Subtyping and Inheritance

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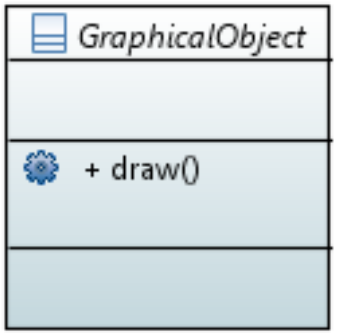
ADAP C03

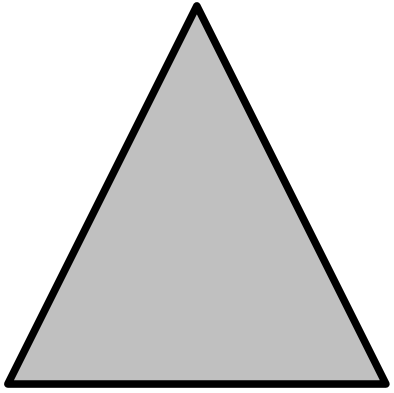
Agenda

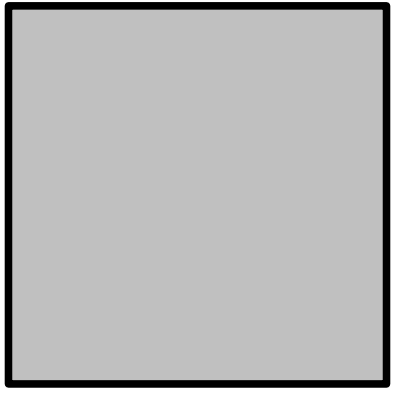
1. Forms of subtyping
2. Liskov Substitutability Principle (LSP)
3. Applied to class hierarchies
4. Co- and contravariance
5. Multiple inheritance
6. Abstract Superclass Rule (ASR)
7. Class hierarchy evolution
8. Cascading superclass calls

