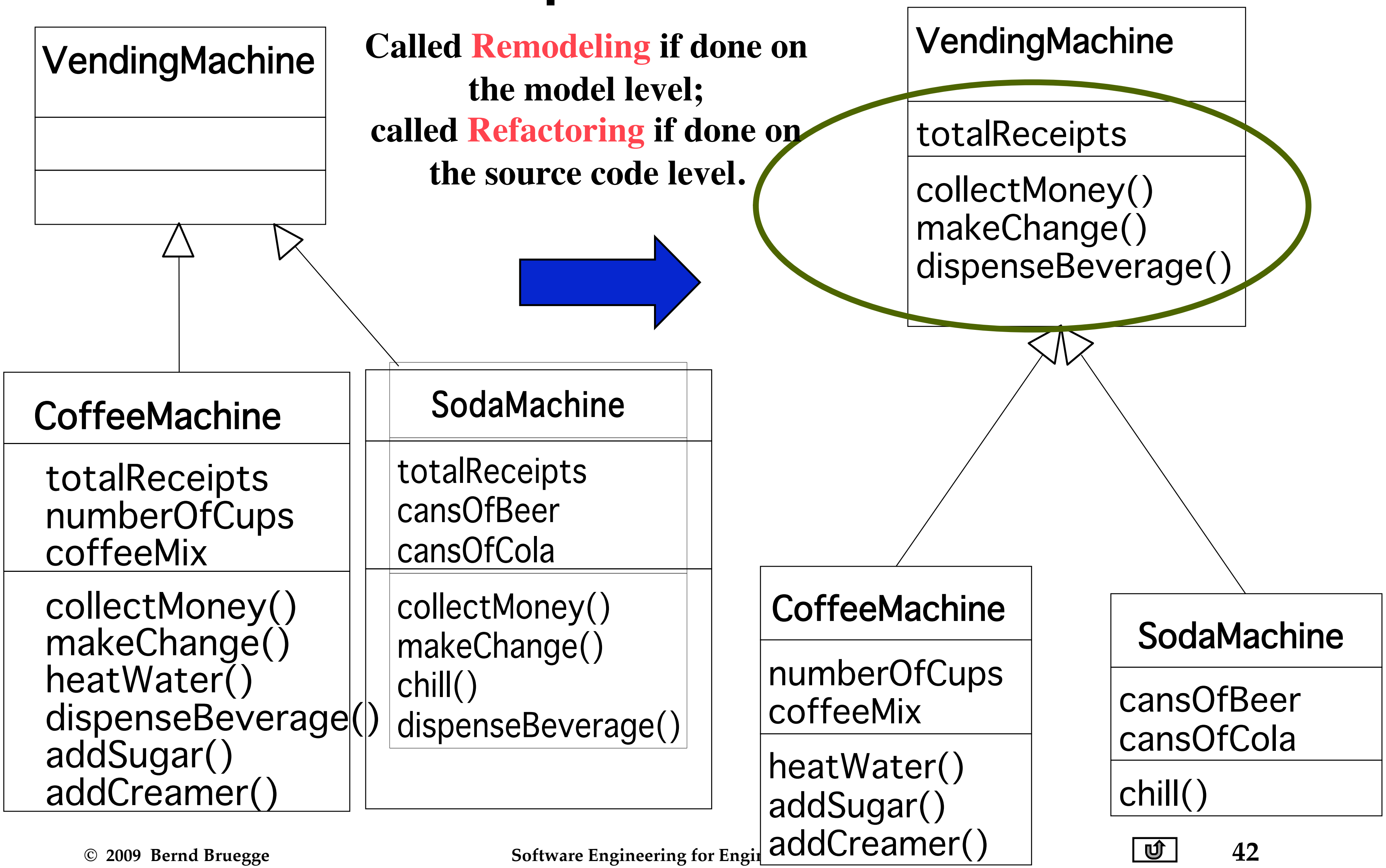
Generalization Example: Modeling a Coffee Machine



