Course "Softwaretechnik"
Book Chapter 8
Object Design: Reuse and Patterns

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http://www.inf.fu-berlin.de/inst/ag-se/

- About "difficult" and "simple"
  - Get-15, Tic-Tac-Toe
- Patterns as simplification and reuse
- Design patterns
  - Composite
  - Adapter
  - Bridge
  - Facade

Wo sind wir?: Taxonomie "Die Welt der Softwaretechnik"

Welt der Problemstellungen:

- Produkt (Komplexitätsprob.)
  - Anforderungen (Problemraum)
  - **Entwurf (Lösungsraum)**
- Prozess (psycho-soziale P.)
  - Kognitive Beschränkungen
  - Mängel der Urteilskraft
  - Kommunikation, Koordination
  - Gruppendynamik
  - Verborgene Ziele
  - Fehler

Welt der Lösungsansätze:

- Technische Ansätze ("hart")
  - **Abstraktion**
  - **Wiederverwendung**
  - Automatisierung
- Methodische Ansätze ("weich")
  - Anforderungsermittlung
  - **Entwurf**
  - Qualitätssicherung
  - Projektmanagement

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Wo sind wir?:
Entwurf

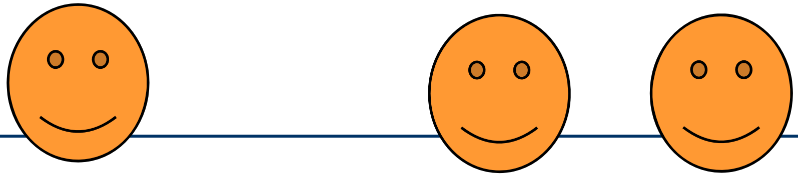
- Einsicht: Man sollte *vor* dem Kodieren über eine günstige Struktur der Software nachdenken
  - und diese als Koordinationsgrundlage schriftlich festhalten

- Prinzipien:
  - **Trennung von Belangen**
  - **Architektur**: Globale Struktur festlegen (Grobentwurf), insbes. für das Erreichen der nichtfunktionalen Anforderungen
  - **Modularisierung**: Trennung von Belangen durch Modularisierung, Kombination der Teile durch Schnittstellen (information hiding, Lokalität)
  - ***Wiederverwendung***: Erfinde Architekturen und Entwurfsmuster nicht immer wieder neu
  - **Dokumentation**: Halte sowohl Schnittstellen als auch zu Grunde liegende Entwurfsentscheidungen und deren Begründungen fest

A game: Get-15

- Start with the nine numbers 1, 2, 3, 4, 5, 6, 7, 8, 9
- You and your opponent take alternate turns, each taking a number
  - Each number can be taken only once: If your opponent has selected a number, you cannot also take it
- The first person to have any three numbers that sum up to 15 wins the game
- Example:

You:	**1**	**5**	**3**	**8**
Opponent:	**6**	**4**	**7**	**2**



Opponent Wins!

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Get-15 is "difficult"

- Hard to play
- The game is especially hard if you are not allowed to write anything down

- Why?
  - All the numbers need to be scanned to see if you have won/lost
  - It is hard to see what the opponent will take if you take a certain number
  - The choice of the number depends on all the previous numbers

  - Not easy to devise a simple strategy

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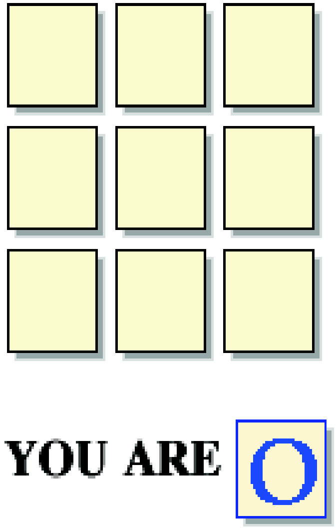
Another game: Tic-Tac-Toe

Players take turns signing a field with their mark.
The first player to get three of his marks in a row, column, or diagonal wins.



Source: http://boulter.com/ttt/index.cgi

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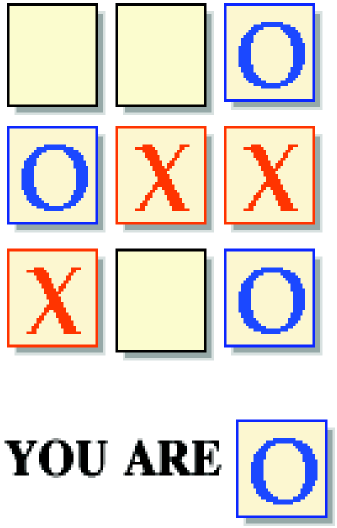
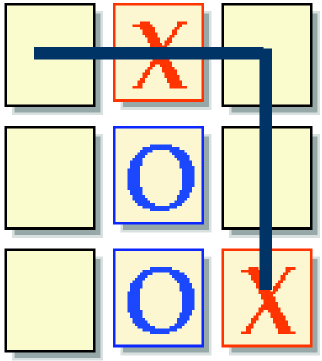
A draw sitation



		O
O	X	X
X		O

YOU ARE O

Strategy for determining a winning move



You win if

- you hold three fields on the two-segment line
- your opponent has none
- and yours include the corner