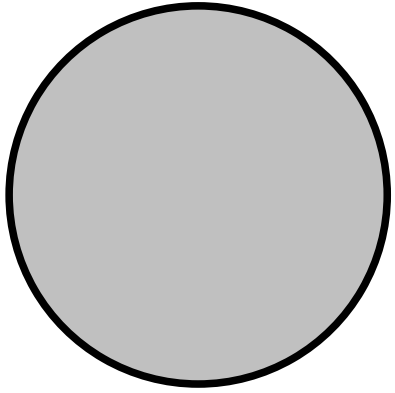
1. Forms of Subtyping

Subtyping Examples 1 / 3

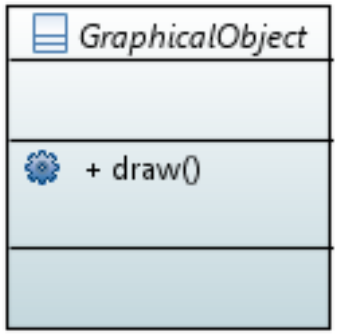


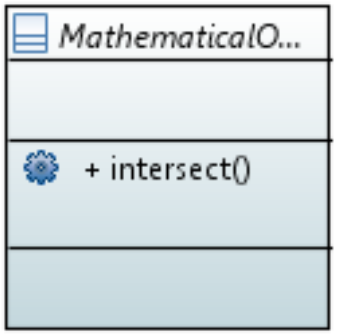


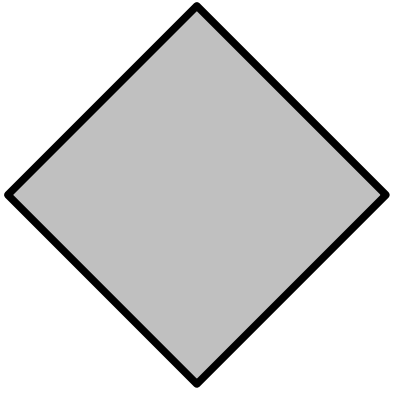


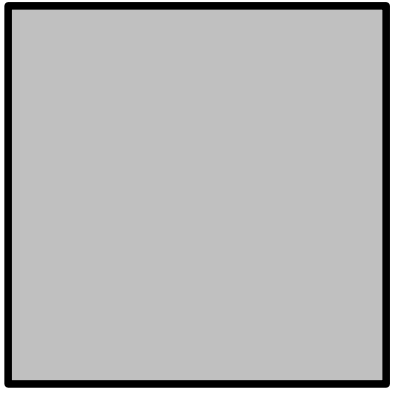


Subtyping Examples 2 / 3

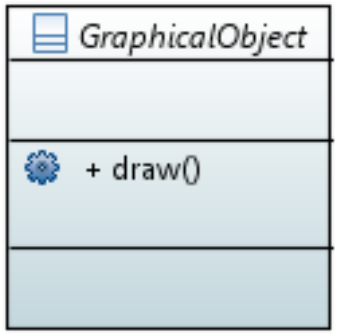


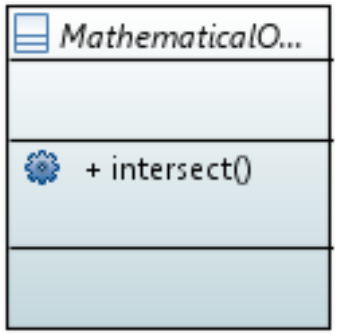


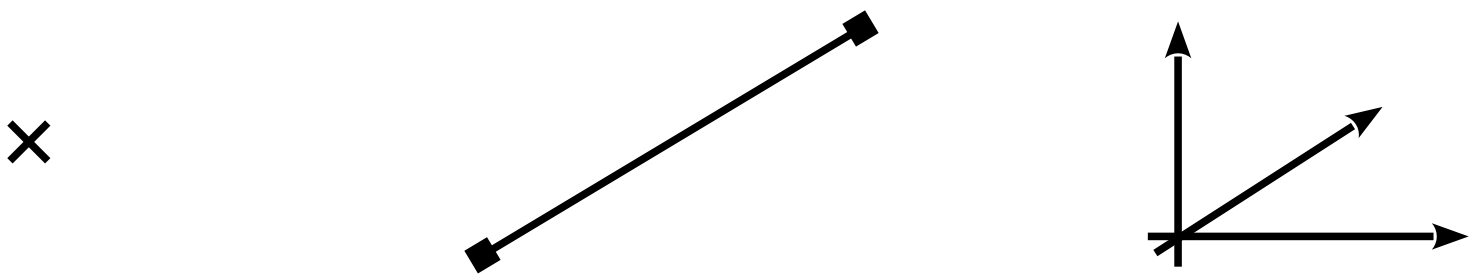




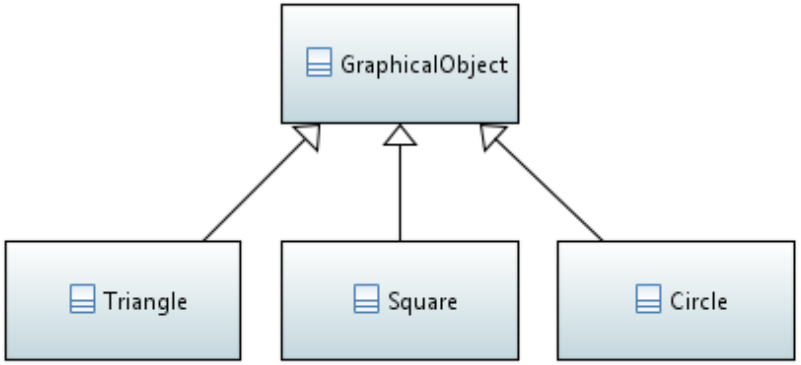
Subtyping Examples 3 / 3

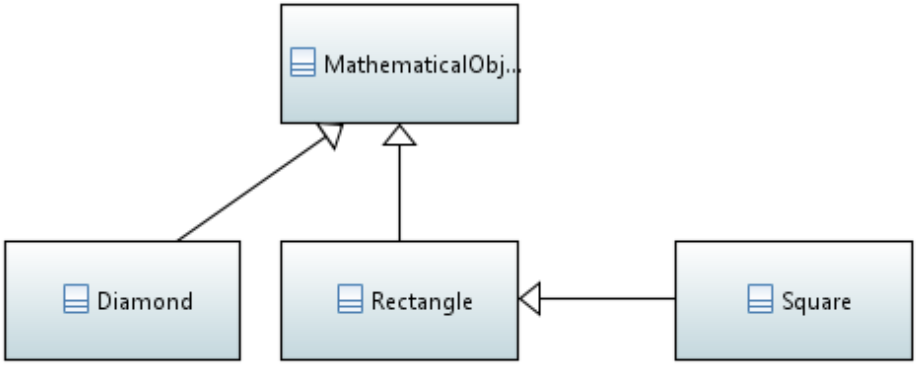