Generalization:
The class **CoffeeMachine** is discovered first, then the class **SodaMachine**, then the superclass **VendingMachine**

Restructuring of Attributes and Operations is often a Consequence of Generalization

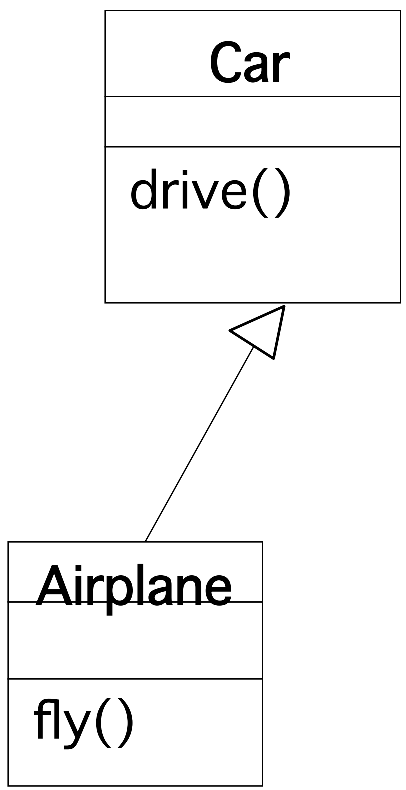
Called Remodeling if done on the model level; called Refactoring if done on the source code level.

