

Subtyping and Inheritance

Prof. Dr. Dirk Riehle

Friedrich-Alexander University Erlangen-Nürnberg

ADAP C03

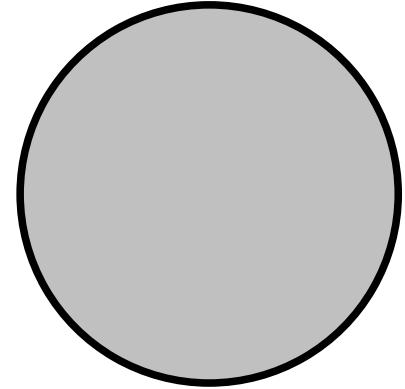
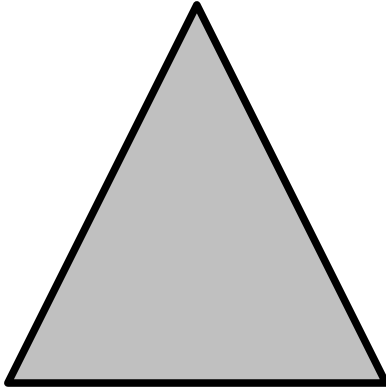
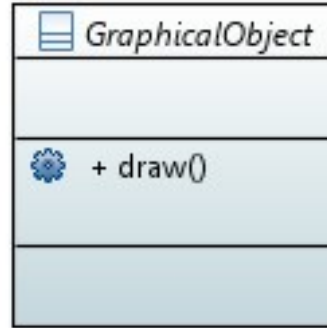
Licensed under [CC BY 4.0 International](#)

Agenda

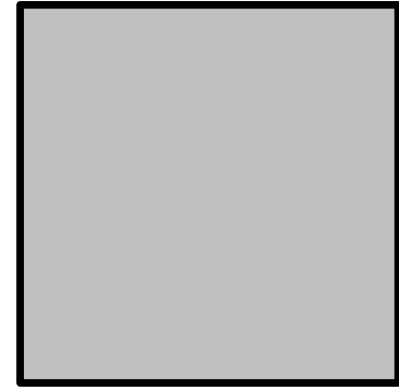
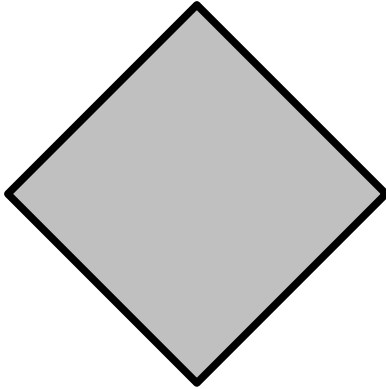
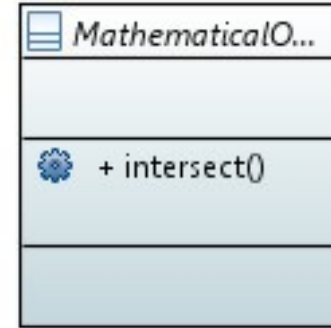
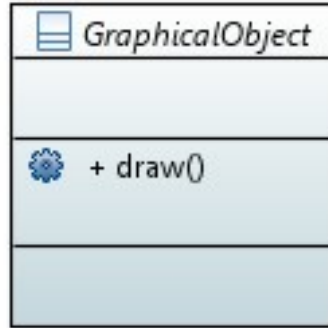
1. Forms of subtyping
2. Liskov Substitutability Principle (LSP)
3. Applied to class hierarchies
4. Co- and contravariance
5. Multiple inheritance
6. Abstract Superclass Rule (ASR)
7. Class hierarchy evolution
8. Cascading superclass calls

1. Forms of Subtyping

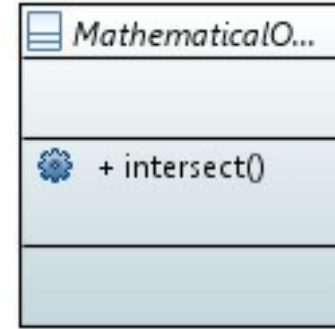
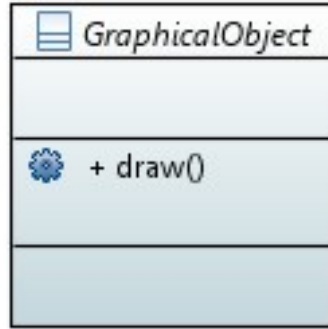
Subtyping Examples 1 / 3