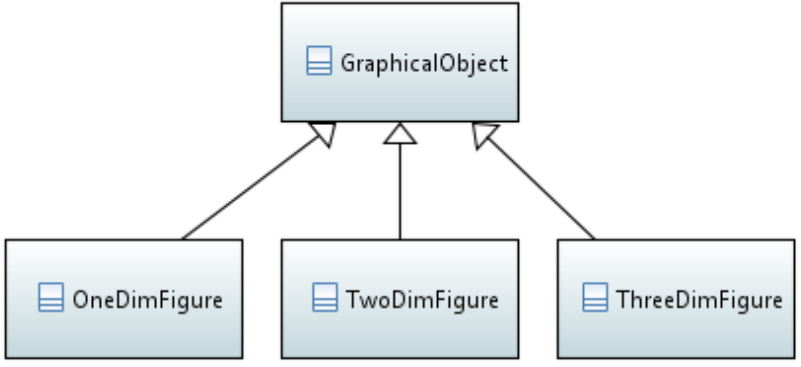


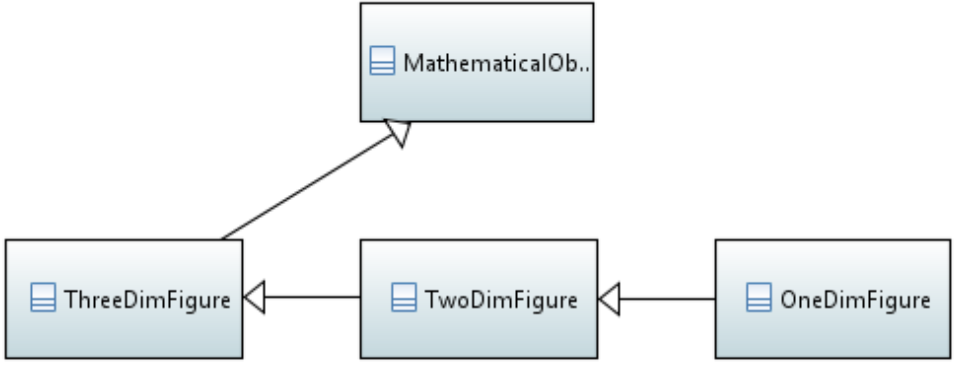


Subtyping Examples Discussion Continued









2. Liskov Substituability Principle

The Subtype Requirement [LW94] [1]

Let Φ(x) be a property provable about objects x of type T. Then Φ(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)

In Simpler Words

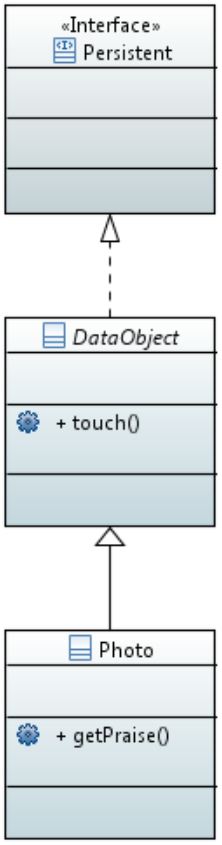
All properties that hold for instances of a supertype should also hold for instances of a subtype.