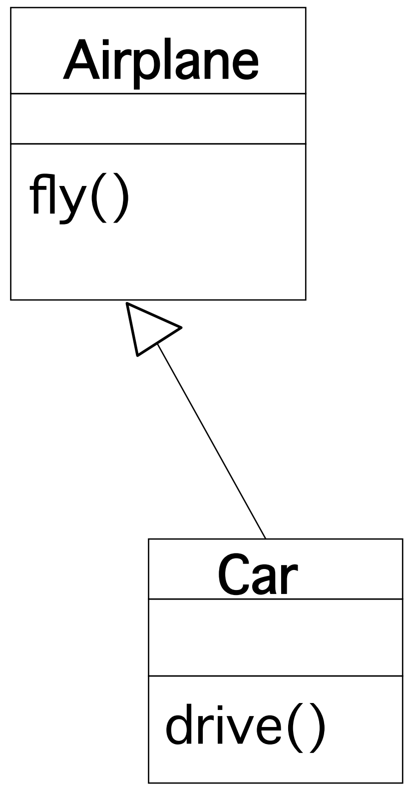


Specialization

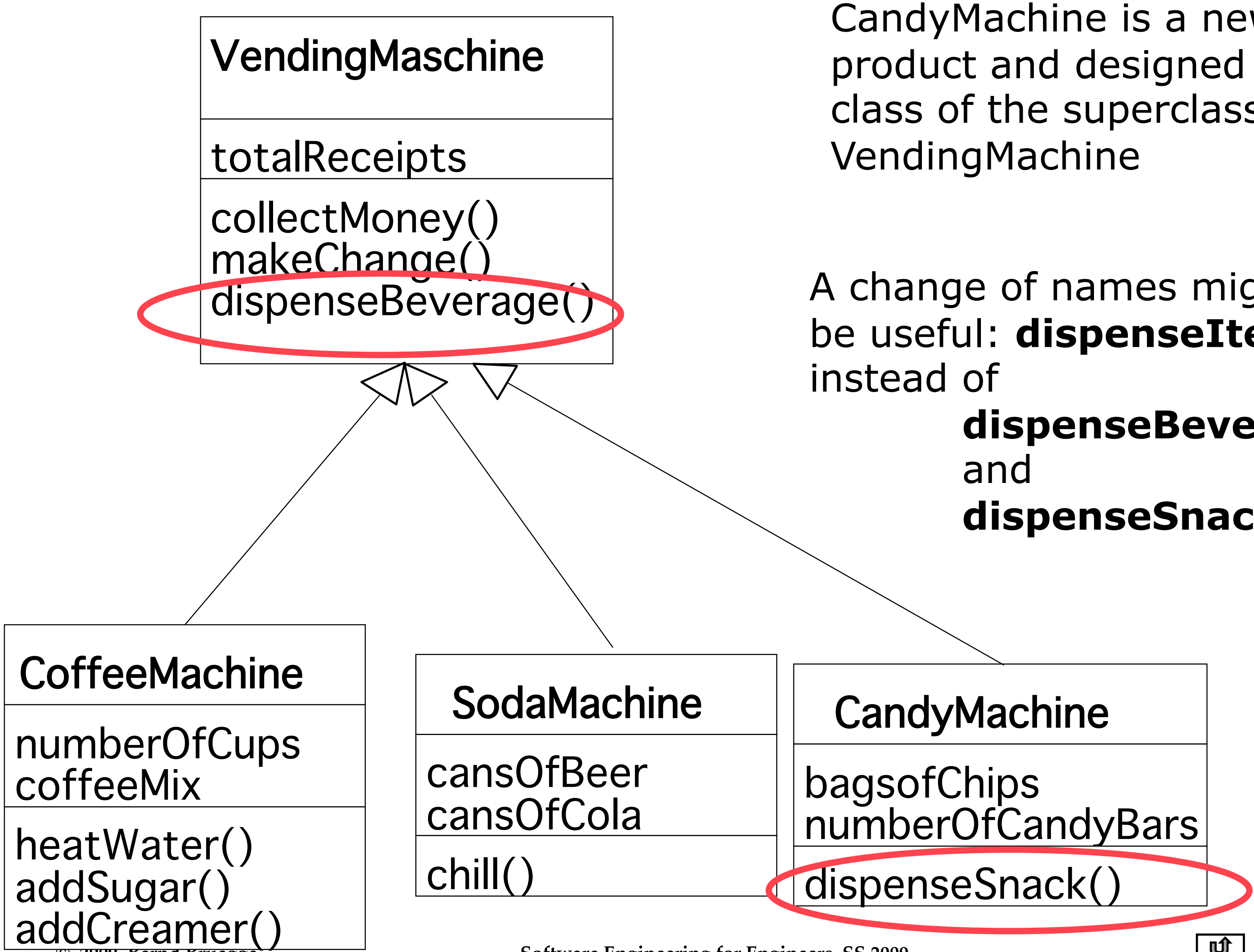
- Specialization occurs, when we find a subclass that is very similar to an existing class.
  - Example: A theory postulates certain particles and events which we have to find.
- Specialization can also occur unintentionally:

Which Taxonomy models the scenario in the previous Slide?