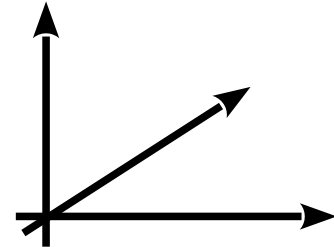
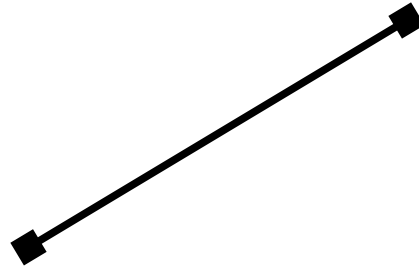
Subtyping Examples 2 / 3



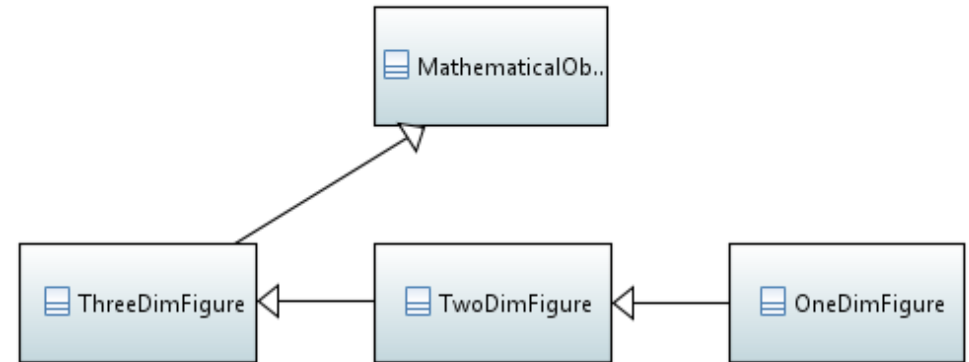
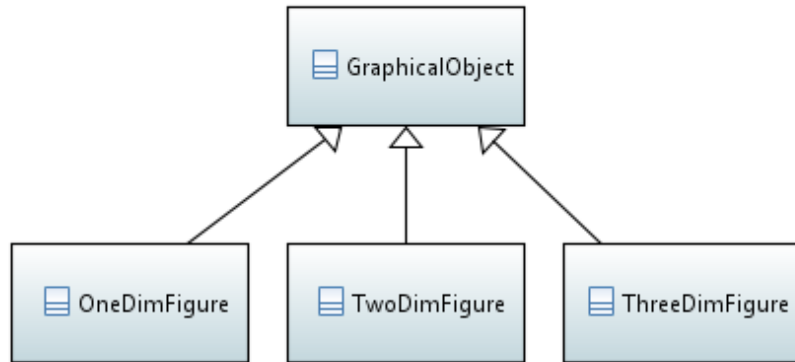
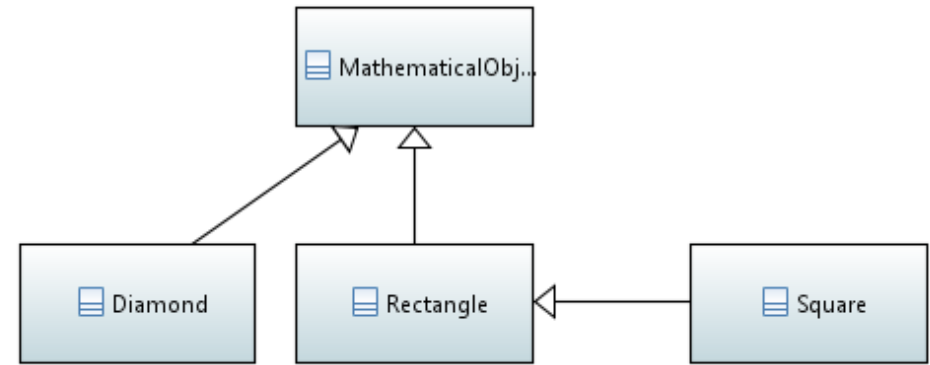
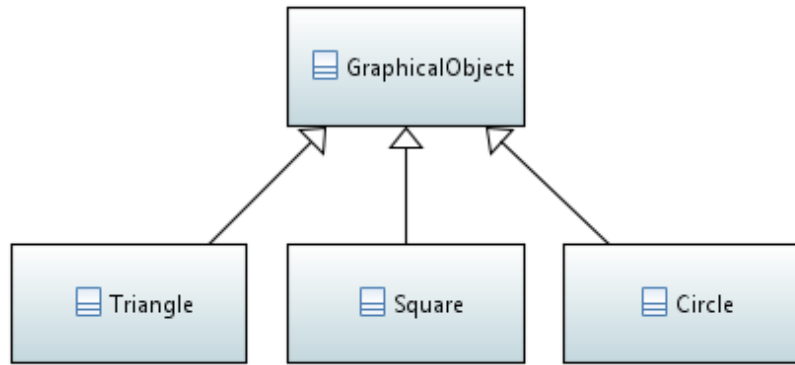
Subtyping Examples 3 / 3