Even Simpler

No surprises
for a use-client

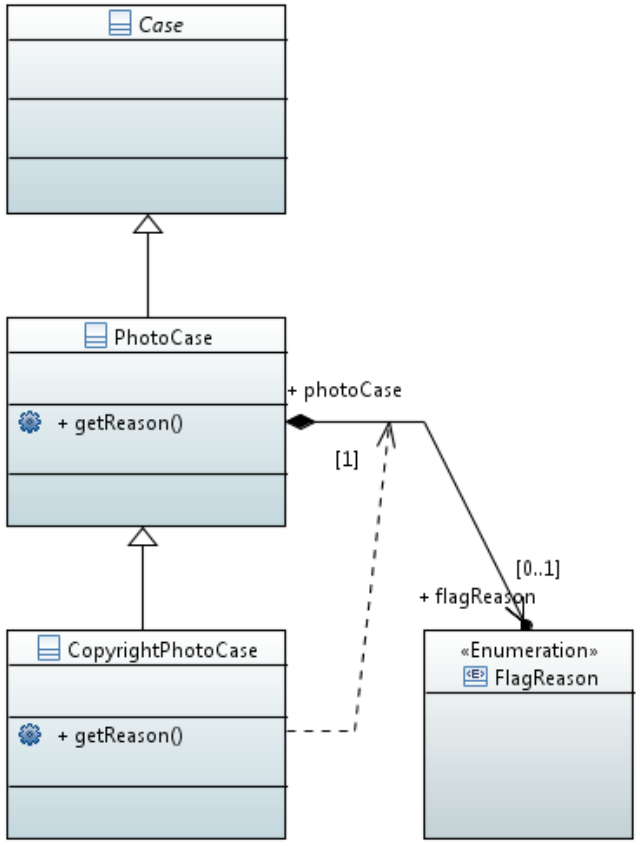
3. Applied to Class Hierarchies

Subclasses as Extended Subtypes



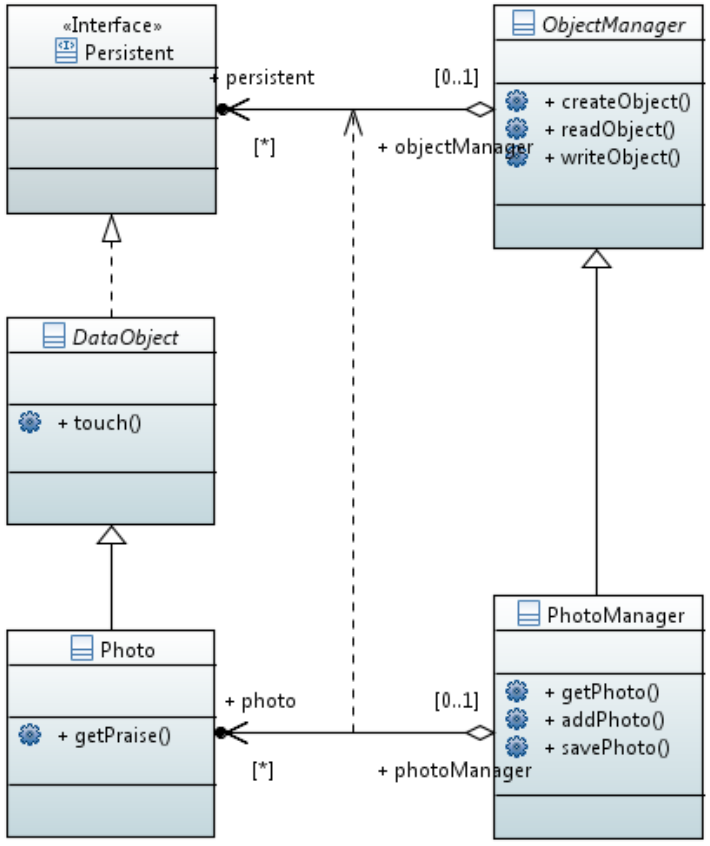
- Subclass
  - Adds methods and state
  - Does not constrain superclass
- Example
  - public void DataObject#touch()
  - public float Photo#getPraise()