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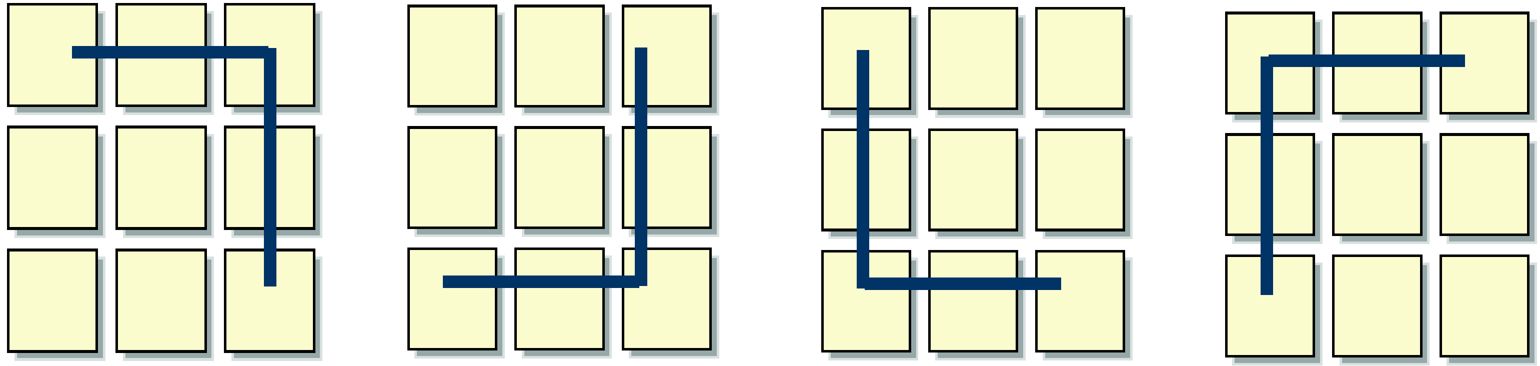
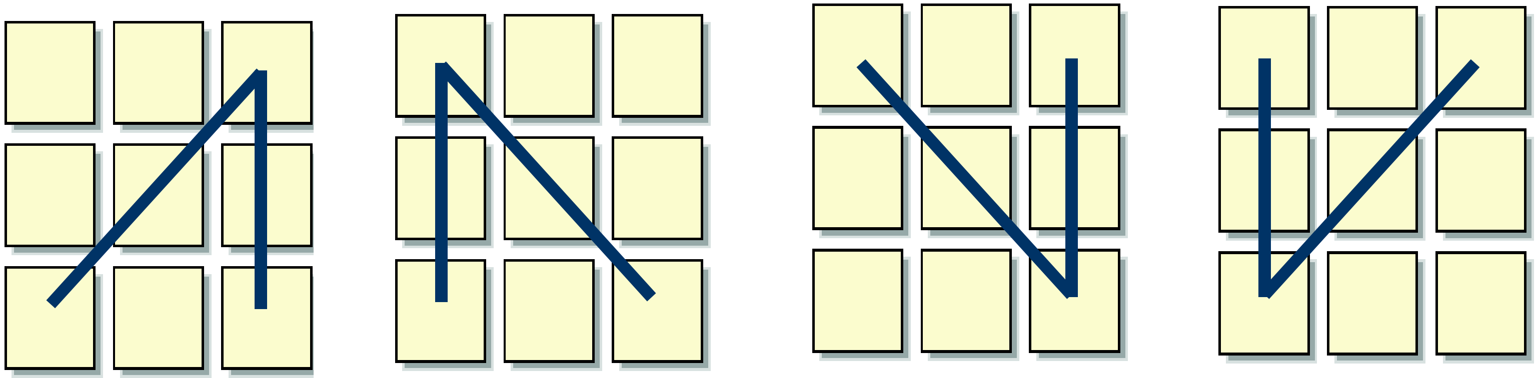
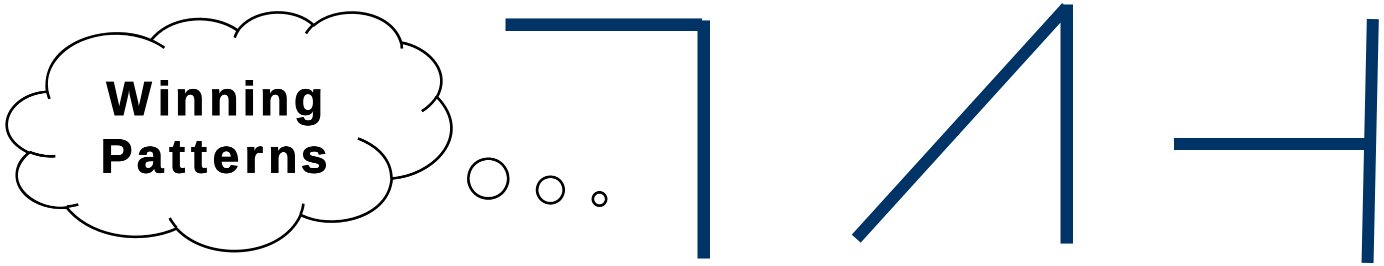
Winning situations for Tic-Tac-Toe



or likewise with the middle row or column



or likewise with a horizontal and diagonal



Tic-Tac-Toe is "Easy"

- Why? Reduction of complexity through patterns and symmetries
- **Patterns**: Knowing the following patterns, the player can anticipate the opponents move

- Symmetries:
  - The player needs to remember only these three patterns to deal with all different game situations

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Get-15 and Tic-Tac-Toe are identical problems!

- Any three numbers that solve the Get-15 problem also solve tic-tac-toe
- Any tic-tac-toe solution is also a solution of Get-15
- To see the relationship between the two games, we simply arrange the 9 digits into the following pattern

8	1	6
3	5	7
4	9	2

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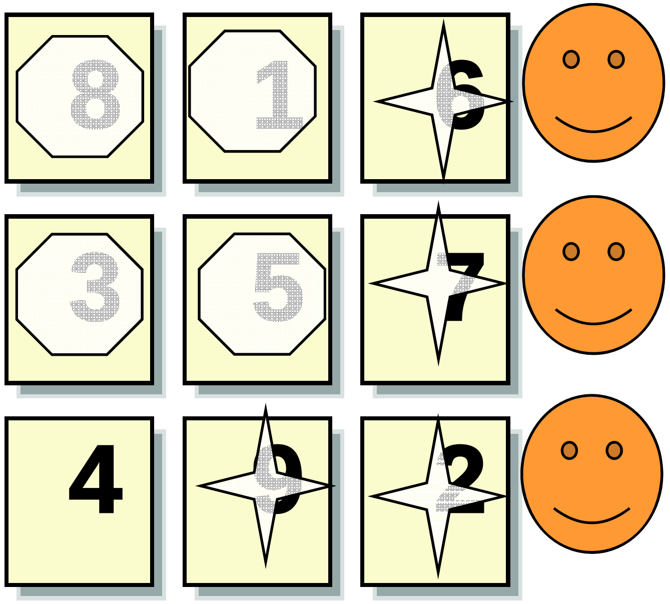
Get-15 as Tic-Tac-Toe

○ **You:** 1 5 3 8

✦ **Opponent:** 6 9 7 2

8	1	6
3	5	7
4	9	2



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Why patterns are helpful

- Patterns are abstractions
  - Understanding a pattern reduces a number of elements to a single idea
  - This saves mental resources and simplifies understanding
    - and communication

- Patterns provide reuse
  - If I know the patterns solution previously,
    I do not have to invent my own solution: Reuse of ideas!

- In the next two lectures we show how to use design patterns

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Modeling heuristics

- Modeling must address our mental limitations:
    - Our short-term memory has only limited capacity (7+-2)

- Good models deal with this limitation, because they
    - reduce complexity
        - Turn complex tasks into easy ones (by good choice of representation)
        - Use symmetries or other regularities
        - Use helpful abstractions
            - "Obvious" taxonomies
            - Memory limitations are overcome with an appropriate representation ("natural model")
    - and therefore do not tax the mind
        - A good model requires only little mental effort to understand

Design patterns have these properties

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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
- Patterns covered in the next lecture
    - Abstract Factory
    - Builder
    - Command
    - Observer
    - Proxy
    - Strategy

Patterns help finding objects

- The possibly hardest problems in object-oriented system development are:
  - Identifying objects
  - Decomposing the system appropriately into objects
- Requirements Analysis focuses on application domain:
  - Identify application objects
- System Design addresses both, application and implementation domain:
  - Identify architecture
  - Partition into subsystems and modules
- Object Design focuses on implementation domain:
  - Transform application objects into solution objects
  - Identify technical solution objects

Design patterns help with Object Design

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Definition: 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 **idea of a solution** to that problem
  - in such a way that you can use the pattern many times, without ever doing it the exact same way twice:
  - The solution idea will always be **adapted** to the specific context in which the pattern is being used

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What is common between these two definitions?

