IMPORTANT NOTICE TO STUDENTS

These slides are **NOT** to be used as a replacement for student notes.
These **slides** are sometimes **vague and incomplete on purpose** to spark class discussions

Gang of Four (GoF)
OO Design Patterns

CS 446/646 ECE452
May 11th, 2011

WATERLOO
CHERITON SCHOOL OF
COMPUTER SCIENCE

Motivation

Object Oriented Analysis (OOA)

- domain problem **designed** as (domain) objects
  - addresses the **functional challenges**
  - what a system does
  - provides guidance for implementation

Object Oriented Design (OOD)

- domain problem **solved** as (implementation) objects
  - addresses the implementation challenges
  - how a system realizes OOA

Motivation

How can we improve OOD

- identify common characteristics
  - creation, structure, behaviour & interactions

- design patterns (design reuse)
  - generic blueprints (*micro architecture*)
  - language and implementation independent
  - two main catalogues
    - **GoF:** Gang of Four (Gamma, Helm, Johnson, Vlissides, 1995)
    - POSA: Pattern Oriented Software Architecture (Buschmann, et al.; Wiley, 1996)

Motivation

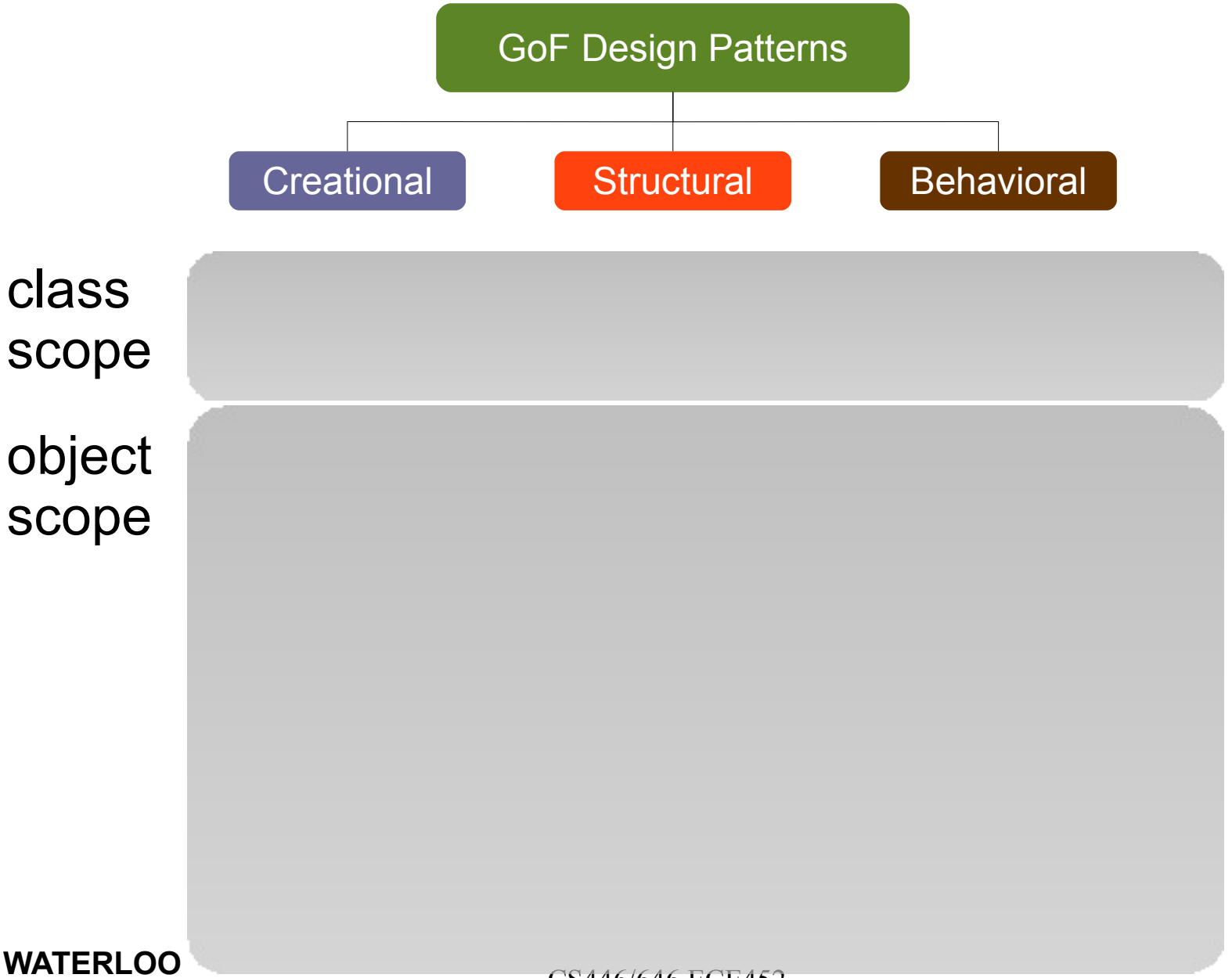
What is a Design Pattern

- common solution to a reoccurring problem in design

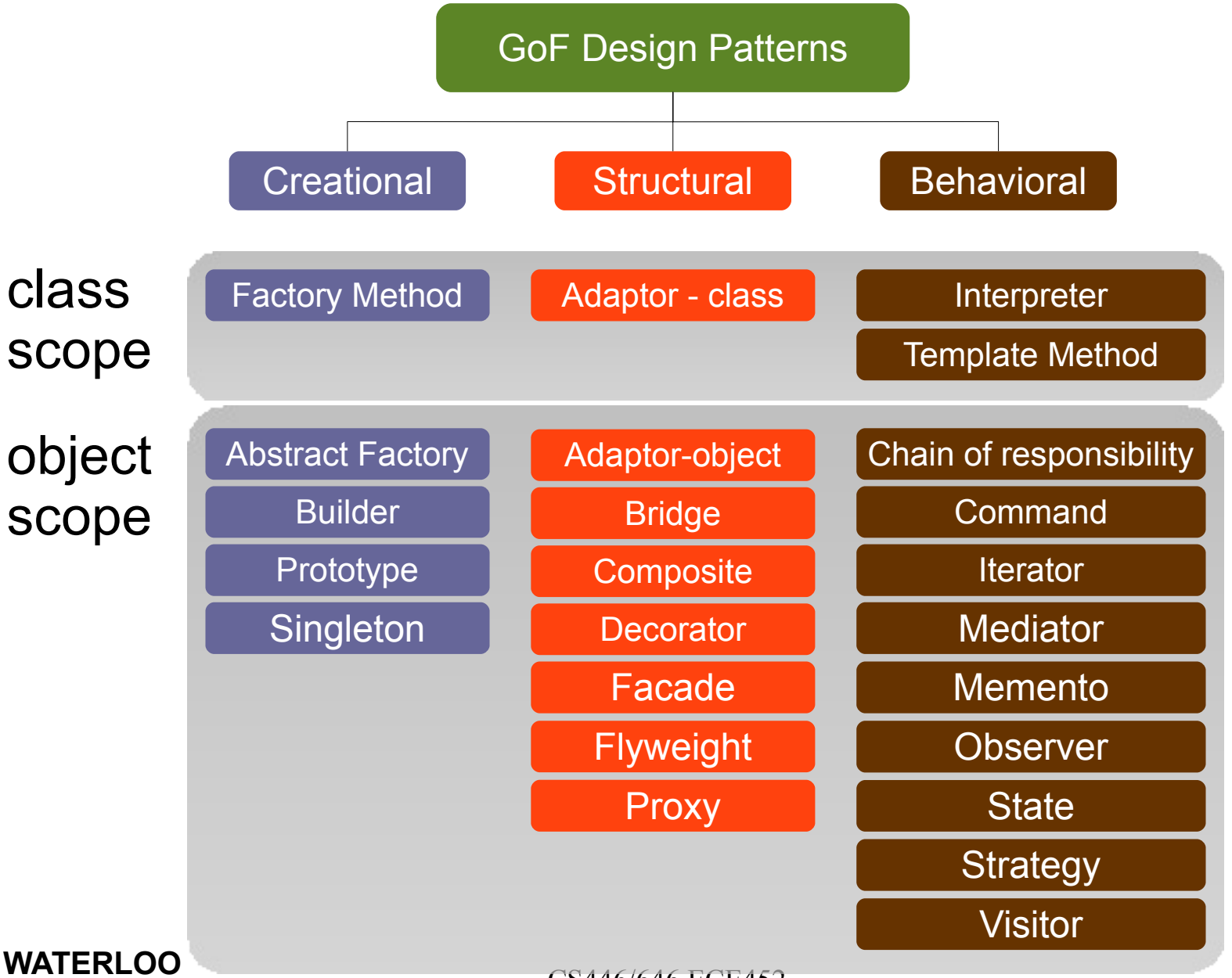
Anatomy

- name
- problem/motivation
- solution
- consequences & tradeoffs
- which ones are important for us?