×



Subtyping Examples Discussion Continued



2. Liskov Substituability Principle

Let $\phi(x)$ be a property provable about objects x of type T . Then $\phi(y)$ should be provable for objects y of type S , where S is a subtype of T .

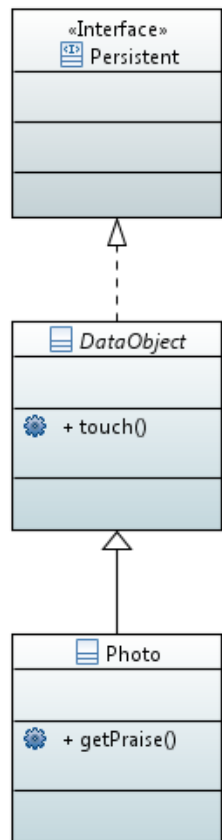
[1] A.k.a. Liskov Substitutability Principle (LSP)

All properties that hold for instances of a supertype should also hold for instances of a subtype.

**No surprises
for a use-client**

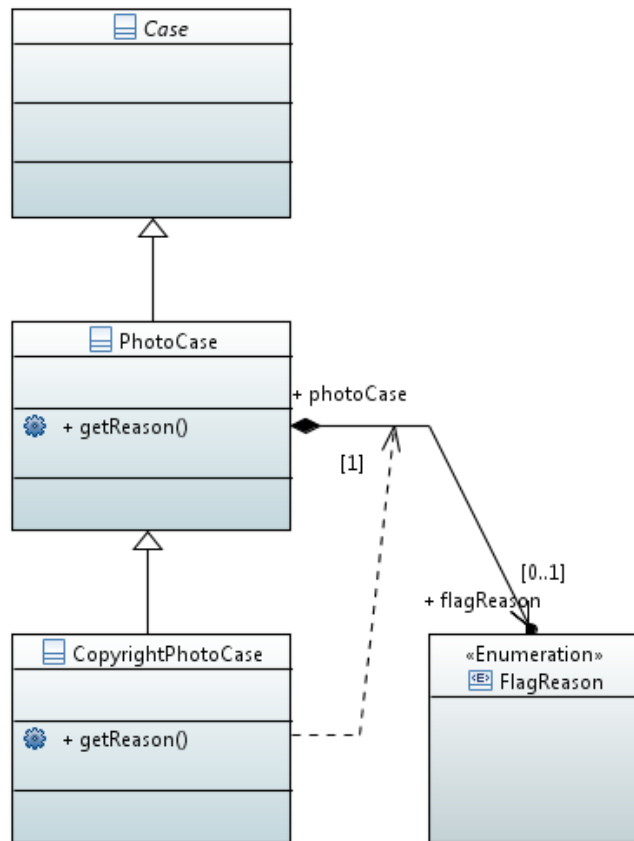
3. Applied to Class Hierarchies

Subclasses as Extended Subtypes



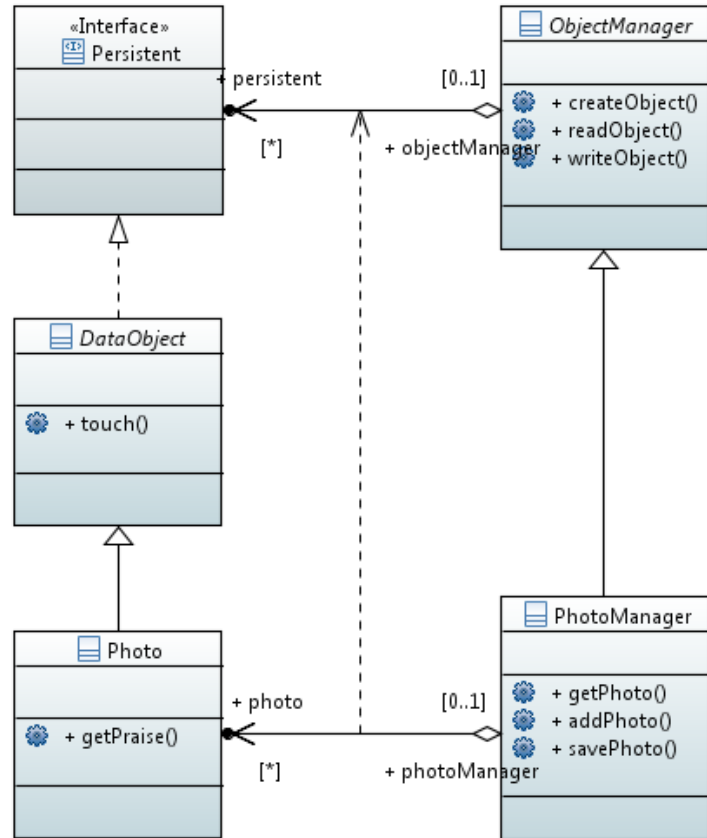
- Subclass
 - Adds methods and state
 - Does not constrain superclass
- Example
 - `public void DataObject#touch()`
 - `public float Photo#getPraise()`

Subclasses as Constrained Subtypes



- Constrained subtypes
 - Superclass defines possibility space
 - Subclass constrains behavior or return results
- Example
 - `FlagReason PhotoCase#getReason()`
 - Returns any of enum `FlagReason`
 - `FlagReason CopyrightPhotoCase#getReason()`
 - Returns only `FlagReason.COPYRIGHT`

Dual Class Hierarchies



- Constrained subtypes
 - ObjectManager
 - PhotoManager
- Extended subtypes
 - ObjectManager and DataObject
 - PhotoManager and Photo
- Association refinement