- Definition Software System:
  - "A software system consists of parts which are either themselves systems (called subsystems) or individual classes"
- Definition Software Lifecycle:
  - "A software development process consists of steps which are either smaller processes (called activities) or elementary tasks"

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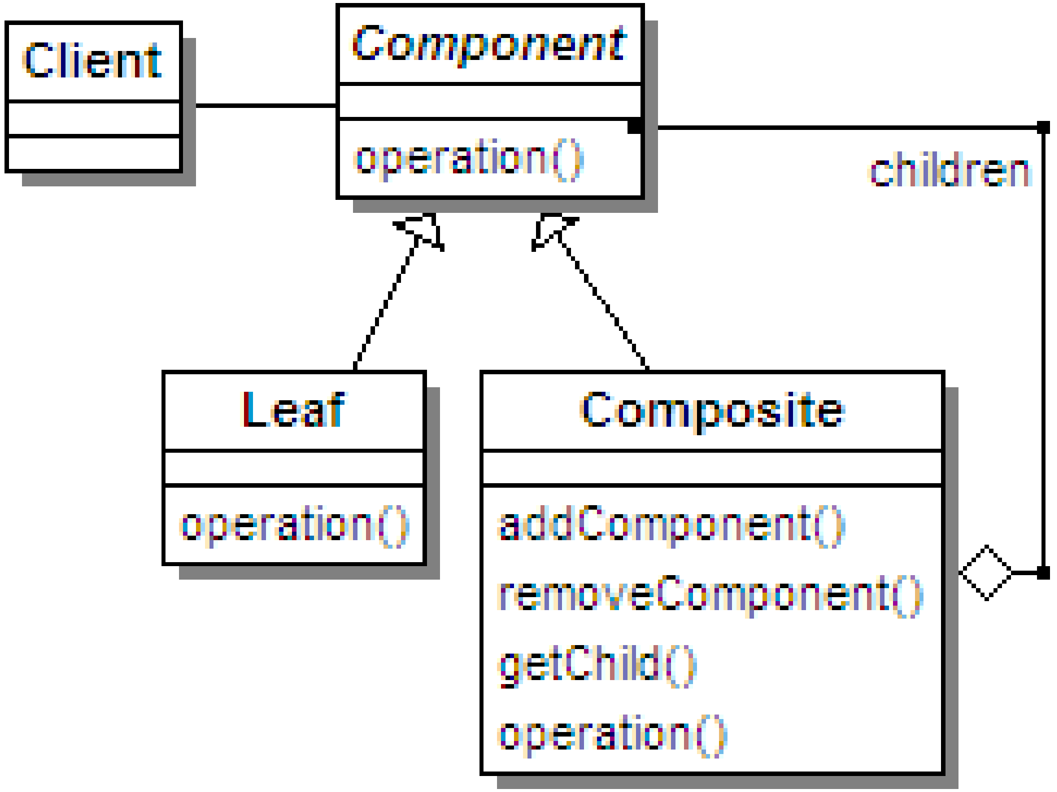
The Composite Pattern

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



Describing the Composite Pattern

- Problem: Represent part/whole hierarchies so that
  1. they can have arbitrary depth and width
  2. can be created and modified dynamically
  3. composite parts can be handled just like elementary parts
- Solution idea:
  - Have a common superclass Component
  - Have two kinds of subclasses, one for elementary parts, one for composite parts
  - The composite part classes are containers holding Component objects
    - This realizes (1) and (2)
  - Operations common to all parts are defined in the Component class
    - This realizes (3)

- http://c2.com/cgi/wiki?CompositePattern

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Two applications of the Composite Pattern

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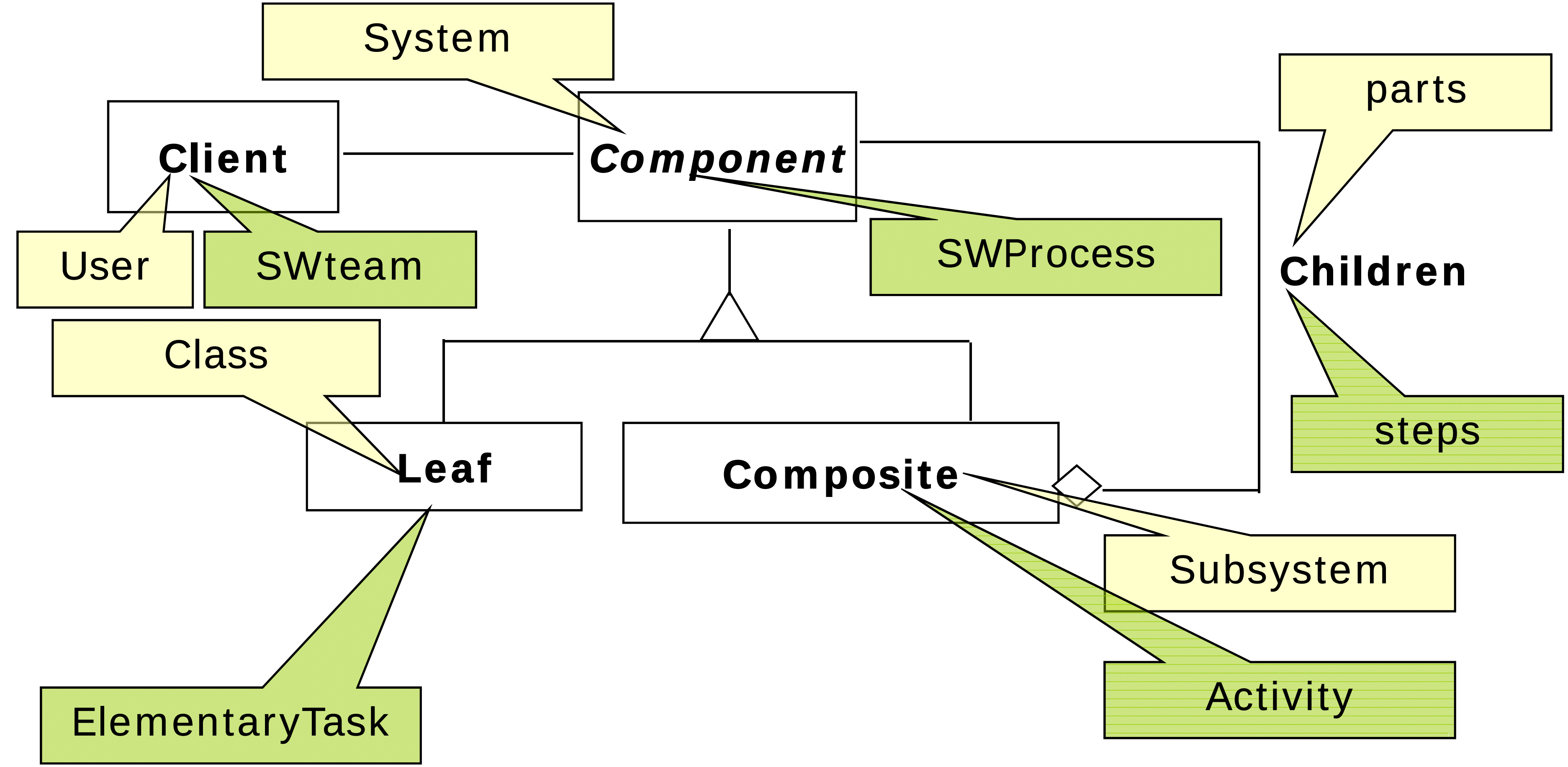
A software system consists of parts which are either themselves systems (called subsystems) or indiv. classes	A SW dev. process consists of steps which are either smaller processes (called activities) or elementary tasks