Design Patterns Classification



Design Patterns Classification



Design Patterns Classification

"Purpose" based classification

- creational:
  - concerns with **creation process** of objects & classes
- structural
  - **composition** of classes & objects
- behavioral
  - characterizes **interaction & responsibility** of objects & classes

Design Patterns Classification

"Scope" based classification

- decided if the pattern applies to mainly classes or objects

Two categories

- class scope
  - relationship between classes & subclasses
  - statically defined at run-time
- object scope
  - object relationships (***what type?***)
  - can be manipulated at runtime (***so what?***)

Design Patterns Classification

Creational class

- defers object creation to sub-classes (*factory method*)

Creational object

- defers object creation to other objects (*abstract factory*)

Structural class

- inheritance to compose classes (*adapter*)

Structural object

- deals with object assembly (*adapter*)

Behavioral class

- uses inheritance to describe flow of control, algorithms (*template*)

Behavioral object

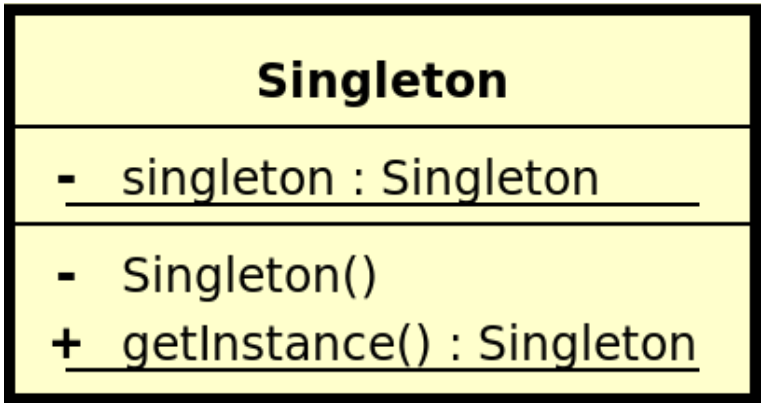
- group of objects working together to carry out a task (*iterator*)

Singleton

Intent

- *"ensure a class only has one instance, and provide a global point of access to it."*

Construction



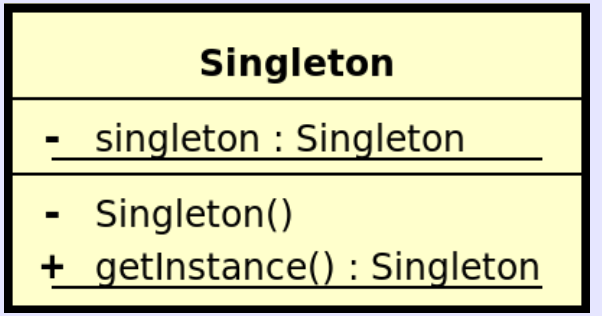
Singleton

Intent

- *"ensure a class only has one instance, and provide a global point of access to it."*

Construction

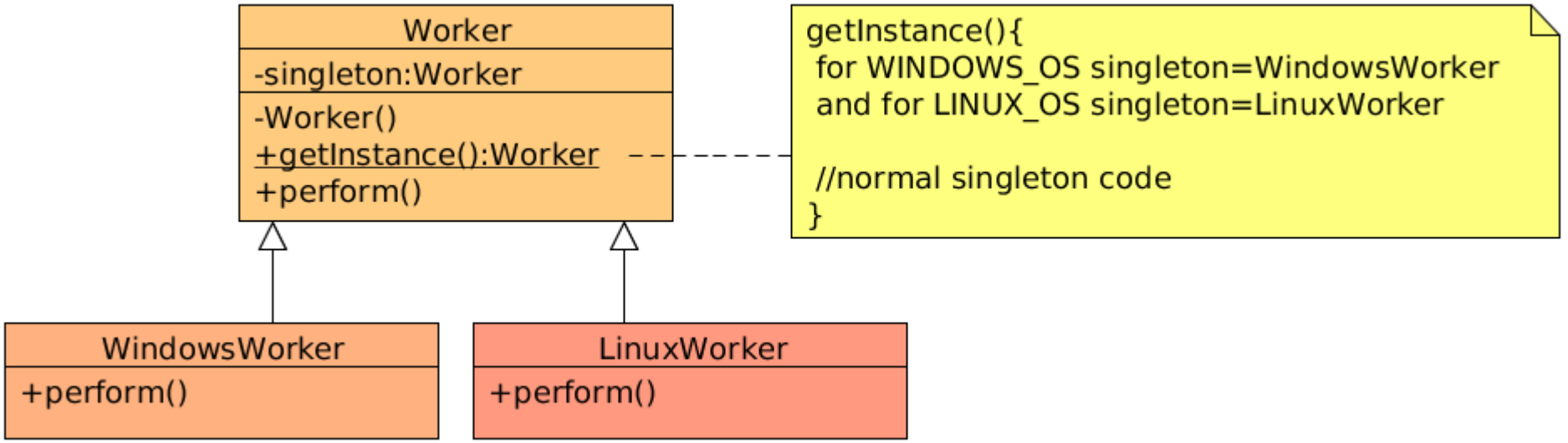
```
public class Singleton {
  private static final Singleton INSTANCE = new Singleton();

  // Private constructor prevents
  // instantiation from other classes
  private Singleton() {}

  public static Singleton getInstance() {
     return INSTANCE;
  }
}
```



Singleton

Advantages

- controlled access to the class instance(s)
  - can dictate who, and when a client can access
- refinement of functionality
  - via inheritance/subclass



Singleton

Advantages

- variable number of instances
  - the *getInstance()* method needs modification
  - *what else needs to change?*

Singleton

A closer look at Singleton

- reuse
- separation of concerns
- global presence
- stateful vs. stateless
- multiple instances
- life cycle

Singleton – A Closer Look

Reuse

- coupling
  - results in tighter coupling
  - couples with the exact type of the singleton object
  - pass by reference to reduce coupling?

Singleton – A Closer Look

Reuse

- coupling
  - results in tighter coupling
  - couples with the exact type of the singleton object
  - pass by reference to reduce coupling?

```
public void doSomething(){
   Worker worker = Worker.getInstance();
   worker.perform();
}
```

```
public void doSomething(Worker worker){
   worker.perform();
}
```

Singleton – A Closer Look

Reuse

- inheritance
  - easy to extend functionality in subclasses
  - not easy to override the object instance in subclasses

Singleton – A Closer Look

Separation of concerns

- singleton class responsible for creation
  - acts as a builder/factory
- what if we were to separate the two concerns
  - example
    - database connection as a singleton
    - system 1 uses a singleton to ensure only a single database connection
    - system 2 needs to connection pool of 10 databases connections

Singleton – A Closer Look

Global presence

- provides a global access point to a service
  - aren't global variables bad?
  - can be accessed from anywhere
    - violation of layered access
- not part of method signature
  - dependency is not obvious
  - requires code inspection
- a large system may require many singletons
  - use a registry/repository

Singleton – A Closer Look

Stateful singleton

- same as a global variable in principle
  - aren't global variables bad?
- access concerns
  - synchronization
  - concurrency – multiple threaded using a singleton
- mutable vs. immutable state

Stateless singleton

- better then stateful
- can we have a stateless singleton?