4. Co- and Contravariance

Covariance and Contravariance

- **Covariant redefinition**

- A method has been **covariantly** redefined in its result or argument types if those result or argument types are of a subclass of the original result or argument types

- **Contravariant redefinition**

- A method of a has been **contravariantly** redefined in its result or argument types if those result or argument types are of a superclass of the original result or argument types

Quiz: Co- and Contravariance

1. Which form of redefinition of result types violates the Liskov Substituability Principle, if any?
 - a. Contravariant redefinition
 - b. Covariant redefinition
 - c. None
 - d. Both

2. Which form of redefinition of method argument types violates the Liskov Substituability Principle, if any?
 - a. Contravariant redefinition
 - b. Covariant redefinition
 - c. None
 - d. Both

Covariance of Method Result Types

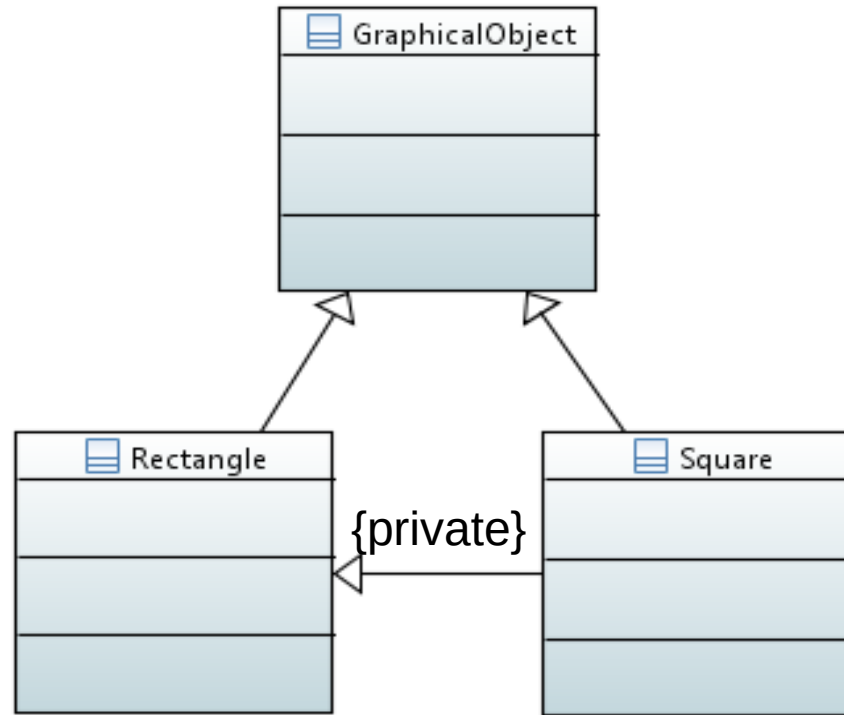
- General Java examples
 - `Object Object#clone()`
 - `MyClass MyClass#clone()`
- Wahlzeit examples
 - `Persistent ObjectManager#createObject(...)`
 - `Photo PhotoManager#createObject(...)`
- Covariant redefinition of method result types satisfies the LSP
 - Case of the constrained subtypes