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

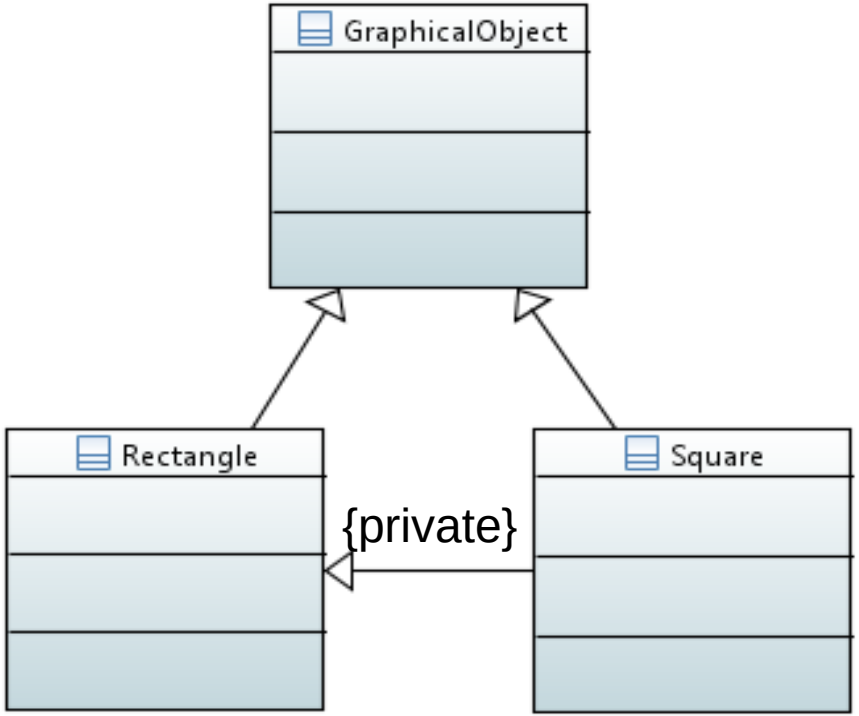
- General Java examples
  - Object Object#clone()
  - MyClass MyClass#clone()
- Wahlzeit examples
  - Persistent ObjectManager#createObject(...)
  - Photo PhotoManager#createObject(...)
- Covariant redefinition of method result types satisfies the LSP
  - Case of the constrained subtypes