Singleton – A Closer Look

Multiple instances

- distributed systems
  - is it possible to have a true singleton in a distributed system?
  - global registries/repositories
- language (Java) specific concerns
  - initialization – has to be thread safe
  - serialization
  - class loaders

Singleton – A Closer Look

Life-cycle & life span

- creation
  - lazy initialization
- singletons are long lived
  - as long as an application's life span
  - registries can outlive applications
  - unit testing requires short lived state
- language (Java) specific concern
  - reloading singleton class (servlets)
  - loss of state

Singleton

When can I use a singleton

- considerations[1]
  - will every user use this class exactly the same way?
  - will every applications ever need only one instance?
  - should the clients be unaware of the application
- examples
  - Java Math class (stateless – static class)
  - top level GUI (window/frame)
  - logging

[1] http://www.ibm.com/developerworks/library/co-single.html

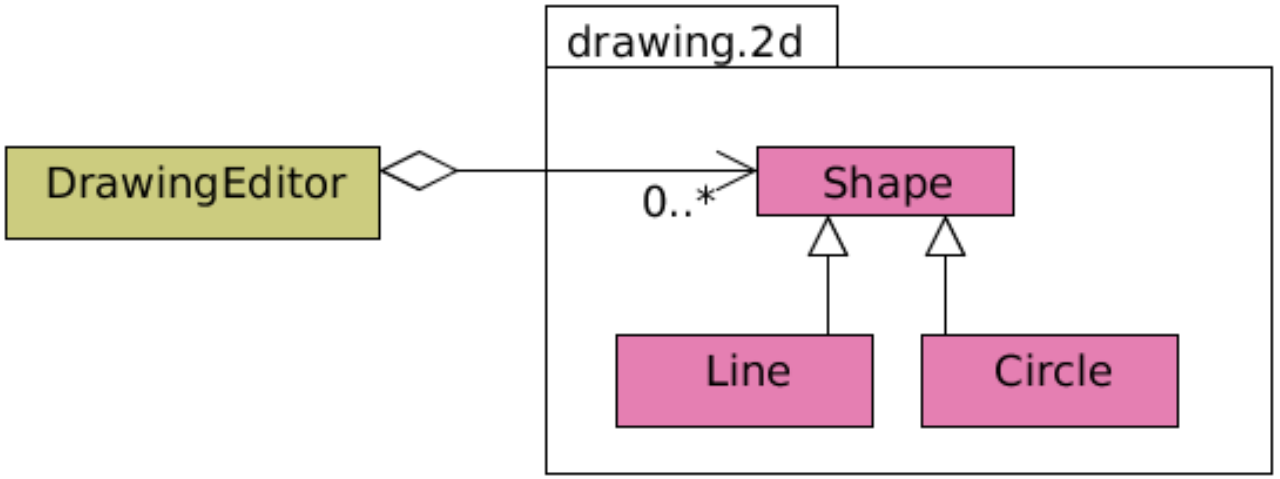
Adapter

Intent

- *"**convert** the **interface of a class** into another interface... Adapter lets classes work together that couldn't otherwise because of **incompatible interface**"*

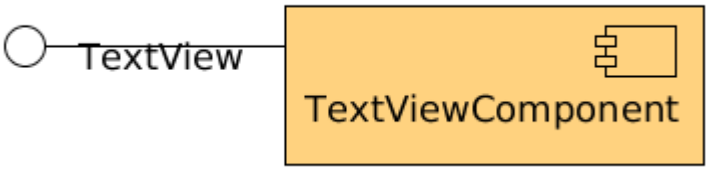
- also known as "wrapper"
- boolean values can be represented by
  - {1,0}, {true, false}, {yes, no}
  - does this qualify as an adapter?

Motivation

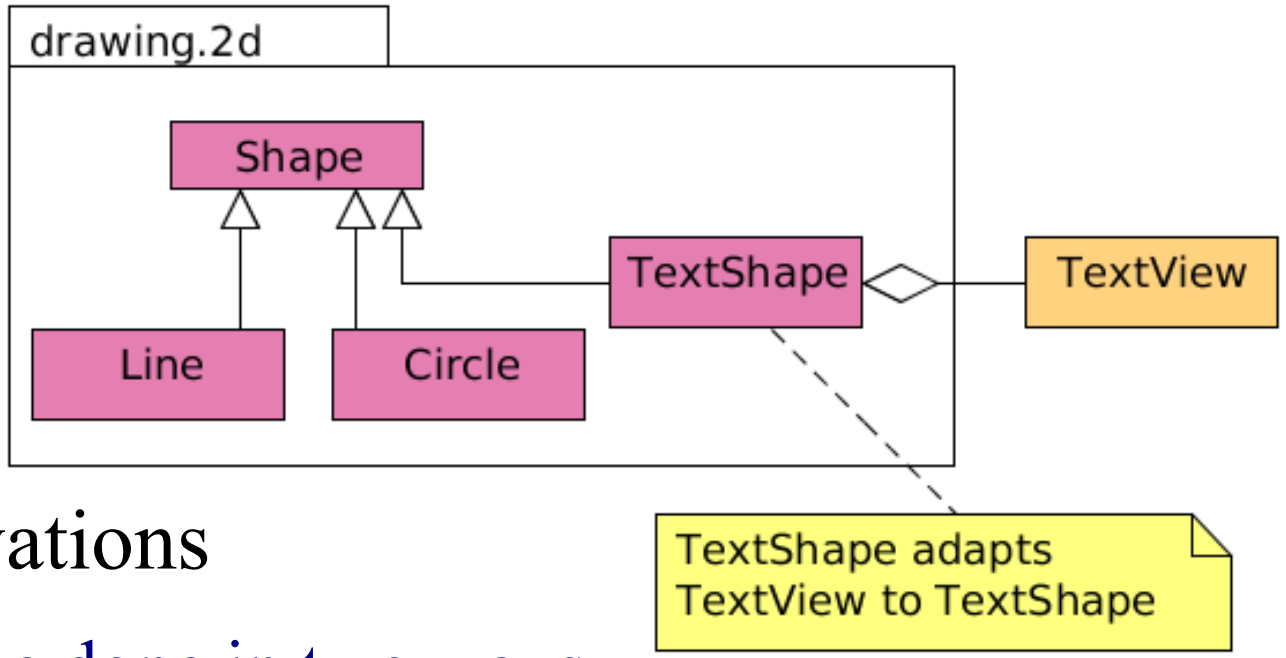


Need to add “Text” capability to our drawing editor.