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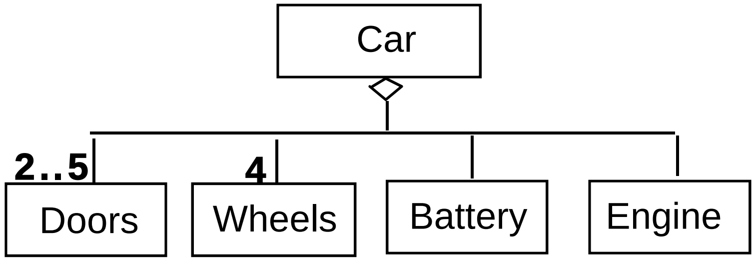
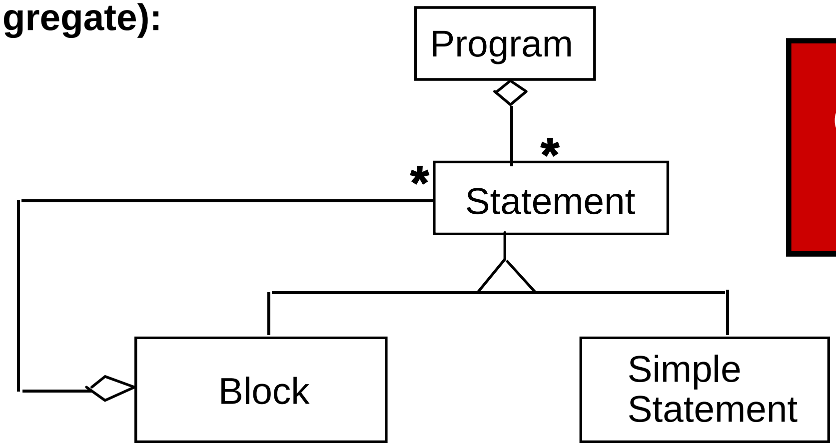
The Composite Patterns models dynamic aggregates

Fixed Structure:



Organization Chart (variable aggregate):

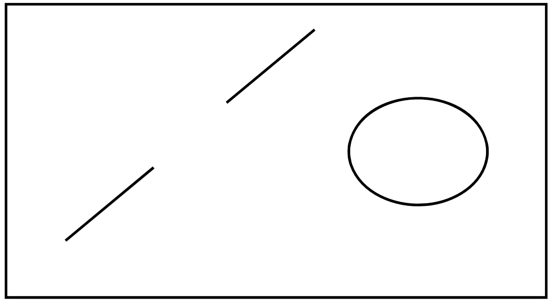
Dynamic tree (recursive aggregate):

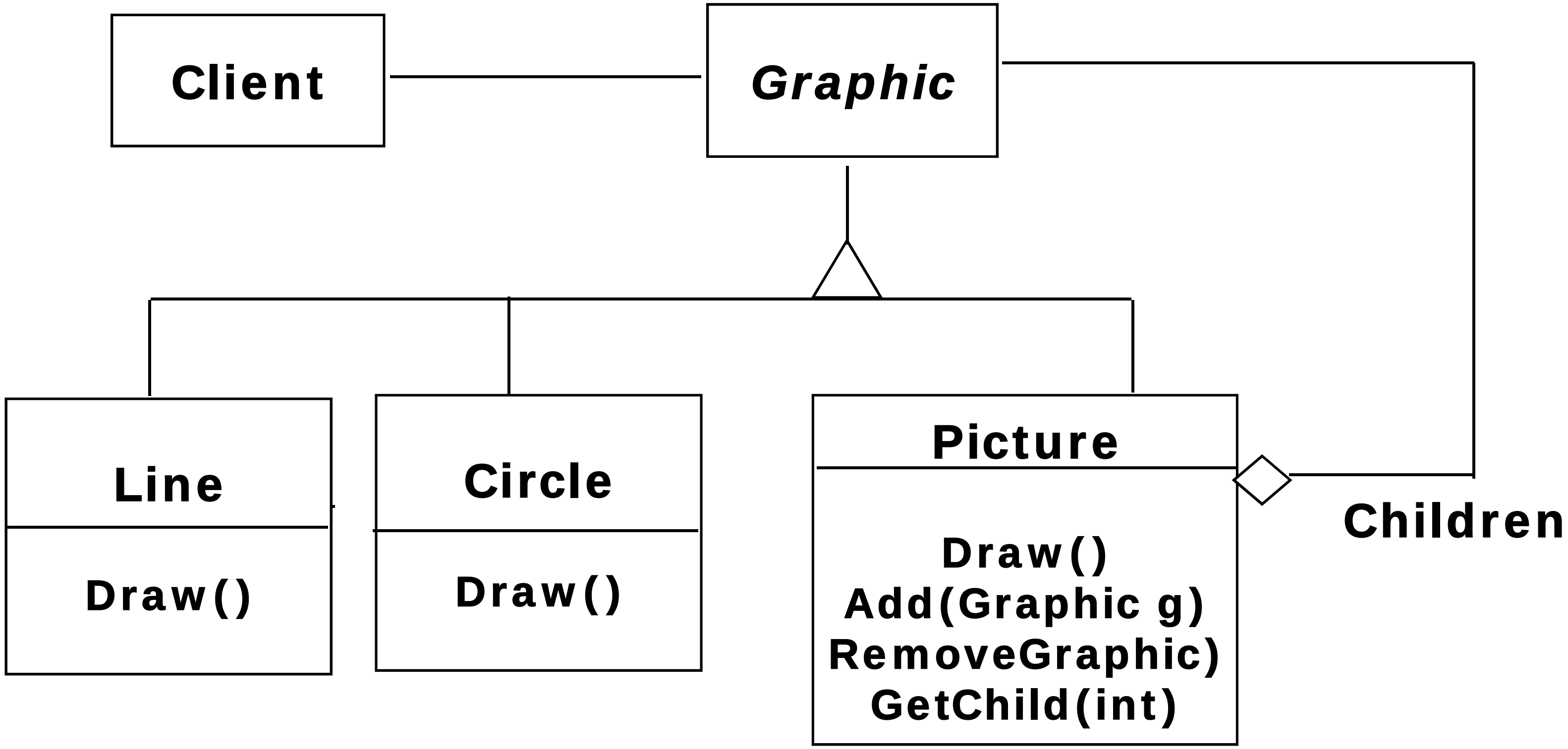


Composite Pattern

Graphic applications also use Composite Patterns

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





Client

Graphic

Line

Draw()

Circle

Draw()