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

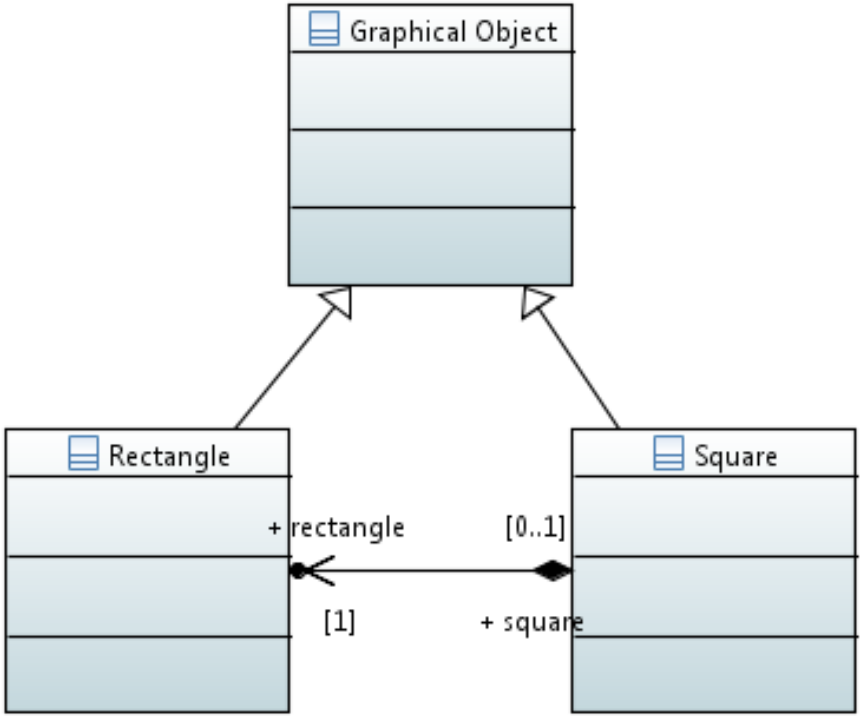
5. Multiple Inheritance

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)

Abstract Superclass Rule (ASR) [H94]

All superclasses must be abstract (in design).

Abstract Superclass Rule as a Guideline

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

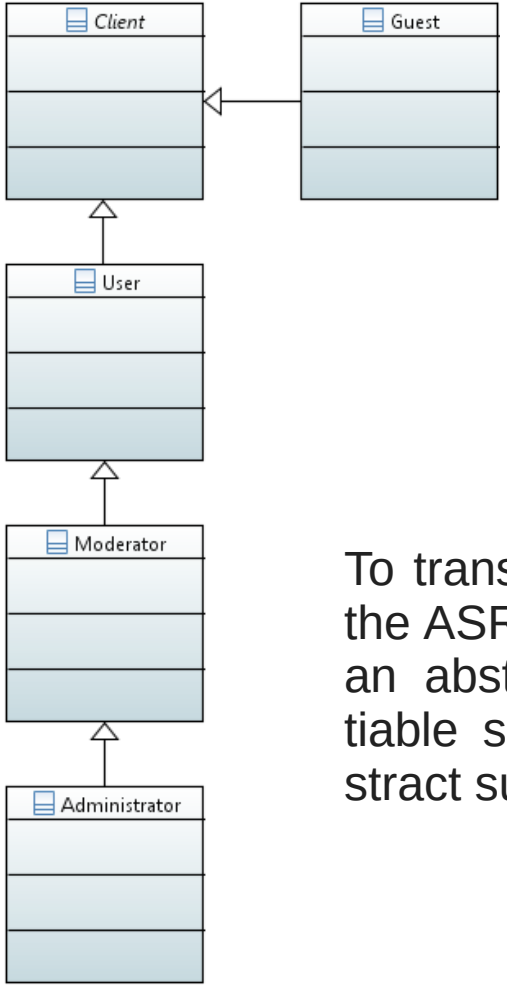
- Hard corollaries (rules)
  - No abstract class should subclass a concrete class
  - All subclasses should first be abstract, then concrete
- Soft corollaries (guidelines)
  - The root of a class hierarchy should be an abstract class
  - (Most) leaf classes in an application should be concrete
- In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