Contravariance of Method Argument Types

- Not a language feature in Java (but in other languages)
 - Hence no examples at hand
- Contravariant redefinition of method arguments satisfies the LSP
 - Case of the extended subtypes

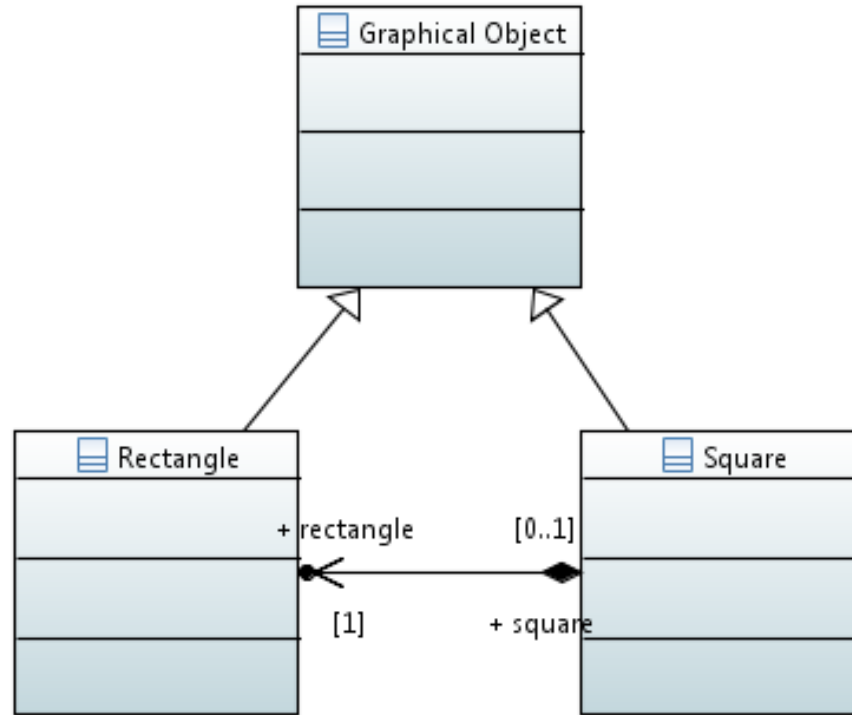
5. Multiple Inheritance

Multiple Inheritance



Not possible in Java (not a language feature)

Implementation Delegation



Well possible in Java (and other languages)

Interface vs. Implementation Inheritance

- **Interface inheritance**

- Follows the LSP
- Can be realized in Java
 - Using Java interfaces
 - Using regular classes

- **Implementation inheritance**

- Breaks the LSP
- Can be realized in Java
 - But is generally a bad idea
 - Rather use delegation

6. Abstract Superclass Rule

Inheritance and Abstractness

- Inheritance
 - Relationship between two classes, a superclass and a subclass
- Abstract(ness)
 - Relationship between a class and its instances (none if abstract)

**All superclasses must be abstract
(in design).**

A superclass should be abstract in implementation.

How to Make a Class Abstract (in Java)

- By declaration
 - of the class, e.g. “abstract class Counter { ... }”
 - of at least one method, e.g. “public abstract void count(...)”
- By hiding constructors
 - by declaring them protected or private
 - by making sure no implicit public empty constructor exists
- By inheritance
 - by inheriting from an abstract class and
 - not completing it
- **The best way is to explicitly declare one's intention**