Consider an off the shelf **TextView** component



Motivation



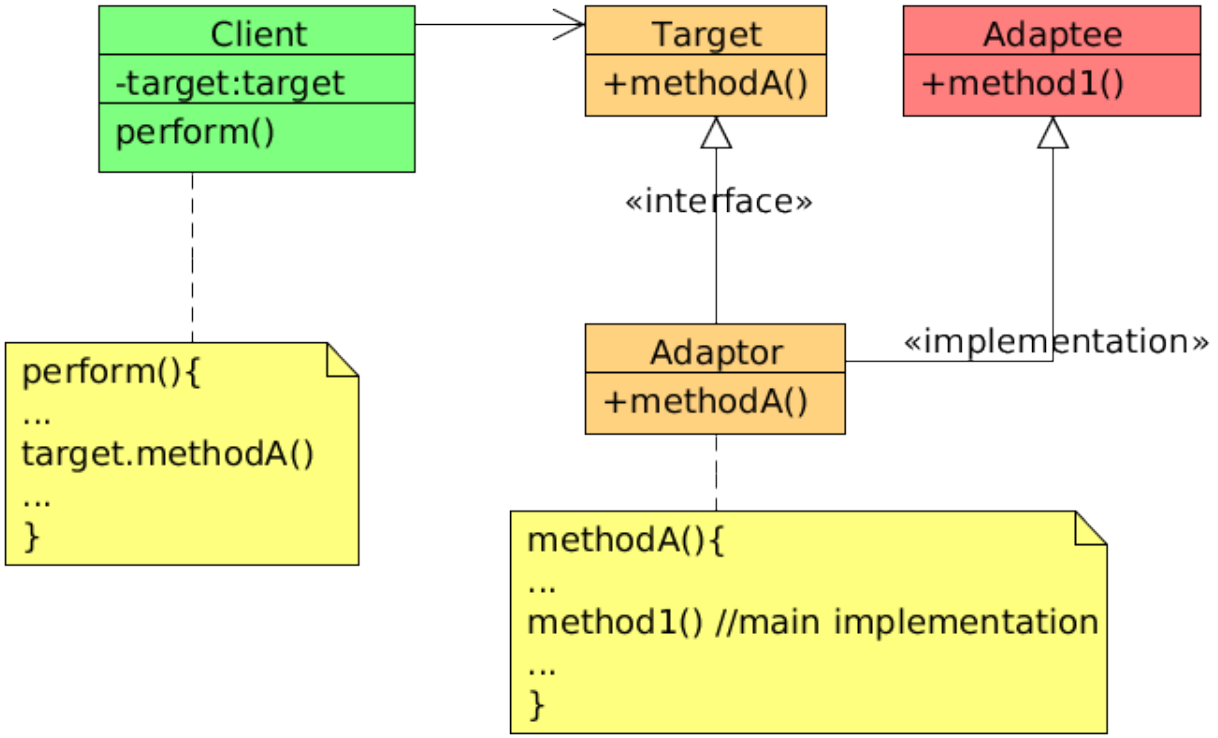
Observations

- can be done in two ways
  - object composition (shown above)
  - inheritance
    - Shape provides "**interface**" and TextView provides an **implementation**
    - Lets try to draw this?

Adapter – Class

Requirement

- requires multiple inheritance

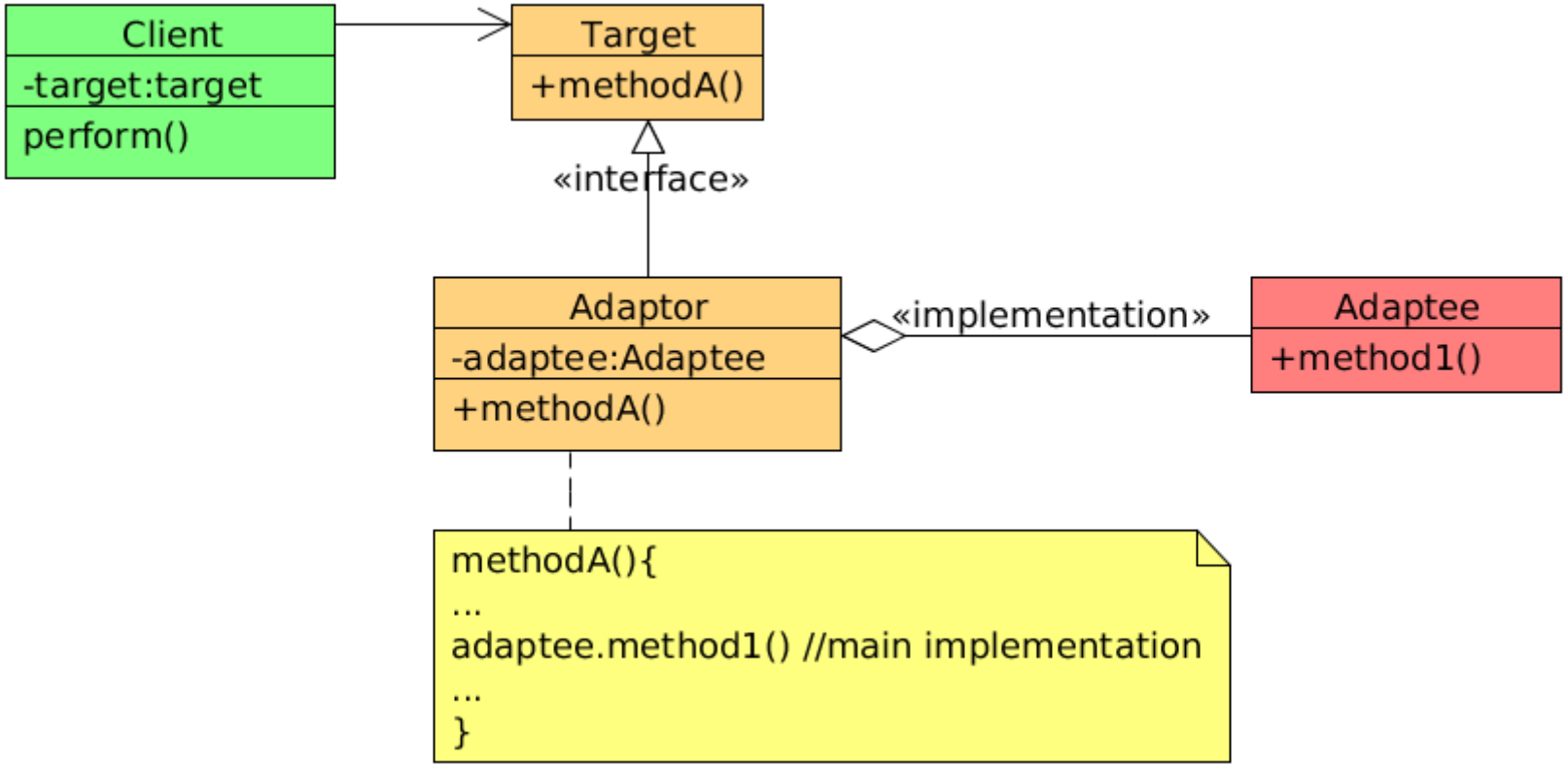


what about implementations that do not support multiple inheritance (Java)?