Picture

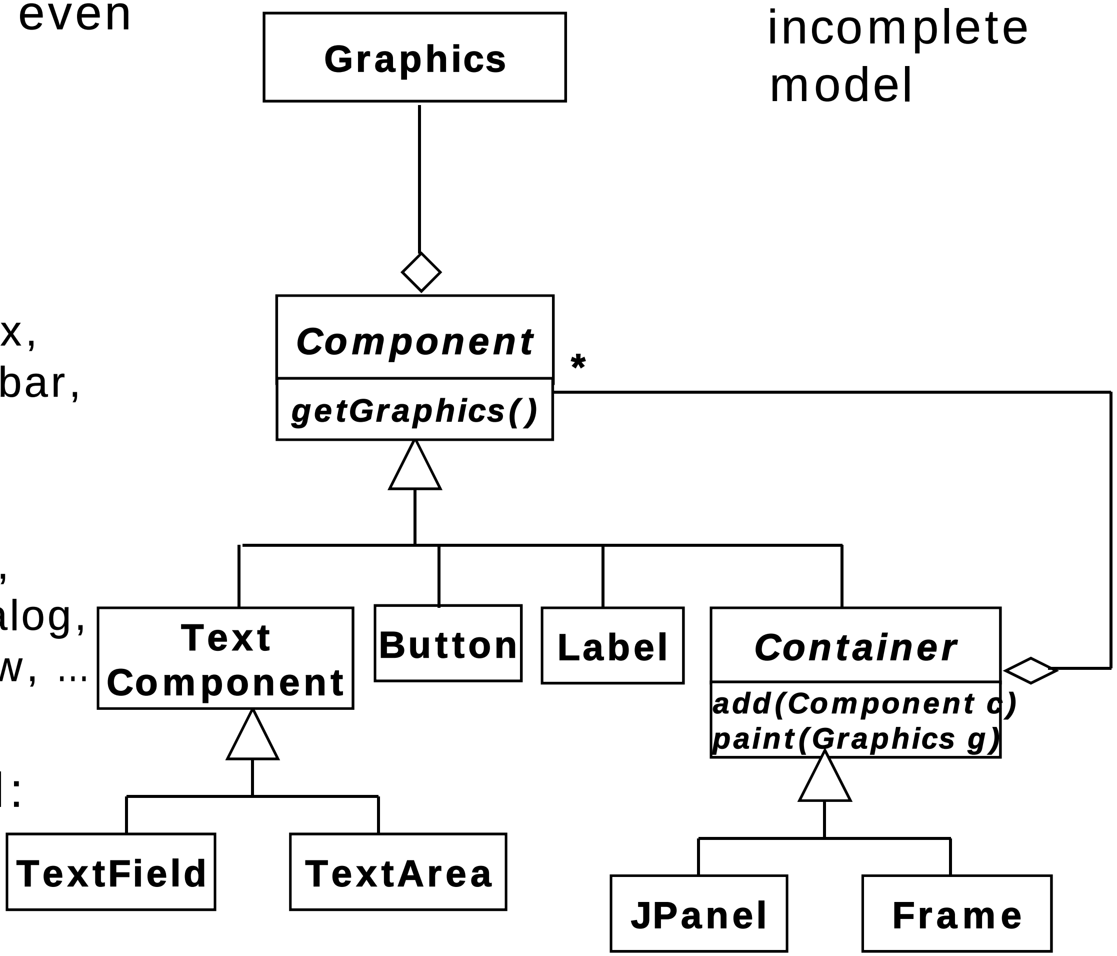
Draw()
Add(Graphic g)
RemoveGraphic)
GetChild(int)

Children

More variants:
many primitives and many containers

- Some Composite structures have many primitives and even several kinds of container
- E.g. the basic Java GUI framework ***java.awt***
- Primitives:
  - Button, Canvas, Checkbox, Choice, Label, List, Scrollbar, TextArea, TextField
- Containers
  - Container, Dialog, Frame, CellRendererPane, FileDialog, Panel, ScrollPane, Window, ...
- This is important about design patterns in general:

  Basic idea is fixed,
  details vary!



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 a CASE tool and dump it in front of somebody
  - The key is to 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 subclasses only separately
  - Then identify (or introduce) patterns in the model
    - We make sure to use the name of the patterns

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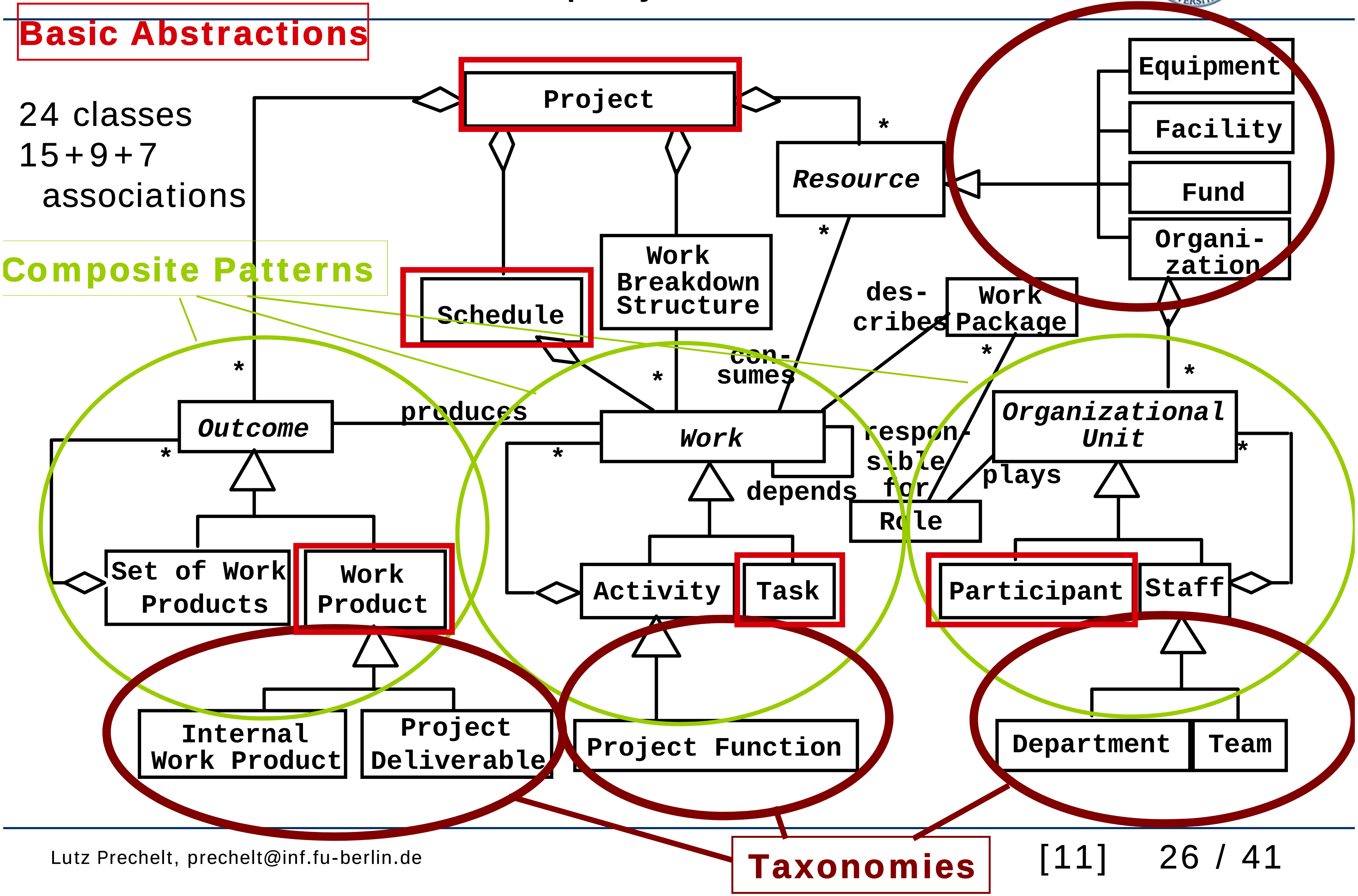
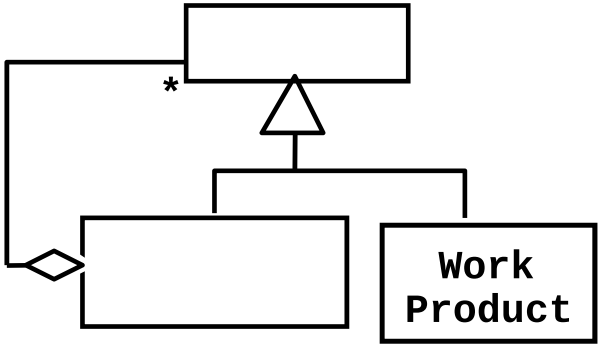
Example:
a model of a software project