Corollaries to Abstract Superclass Rule

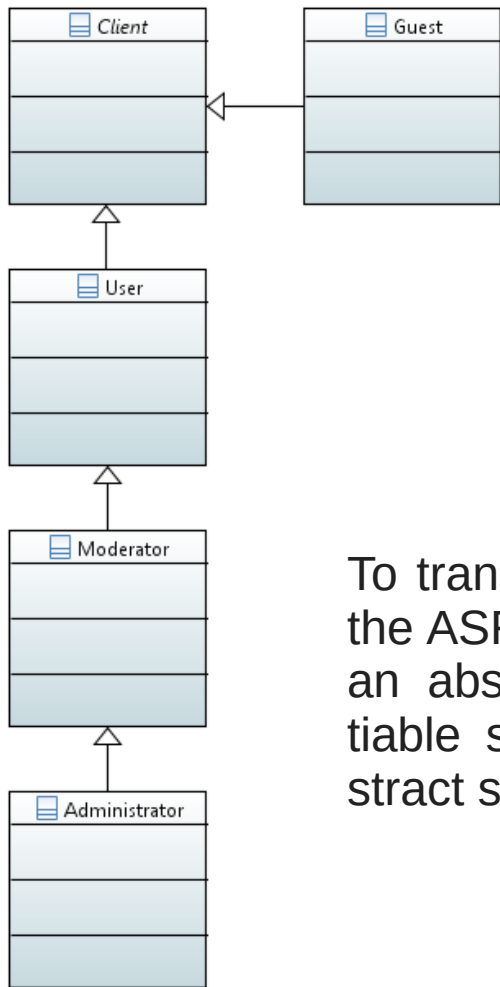
- Hard corollaries (rules)
 - No abstract class should subclass a concrete class
 - All subclasses should first be abstract, then concrete
- Soft corollaries (guidelines)
 - The root of a class hierarchy should be an abstract class
 - (Most) leaf classes in an application should be concrete
- In a framework, leaf classes may be abstract
 - Because they are expecting subclasses in applications

But Why? LSP applied to ASR

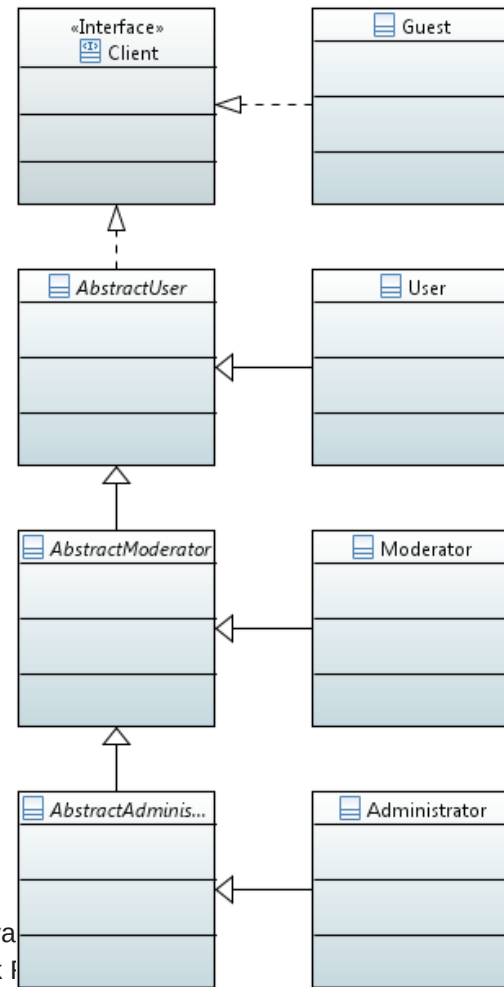
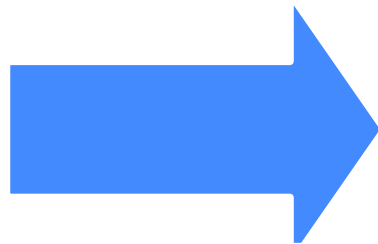
- The ASR helps comply with the LSP
 - The ASR automatically casts subclasses as constrained subtypes
 - Applying the ASR, developers have to think about subclasses
 - Subclasses fill in the holes defined by the abstract superclass
 - Thus, concrete subclasses constrain the abstract superclass
 - With this, the abstract superclass becomes better (re)usable