Adapter – Object

Requirement

- via object composition



Adapter – Class vs. Object

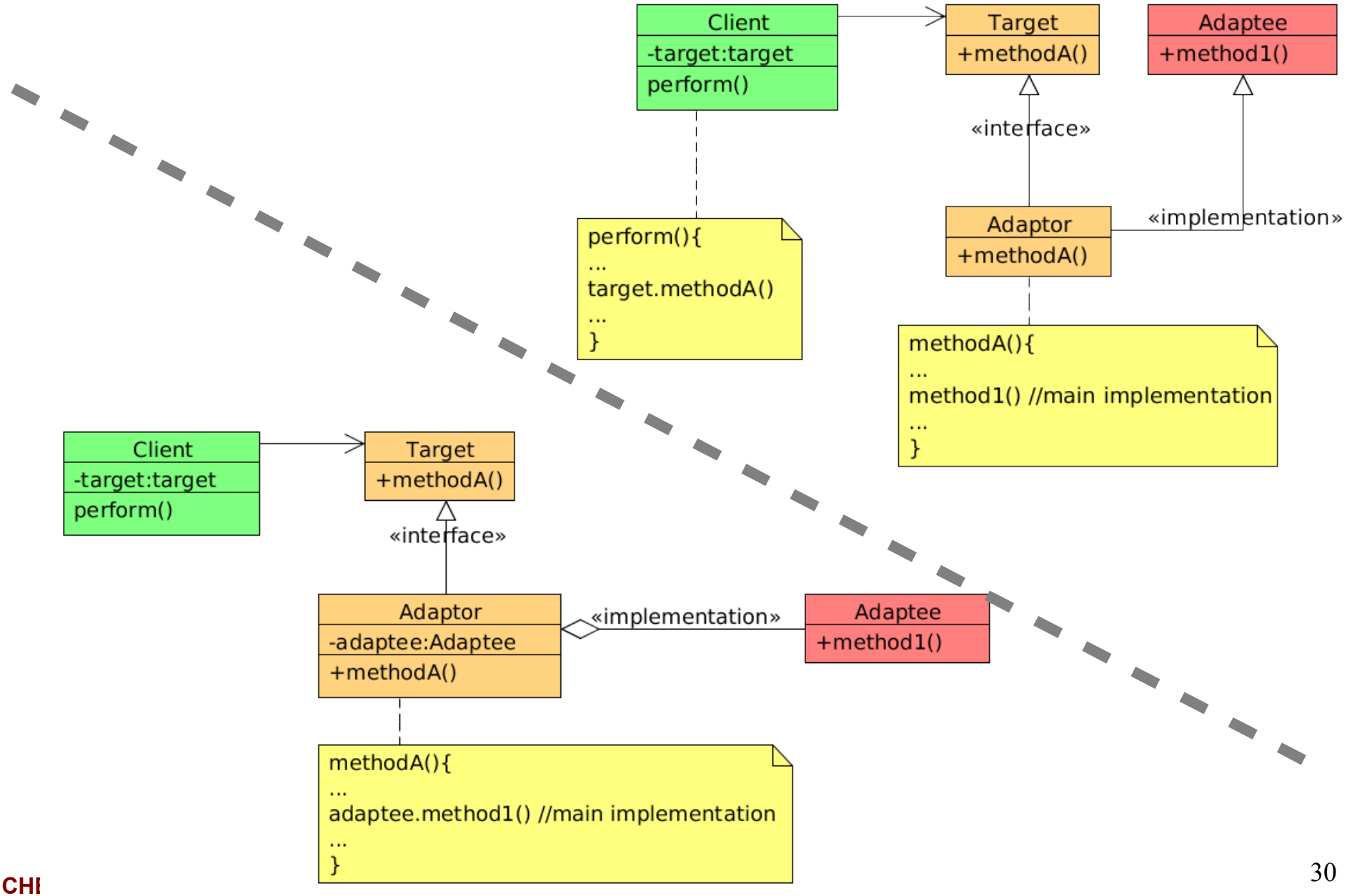
Class

- commitment to a **concrete** adaptee class
  - not to its subclasses (class hierarchy)
- allows for specialization
  - how?
- static in nature

Object

- can use many adaptees
  - including sub-classes
- harder to override the adaptee behavior
  - why?

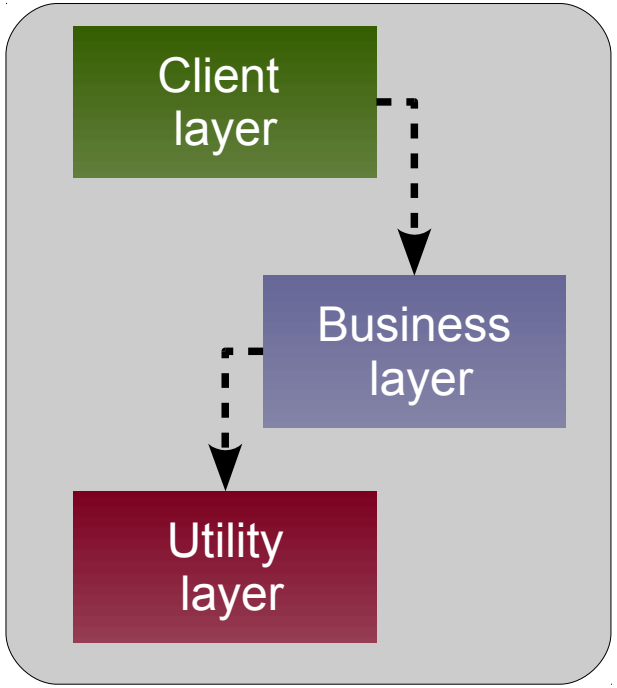
Adapter – Class vs. Object



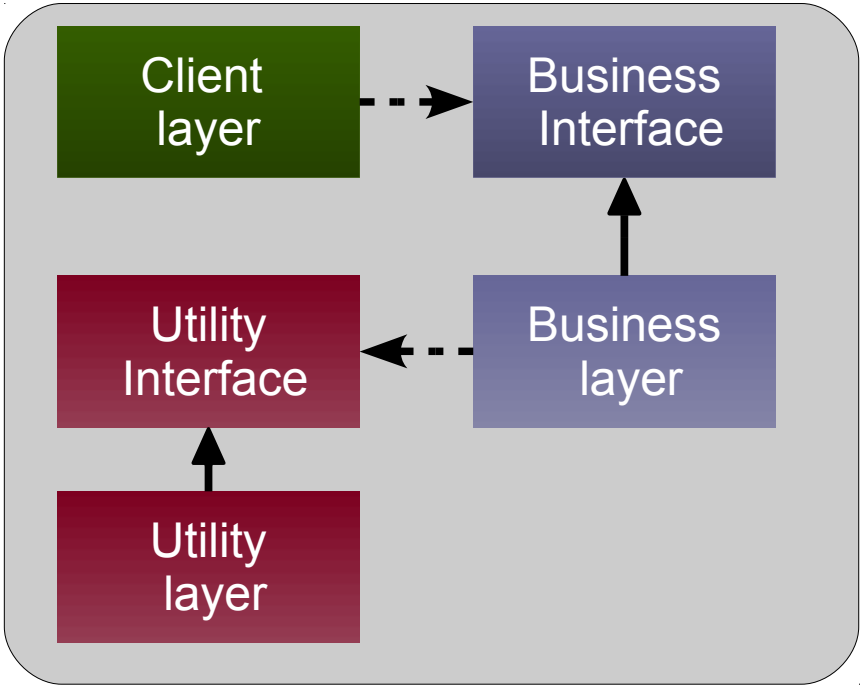
Adapter & Dependency Inversion

Dependency Inversion (DI)

- decouple high level layer from lower level layer(s)