Another Example of a Specialization

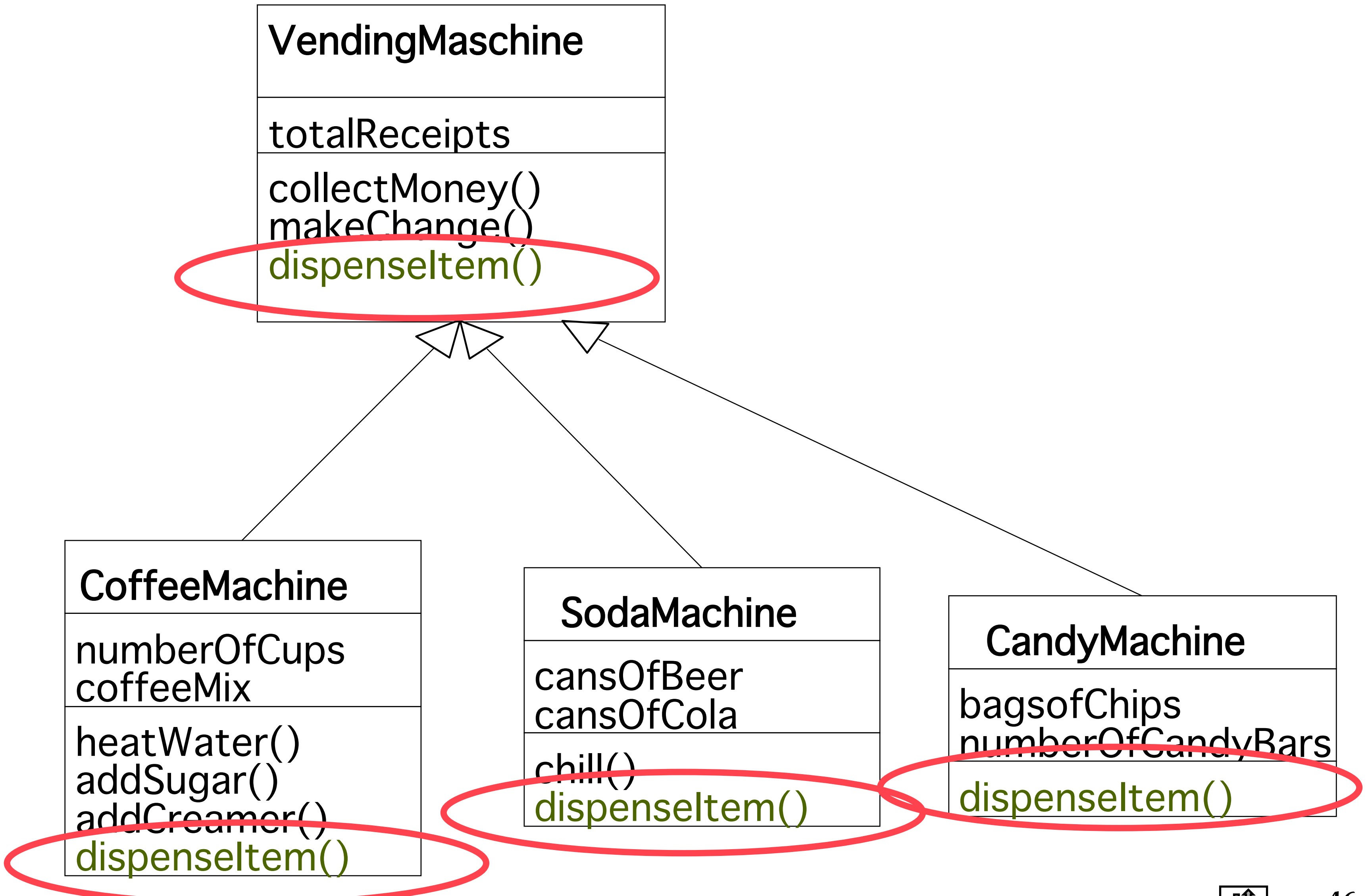


CandyMachine is a new product and designed as a sub class of the superclass VendingMachine