24 classes
15+9+7
associations



Exercise

- There are 55 basic elements (classes, associations) in the model
  - plus association names and multiplicities
- Your short-term memory can hold about 5 to 9 elements
- Redraw the complete model for Project from your memory using the following knowledge
  - Key abstractions: **Project, WorkProduct, Task, Schedule, Participant**
  - WorkProduct, Task and Participant are modeled with composite patterns, such as



- You have 5 minutes!

Adapter pattern

Also known as *Wrapper* pattern

- Problem: We need to provide a service that conforms to a given target interface T.
  We have an existing (legacy) implementation of that service, but it has a different interface S.
- Solution idea: Introduce an adapter class A that implements T based on S
  - Then use an A object plus an S object in place of a T object
- Used in Interface engineering and reengineering
- Two adapter patterns:
  - Class adapter: Uses multiple inheritance
  - Object adapter: Uses single inheritance and delegation
- Object adapters are much more frequent
  - We will only cover object adapters

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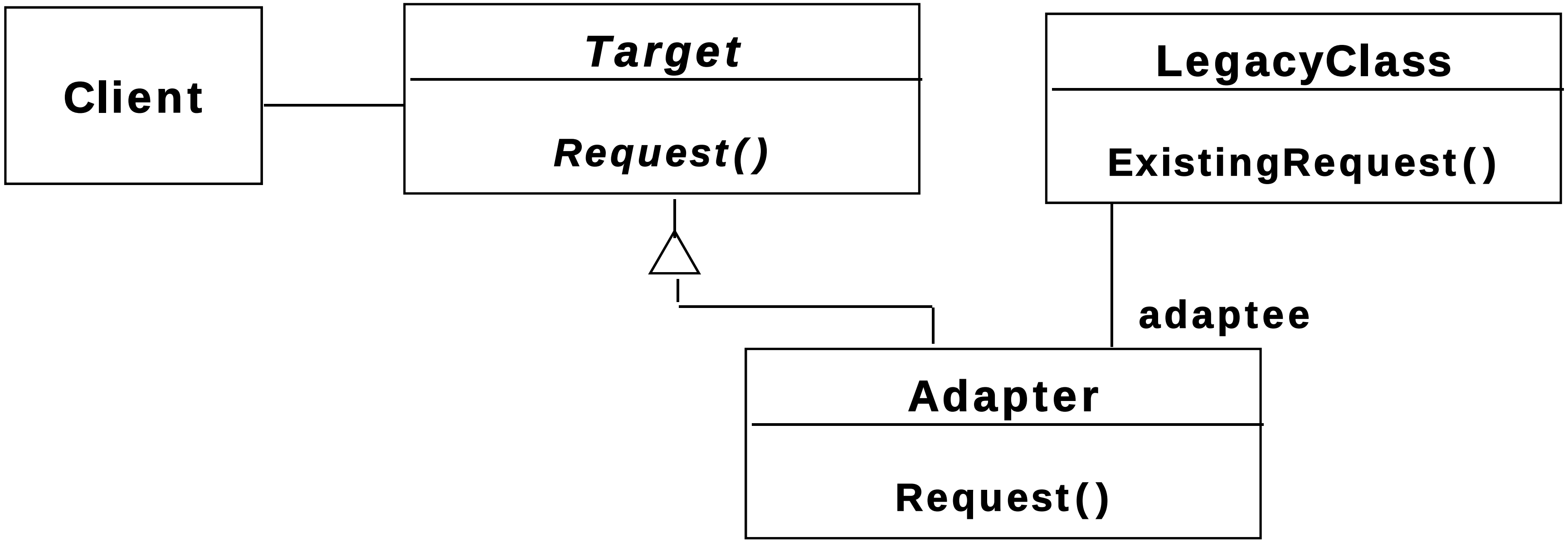
Adapter pattern



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

Bridge pattern

Also known as *Handle/Body* pattern

- Problem: We need a complex domain abstraction (that may even evolve over time) that is realized on a technical basis that also evolves (or may vary or be exchanged completely)
  - Put differently: We want to decouple an abstraction from its implementation so that the two can vary independently
- Allows different implementations of an interface to be decided upon dynamically