Simple Layers

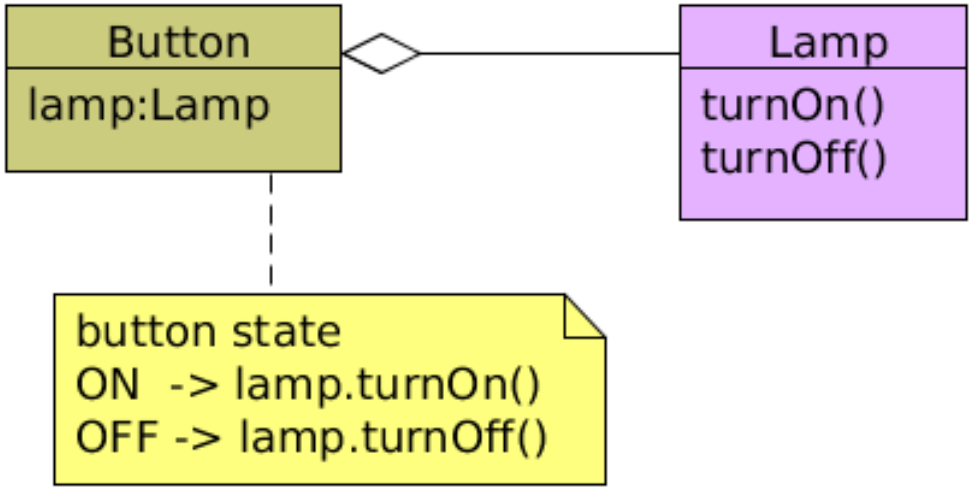


Abstract Layers

Dependency Inversion Example

Implications

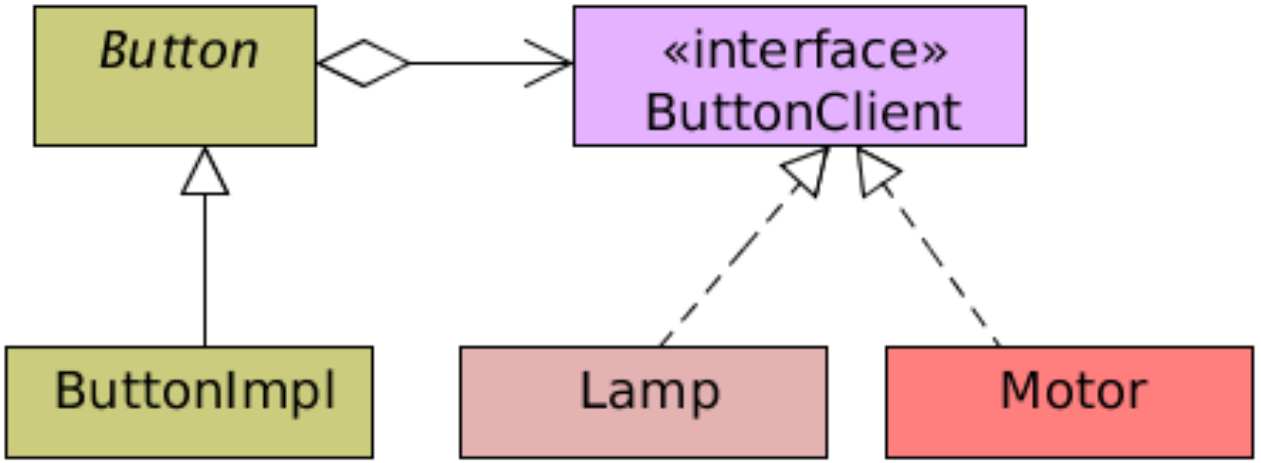
- Button implementation relies on Lamp
- any changes to Lamp will impact Button
- what if we want to **reuse** Button class with a different component
  - such as a motor



Dependency Inversion Example

Dependency Inversion to Rescue

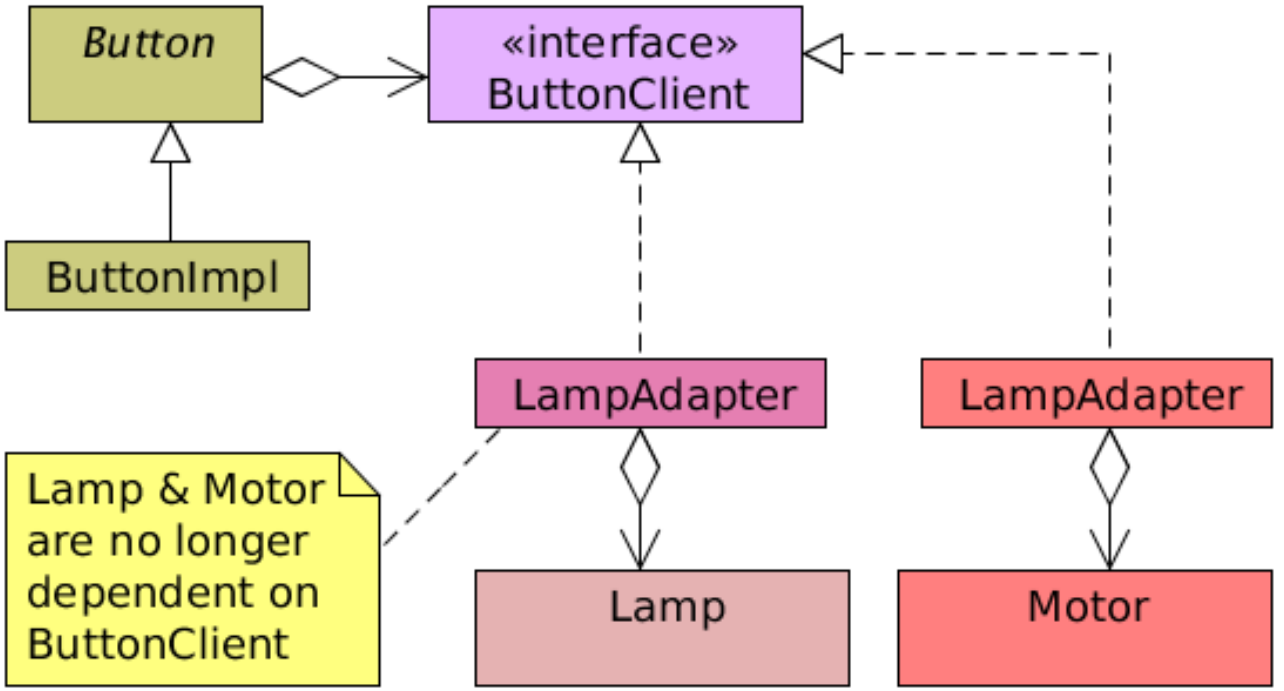
- looks good (?)
- still a dependency left



Dependency Inversion Example

Observation

- adapter enhanced the design
  - increased re-usability at the price of complexity



Adapter

How much adaptation is reasonable?

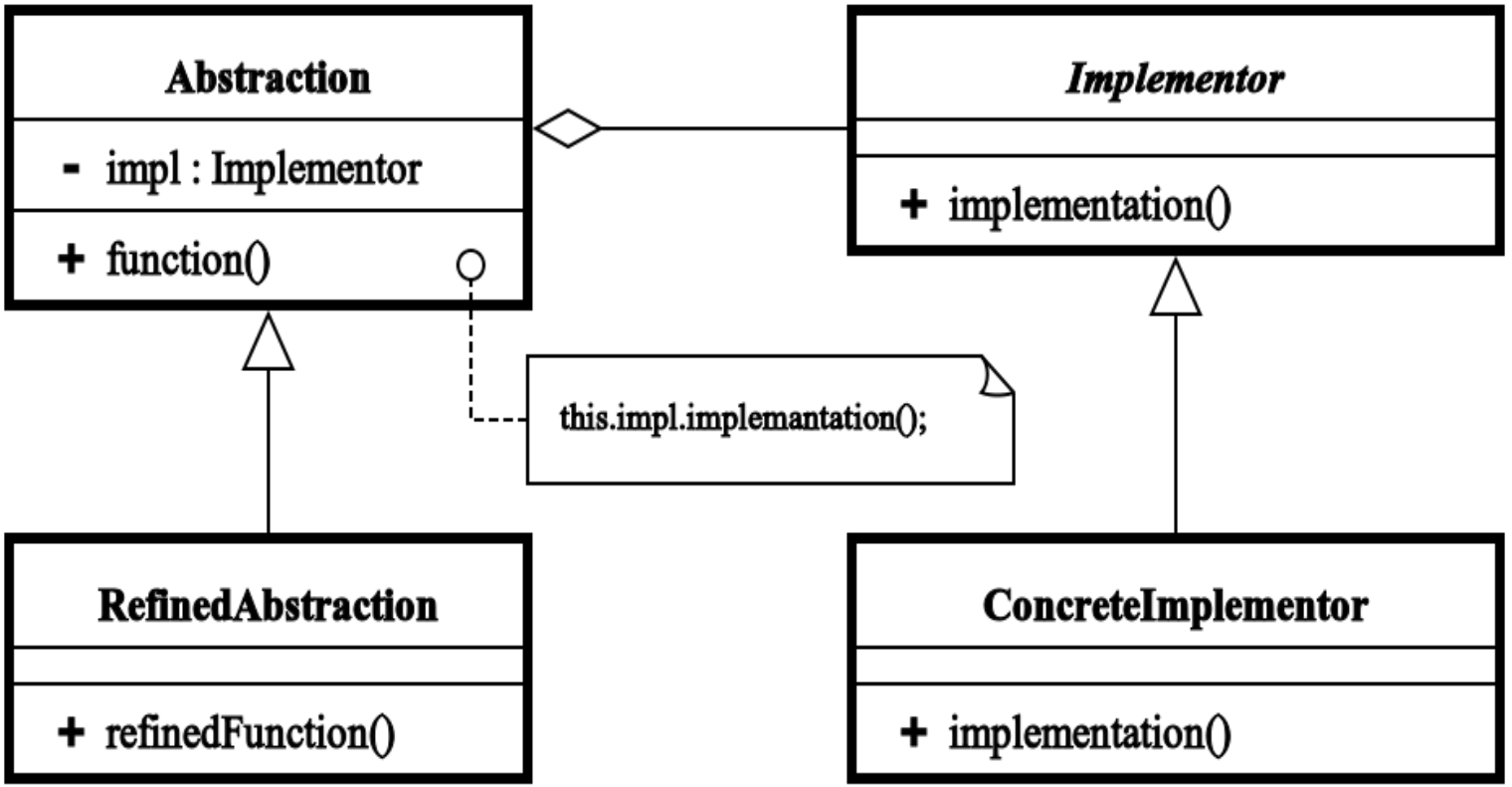
Bridge

Intent

- *"**decouples** an **abstraction** from its **implementation** so the two can vary independently"*