7. Class Hierarchy Evolution

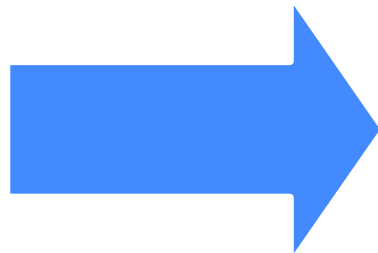
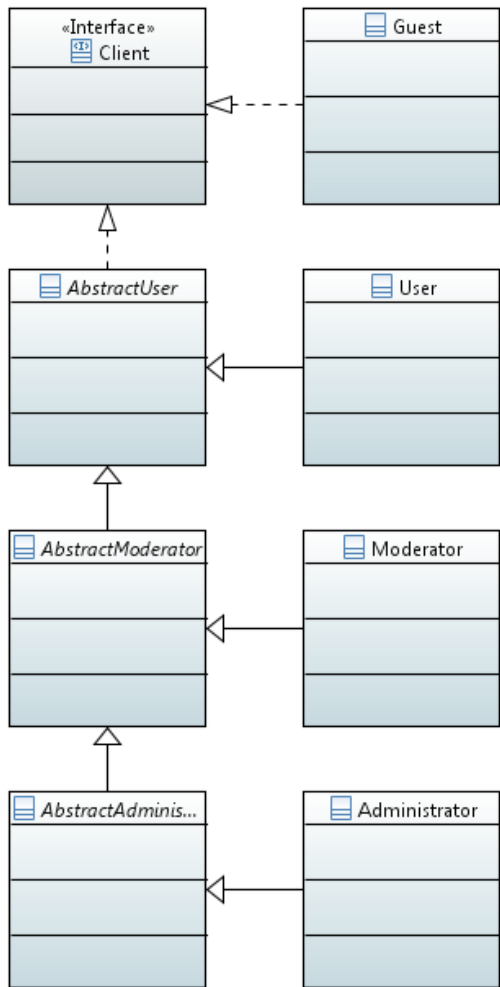
Transforming a Class Hierarchy



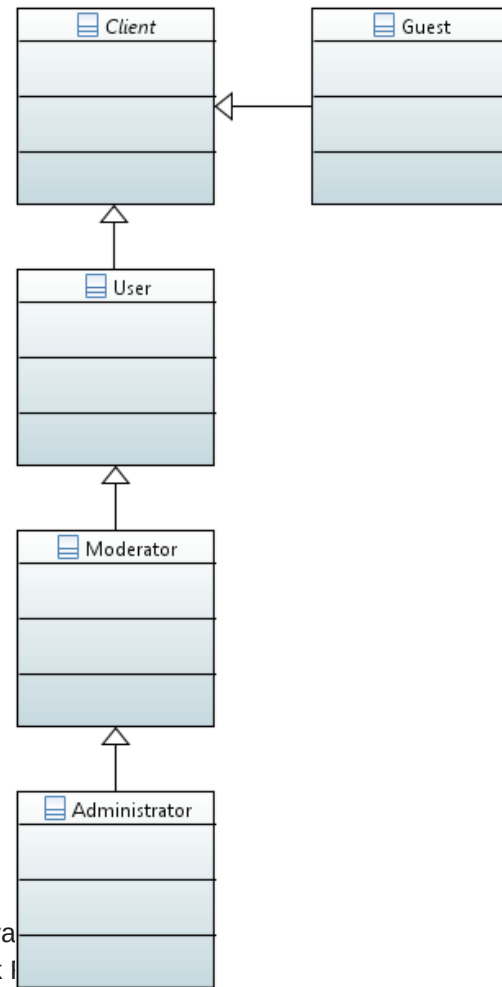
To transform a class hierarchy to conform to the ASR, split the instantiable superclass into an abstract class and introduce an instantiable subclass that completes the new abstract superclass.



Simplifying a Class Hierarchy



To simplify a class hierarchy, merge a default implementation with its abstract super-class.