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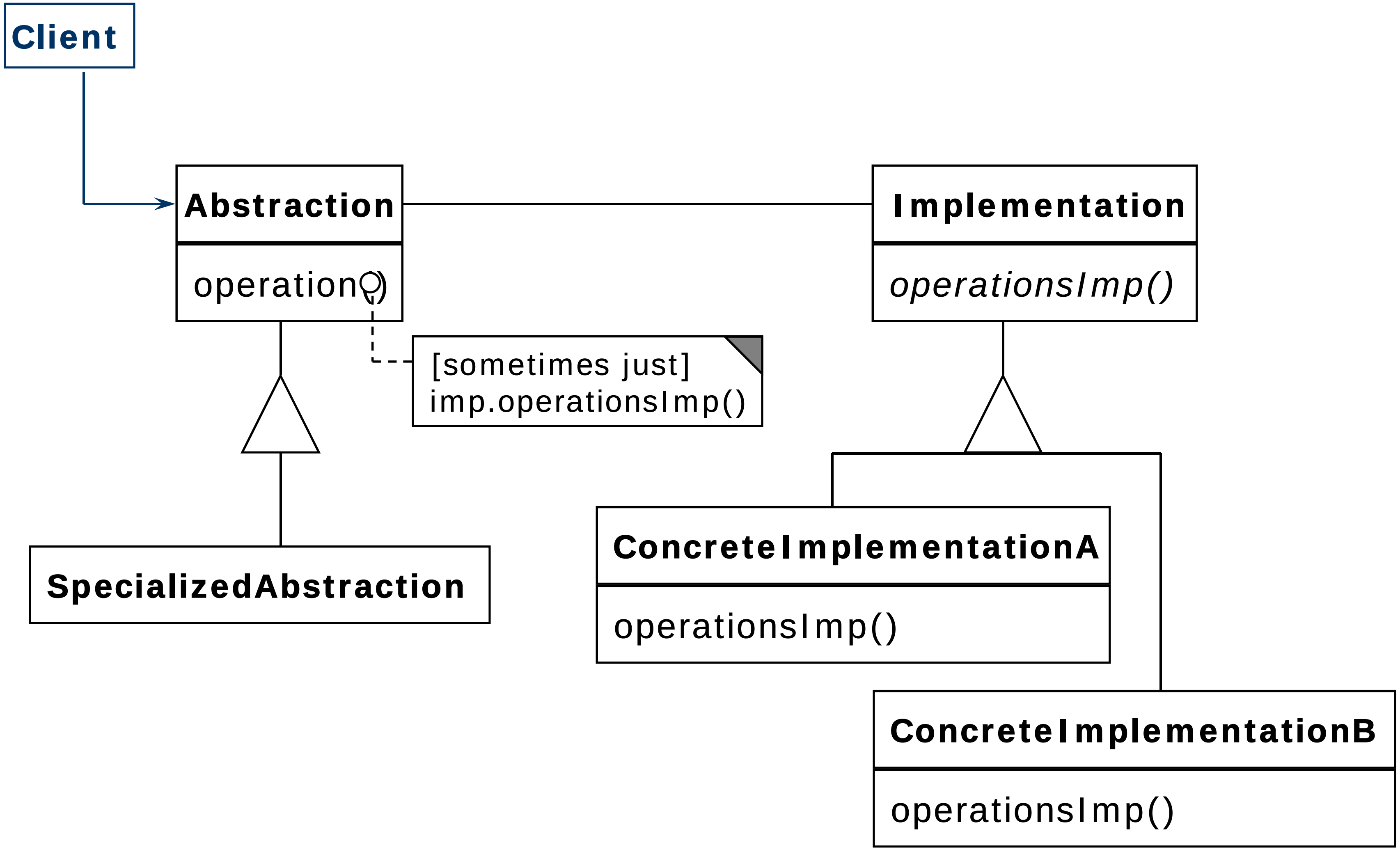
Solution structure of Bridge pattern



Client

Abstraction

operation()

[sometimes just]
imp.operationsImp()

Implementation

operationsImp()

SpecializedAbstraction

ConcreteImplementationA

operationsImp()

ConcreteImplementationB

operationsImp()

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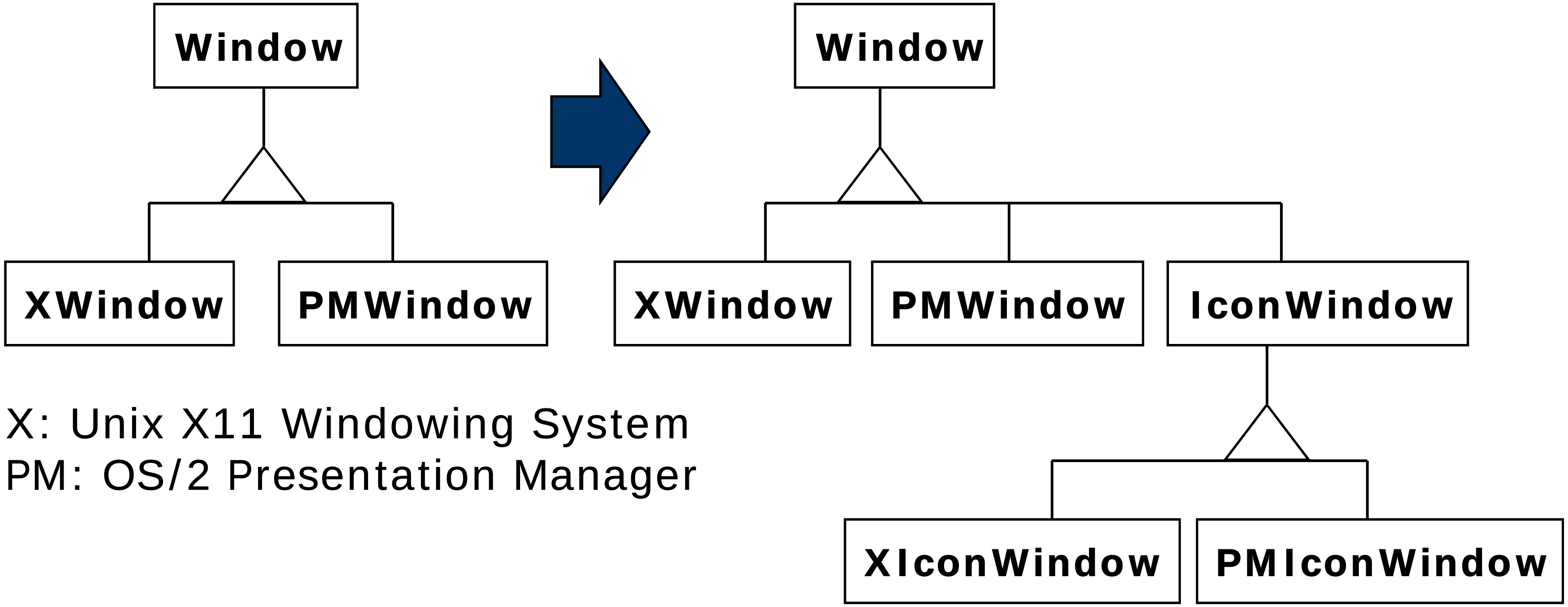
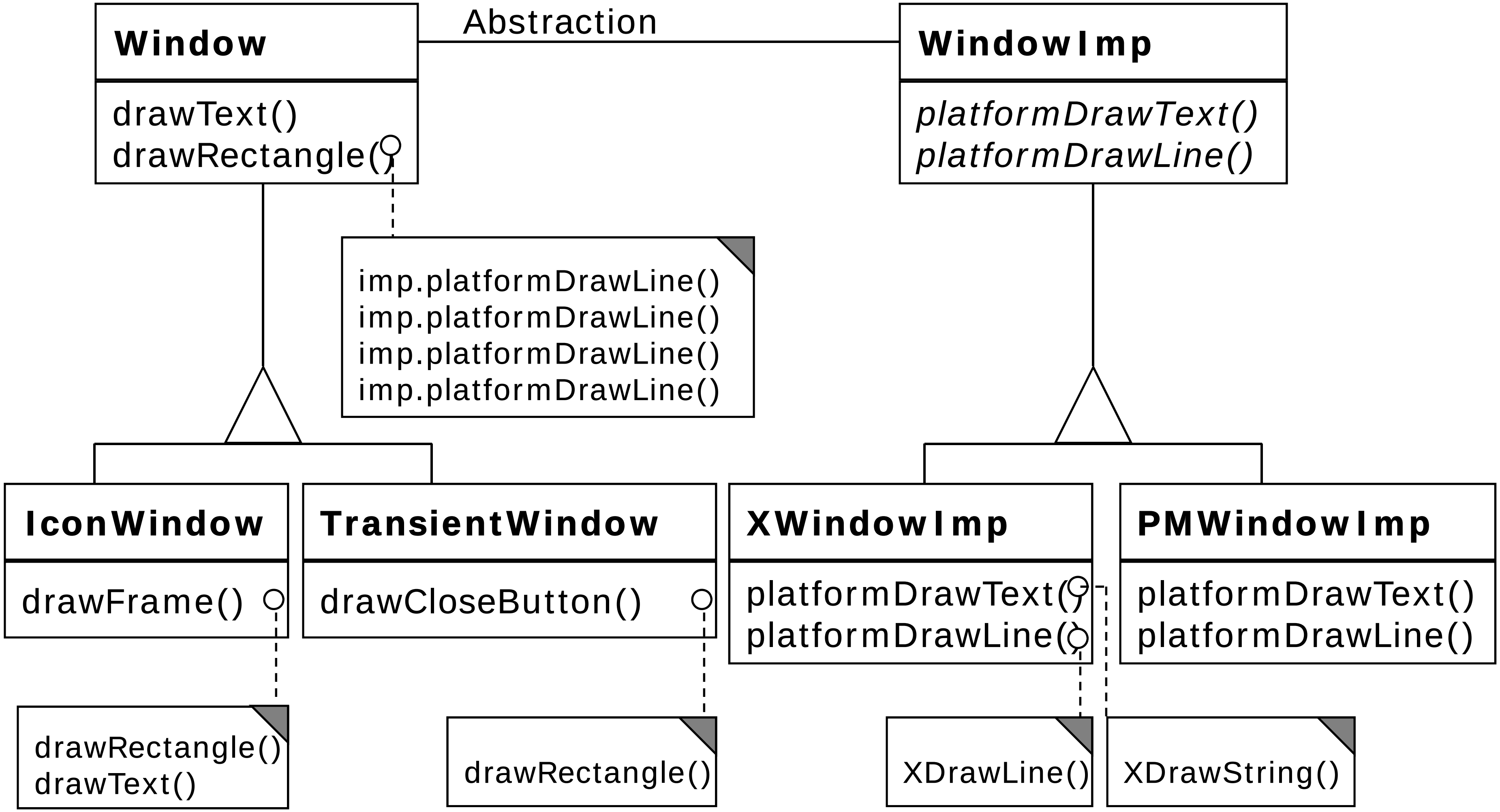
Bridge motivation