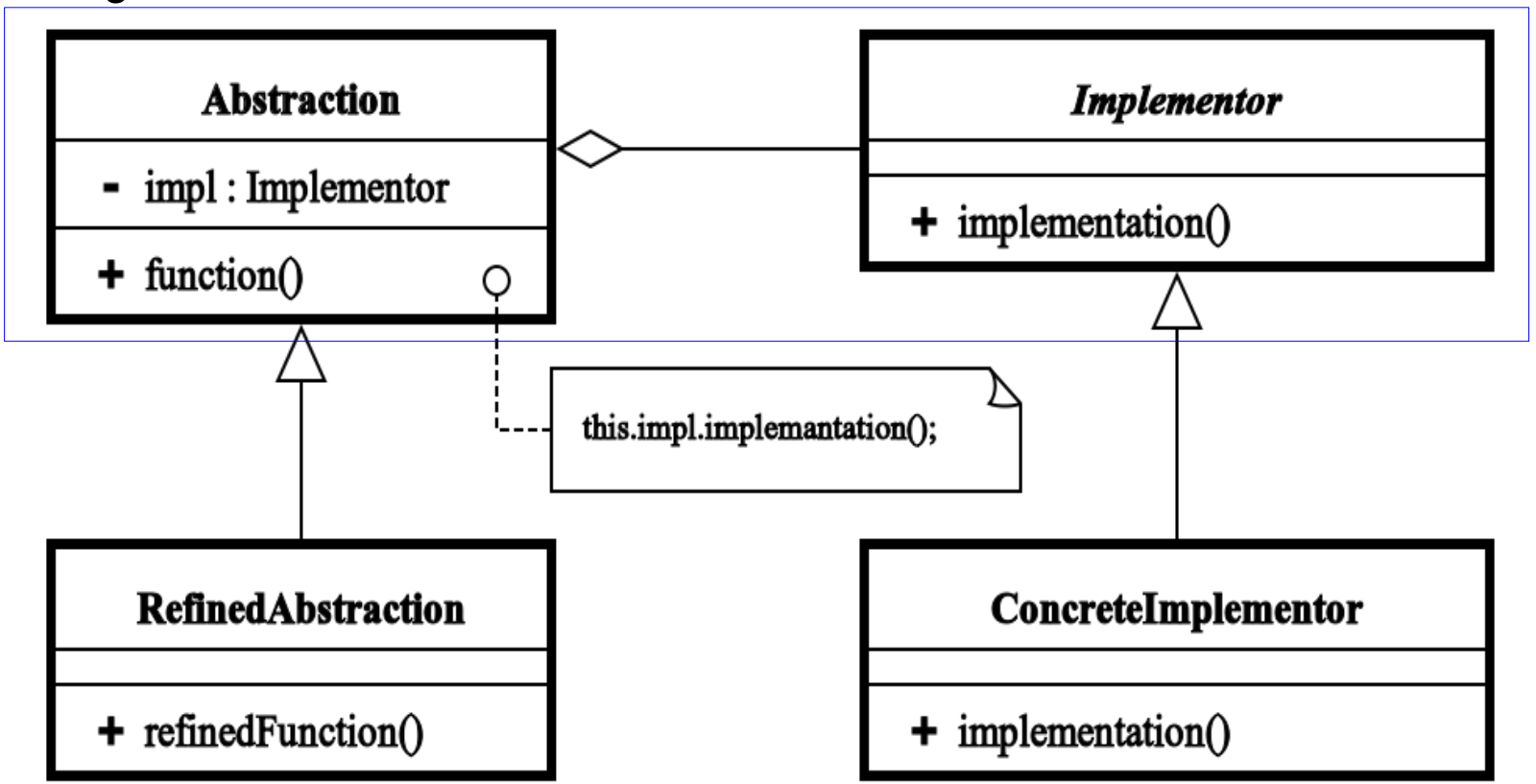
- does this not sounds like an adapter?
  - will take a closer look later

Bridge


Abstraction
- impl : Implementor
+ function()
Implementor
+ implementation()
this.impl.implemantation();
RefinedAbstraction
+ refinedFunction()
ConcreteImplementor
+ implementation()