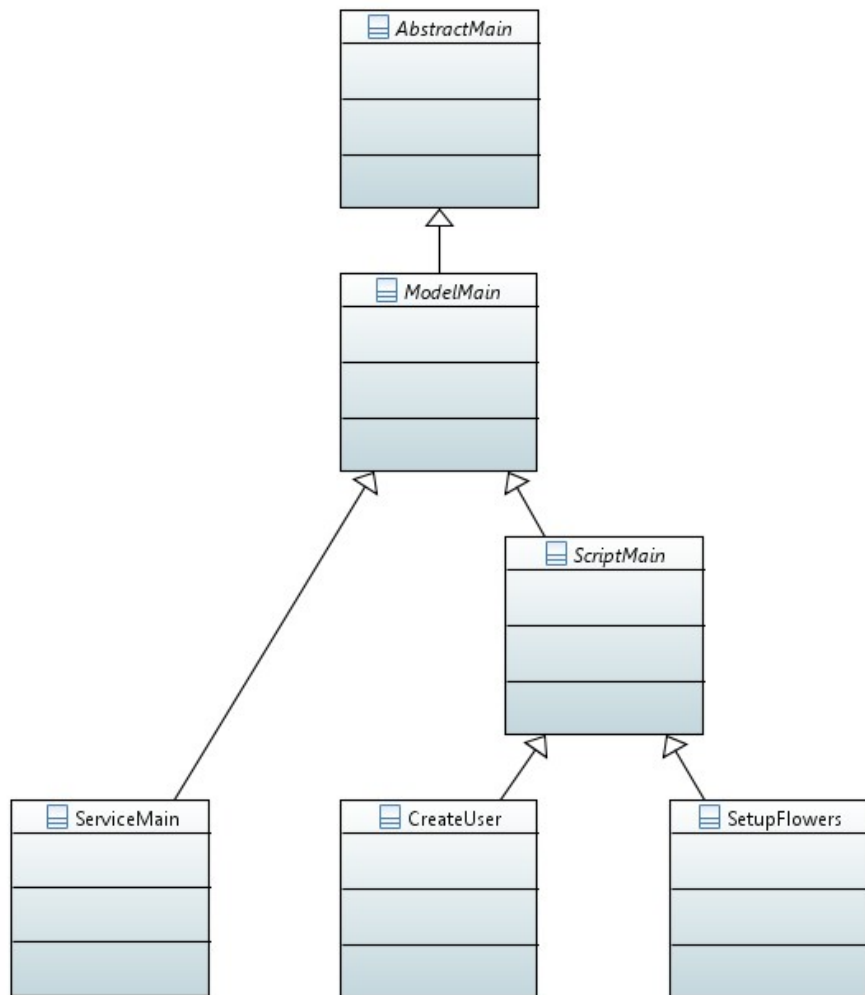


What to Use When?

- Transform to conform in preparation for
 - Increasingly complex default implementation class
 - Other implementation classes as alternatives
- Simplify (and not conform) to
 - Reduce number of overall classes
 - Assuming implementation class is basically empty

8. Cascading Superclass Class

Cascading Inheritance Interfaces



- **ServiceMain#startUp()** →
 - **ModelMain#startUp()** →
 - **AbstractMain#startUp()**
- **ServiceMain#shutDown()** →
 - **ModelMain#shutDown()** →
 - **AbstractMain#shutDown()**
- **CreateUser#execute()** →
- **ScriptMain#execute()**

Cascading Superclass Calls

```
public void ServiceMain#startUp(boolean ip, String rd) ... {  
    super.startUp(ip, rd);  
    log.info("ModelMain#startUp() completed");  
  
    log.config(LogBuilder.createSystemMessage());  
    initWebPartTemplateService();  
    ...  
}
```

```
protected void ModelMain#startUp(boolean ip, String rd) ... {  
    super.startUp(ip);  
    log.info("AbstractMain#startUp() completed");  
  
    log.config(LogBuilder.createSystemMessage());  
    initImageStore();  
    ...  
}
```

```
protected void AbstractMain#startUp(boolean ip) throws Exception {  
    isInProduction = ip;  
}
```

Traditional Run vs. ServletContext

```
public static main(String[] argv) { new FlowersMain.run() }

void FlowersMain#run() {
    ...
    startUp();
    execute();
    shutDown();
    ...
}
```

```
public void contextInitialized(ServletContextEvent sce) {
    ...
    serviceMain.startUp(true, rootDir);
    ...
}
public void contextDestroyed(ServletContextEvent sce) {
    ...
    serviceMain.shutDown();
    ...
}
```

Summary

1. Forms of subtyping
2. Liskov Substitutability Principle (LSP)
3. Applied to class hierarchies
4. Co- and contravariance
5. Multiple inheritance
6. Abstract Superclass Rule (ASR)
7. Class hierarchy evolution
8. Cascading superclass calls

Thank you! Questions?

`dirk.riehle@fau.de` – `https://oss.cs.fau.de`

`dirk@riehle.org` – `https://dirkriehle.com` – `@dirkriehle`

Legal Notices

- License
 - Licensed under the **CC BY 4.0 International** License
- Copyright
 - © 2012-2022 Dirk Riehle, some rights reserved