- GUI libraries often need two inheritance hierarchies:
  - multiple classes for the GUI domain abstractions (design space)
  - multiple implementations for each (solution space)
    - (one per platform: Mac, Windows, X11, OS/2, etc.)
- Combining these into one leads to giant hierarchies:



X: Unix X11 Windowing System
PM: OS/2 Presentation Manager

Bridge example



(Simplified. Actual GUI libraries are more complex than this)

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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 <u>after</u> they're designed (reengineering, interface engineering)
  - A bridge, on the other hand, is used <u>up-front</u> 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

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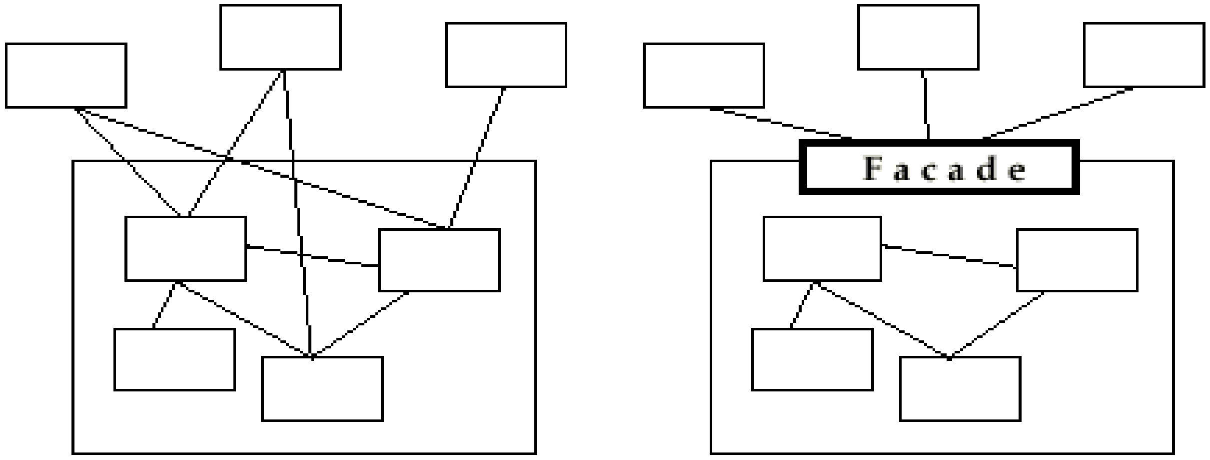
Façade pattern

- 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 away many details
- Facades allow us to provide a closed architecture
  - When a module consists of multiple classes, the Façade represents the module's interface



Subsystem design with Façade, Adapter, Bridge

- The ideal structure of a subsystem consists of
  - an interface object (boundary 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!

Design patterns encourage reusable designs

- A facade pattern should be used for each subsystem in a software system; it defines the visible services
  - 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 interface to existing components
  - For example, a smart card software system should interface to different smart card readers via different adapters

- Bridges should be used to interface to a set of objects
  - where the full set is not 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)

Additional design heuristics

1. Avoid implementation inheritance, always prefer interface inheritance
   - Because implementation inheritance often results in cascading changes when you modify the superclass
   - When you are tempted to use implementation inheritance, consider delegation instead

2. Apply "design by contract" throughout each inheritance hierarchy
   - Each subclass operation
     must require at most the preconditions of the superclass and
     must provide at least the postconditions of the superclass
     - Because only then code using the superclass will always also work correctly with each subclass
     - Make sure not to violate this rule when redefining superclass methods
   - A subclass must never hide operations implemented in a superclass

Literature

- Erich Gamma, Ralph Johnson, Richard Helm, John Vlissides: "*Design Patterns: Elements of Reusable Software*", 1994.
  - The classic "Gang of Four" (GoF) book. Collection of basic design patterns found when constructing GUI frameworks, but useful in many situations
- Frank Buschmann, Regine Meunier, Hans Rohnert, Peter Sommerlad, Michael Stal: "*Pattern-Oriented Software Architecture: A System of Patterns*", 1996
  - The other classic (sometimes called "Gang of Five" book). Discusses architecture patterns, design patterns, idioms, and pattern systems
- http://c2.com *"The Portland Pattern Repository"*
  - The world's first wiki, created for discussing design patterns (and very many other things).
  - Interesting!

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Summary

- Design patterns are solution ideas for common problems such as
  - separating an interface from
    (a number of alternate) existing implementations
  - wrapping around a (set of) legacy class(es)
  - protecting a caller from platform-specific changes
- A (oo-)design pattern describes how to compose a few classes
  - use delegation and inheritance
  - provide a robust and modifiable solution
- The idea underlying the pattern should be adapted/refined for the specific system under construction
  - Customization of the design and purpose
  - Reuse of existing solutions
  - Combination with other patterns

Thank you!