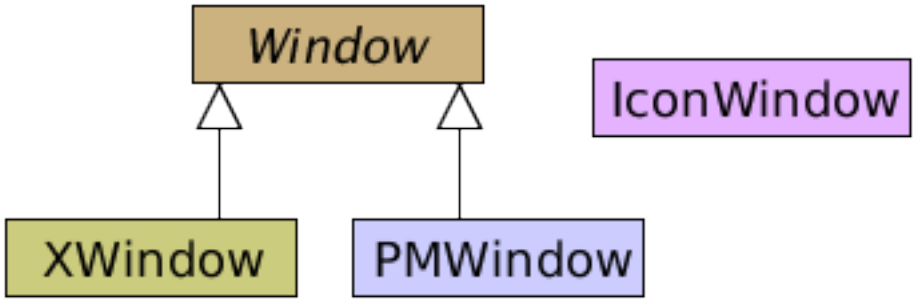
Bridge

Bridge



Bridge Example

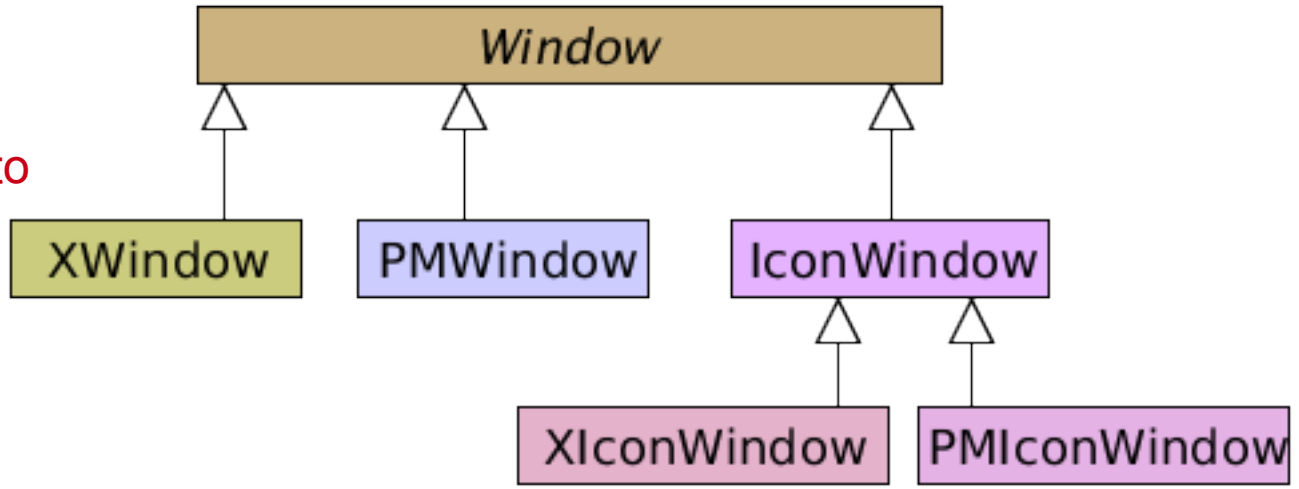
Problem



Solution via inheritance

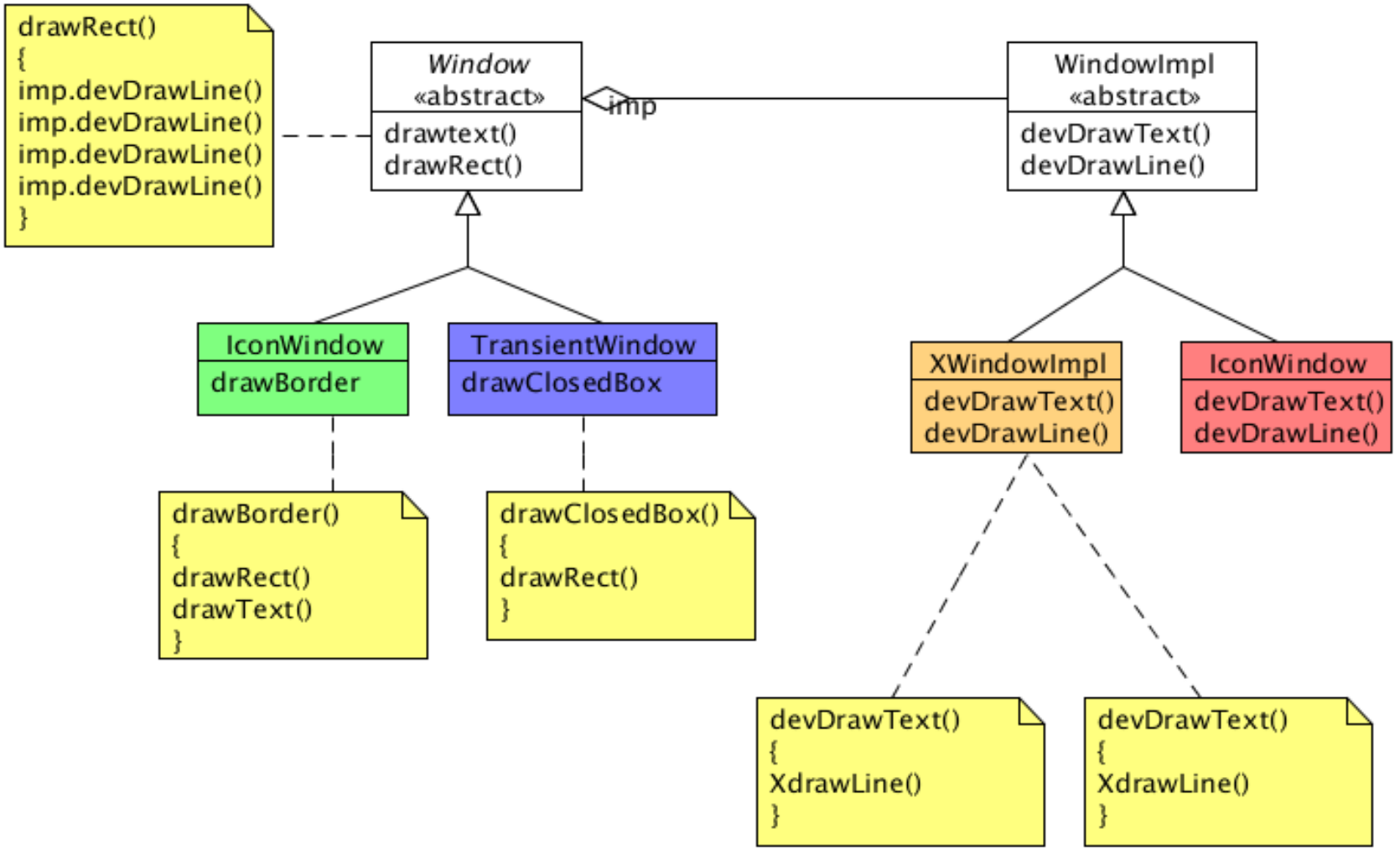
problem1: what if we have to support another platform?

problem2: client code is tied to an implementation.
For portable code, the client should not refer to an implementation



Bridge Example

Solution: Use bridge pattern to place abstraction and implementation in two different hierarchies



Bridge Example

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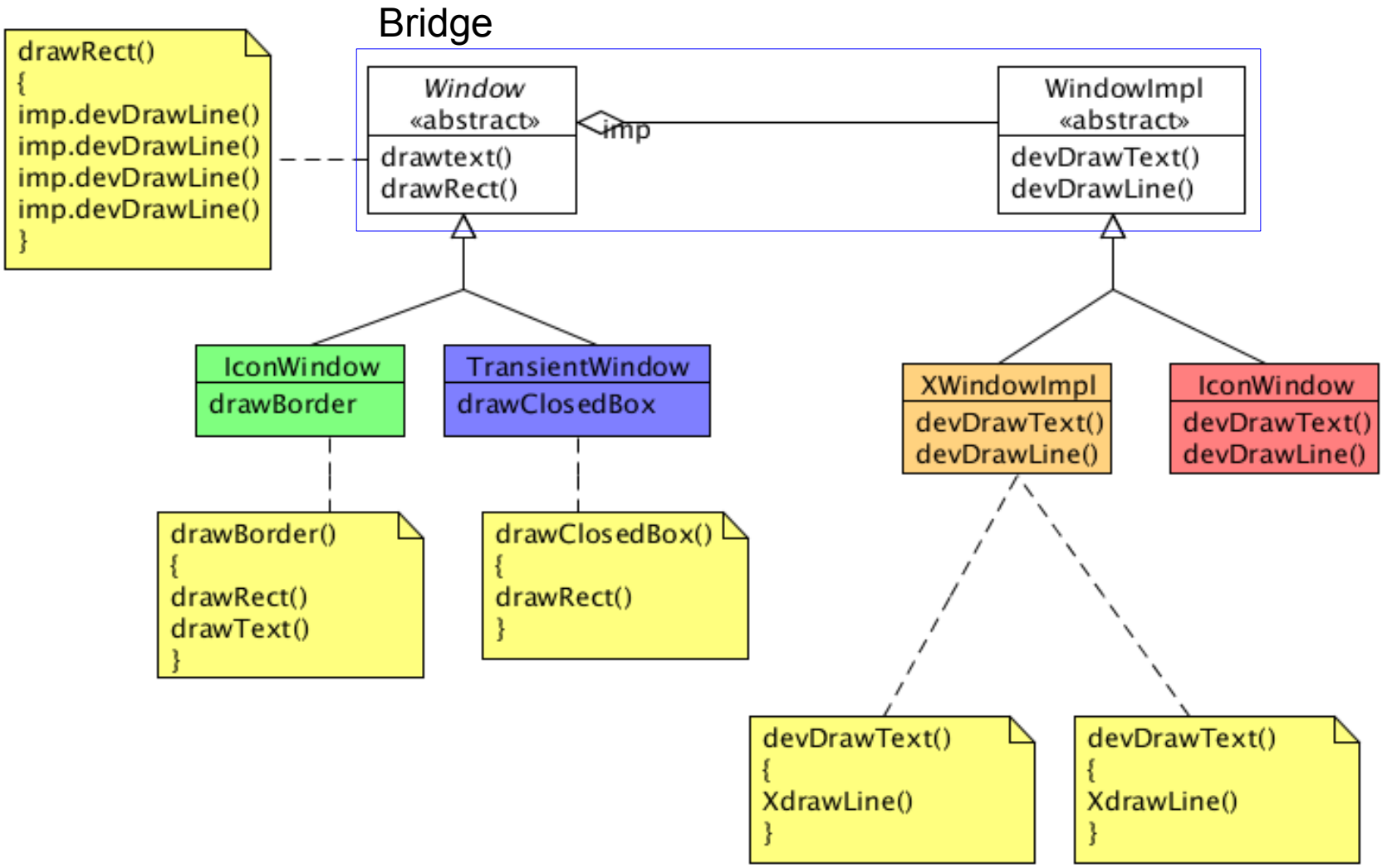

Bridge

Features

- flexible binding between abstraction & implementation
- two class hierarchies
- clients are decoupled

Adapter & Bridge

Common Elements

- flexibility via indirection
- request forwarding

Adapter & Bridge

Difference in intent

- adapter
  - resolves incompatibilities between two existing interfaces
  - two interfaces are independent and can evolve separately
  - coupling is unforeseen
  - adapts components after they have been designed
- bridge
  - connects an abstraction and its many implementations
  - evolution is in accordance with the base abstraction
  - coupling between the abstraction and the implementations are known