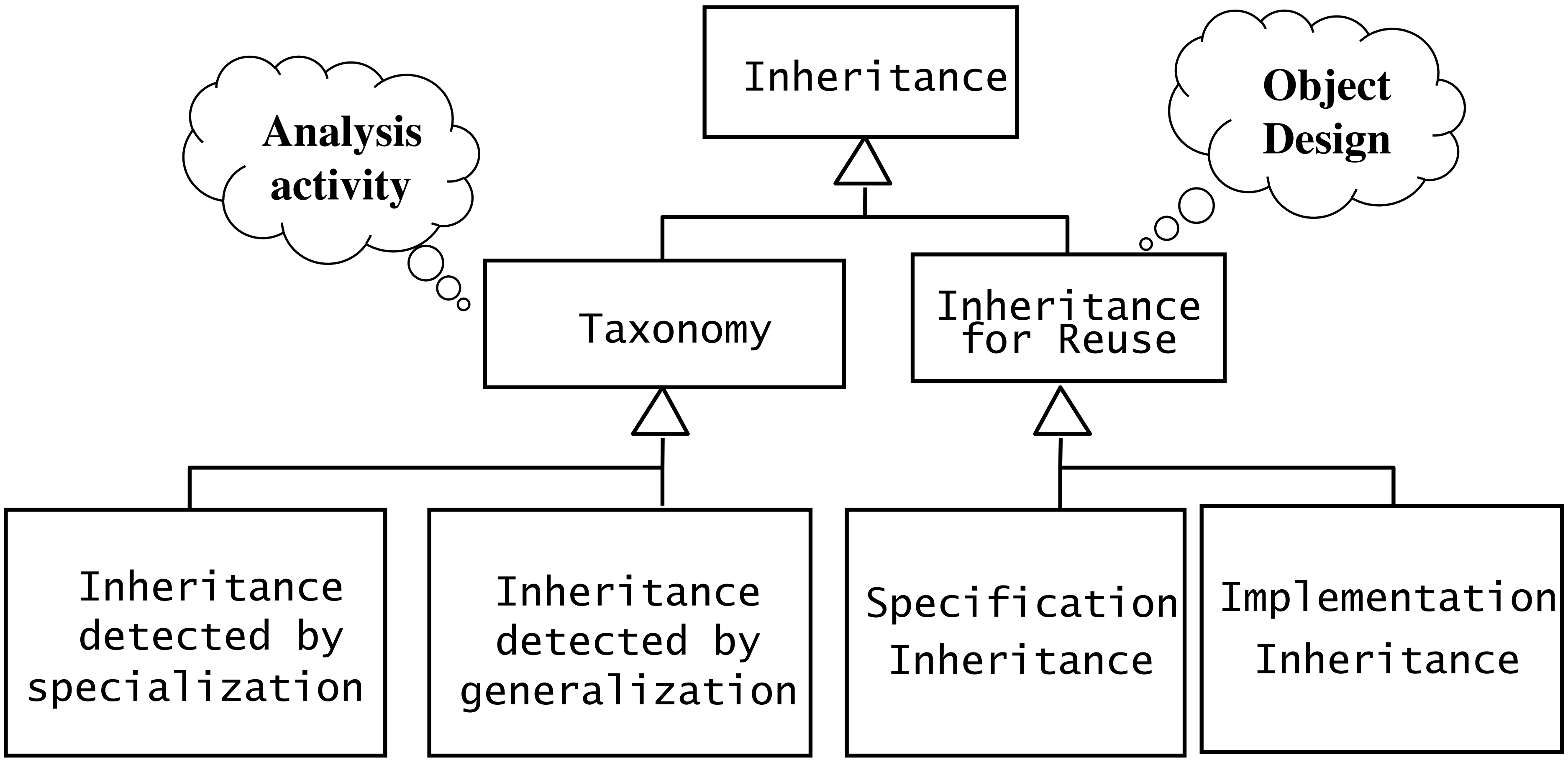
A change of names might now be useful: **dispenseItem()** instead of

dispenseBeverage()
and
dispenseSnack()

Example of a Specialization (2)



Meta-Model for Inheritance



Implementation Inheritance and Specification Inheritance

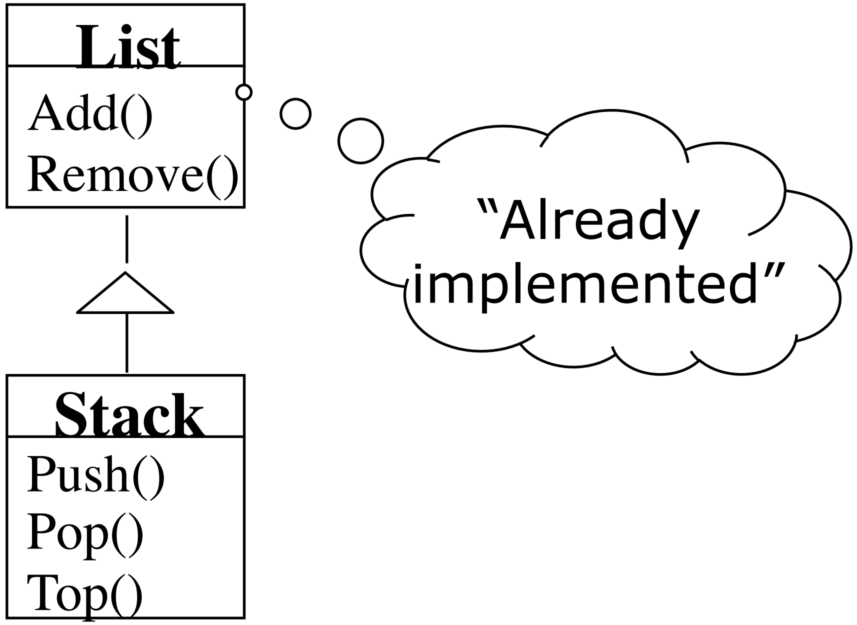
- Implementation inheritance
    - Also called class inheritance
    - Goal:
        - Extend an applications' functionality by reusing functionality from the super class
        - Inherit from an existing class with some or all operations already implemented
- Specification Inheritance
    - Also called subtyping
    - Goal:
        - Inherit from a specification
        - The specification is an abstract class with all operations specified, but not yet implemented.

Implementation Inheritance v. Specification Inheritance

- Implementation Inheritance: The combination of inheritance and implementation
  - The Interface of the superclass is completely inherited
  - Implementations of methods in the superclass ("Reference implementations") are inherited by any subclass
- Specification Inheritance: The combination of inheritance and specification
  - The Interface of the superclass is completely inherited
  - Implementations of the superclass (if there are any) are not inherited.

Example for Implementation Inheritance

- A very similar class is already implemented that does almost the same as the desired class implementation



Example:

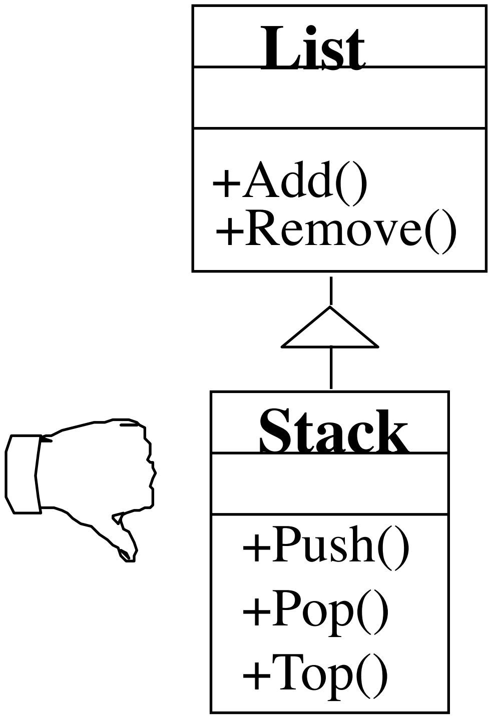
- I have a **List** class, I need a **Stack** class
- How about subclassing the **Stack** class from the **List** class and implementing **Push()**, **Pop(), Top()** with **Add()** and **Remove()**?

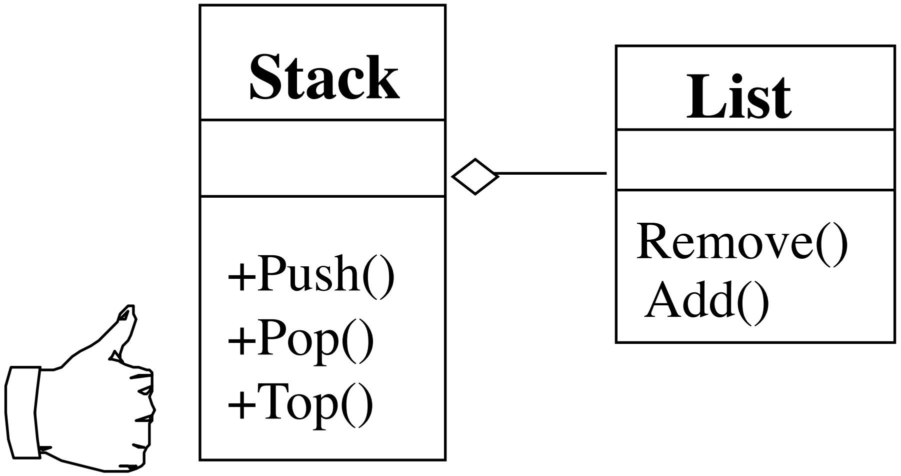
❖ Problem with implementation inheritance:

- The inherited operations might exhibit unwanted behavior.
- Example: What happens if the Stack user calls **Remove()** instead of **Pop()**?

Better Code Reuse: Delegation 5 13 2009

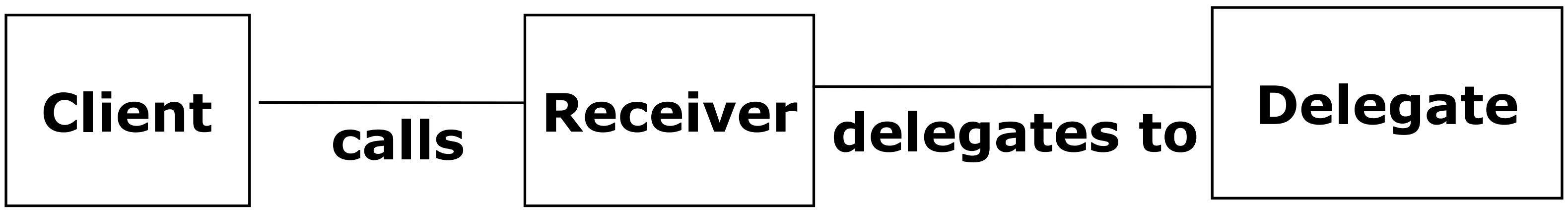
- Implementation-Inheritance: Using the implementation of super class operations
- Delegation: Catching an operation and sending it to another object that implements the operation





Delegation

- Delegation is a way of making composition as powerful for reuse as inheritance
- In delegation two objects are involved in handling a request from a Client
  - The Receiver object delegates operations to the Delegate object
  - The Receiver object makes sure, that the Client does not misuse the Delegate object.



Comparison: Delegation v. Inheritance

- Code-Reuse can be done by delegation as well as inheritance
- Delegation
  - Flexibility: Any object can be replaced at run time by another one
  - Inefficiency: Objects are encapsulated
- Inheritance
  - Straightforward to use
  - Supported by many programming languages
  - Easy to implement new functionality
  - Exposes a subclass to details of its super class
  - Change in the parent class requires recompilation of the subclass.

Finally: Pack up the design

- Goal: Pack up design into discrete physical units that can be edited, compiled, linked, reused
- Two design principles for packaging
  - Minimize coupling:
    - Example: Classes in client-supplier architectures are usually loosely coupled
    - Large number of parameters (> 4-5) in some methods mean high coupling
  - Maximize cohesion:
    - Classes closely connected by associations => same package

Design Heuristics for Packaging

- Each subsystem service is made available by one or more interface objects within the package
- Start with one interface object for each subsystem service
  - Try to limit the number of interface operations (7+-2)
- If the service has too many operations, reconsider the number of interface objects
- If you have too many interface objects, reconsider the number of subsystems

Summary

- Object design closes the gap between the requirements and the system design/machine.
- Object design adds details to the requirements analysis and prepares for implementation decisions
- Object design activities include:
  - Identification of Reuse
  - Identification of interface and implementation inheritance
  - Identification of opportunities for delegation