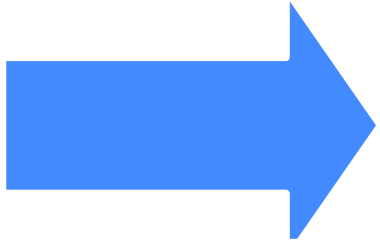
But Why? LSP applied to ASR

- 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

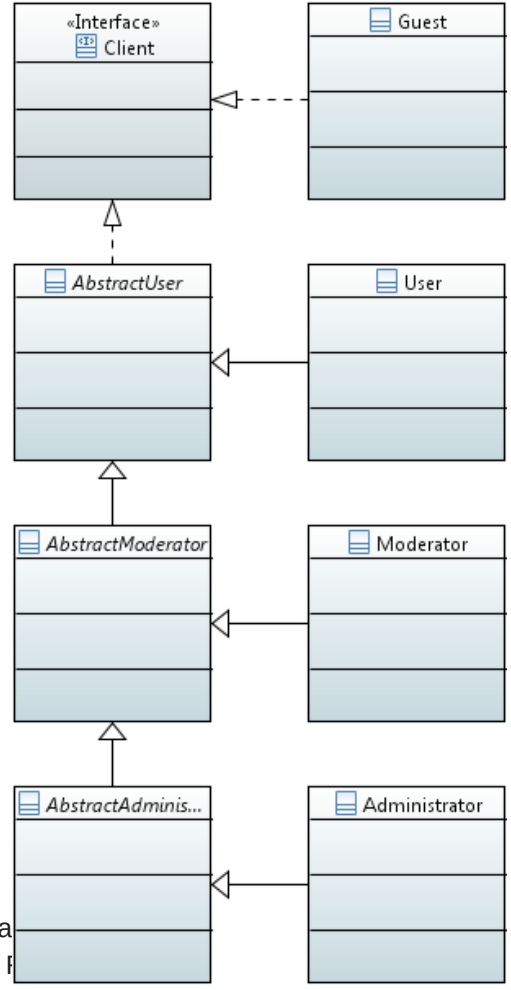
7. Class Hierarchy Evolution

Transforming a Class Hierarchy

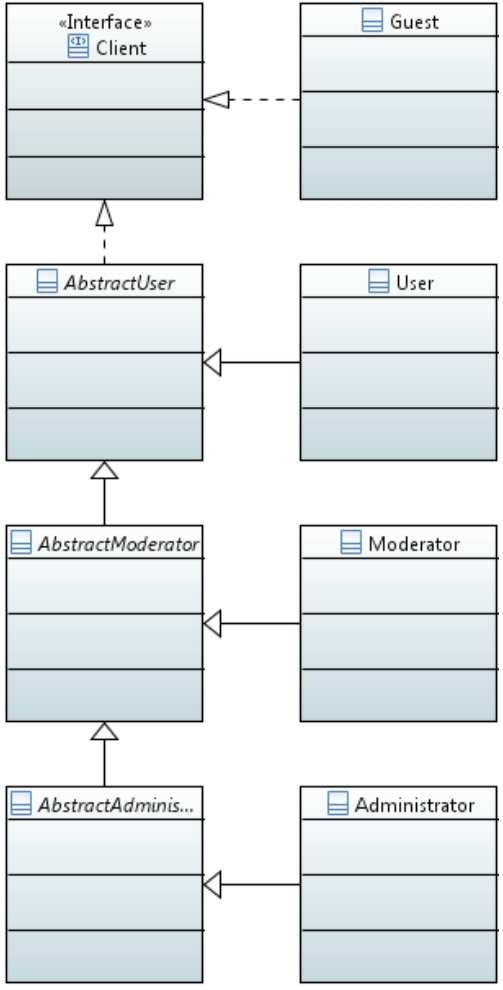


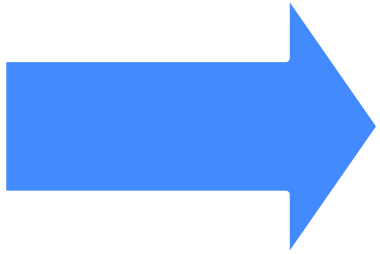


To transform a class hierarchy to conform to the ASR, split the instantiable superclass into an abstract class and introduce an instantiable subclass that completes the new abstract superclass.

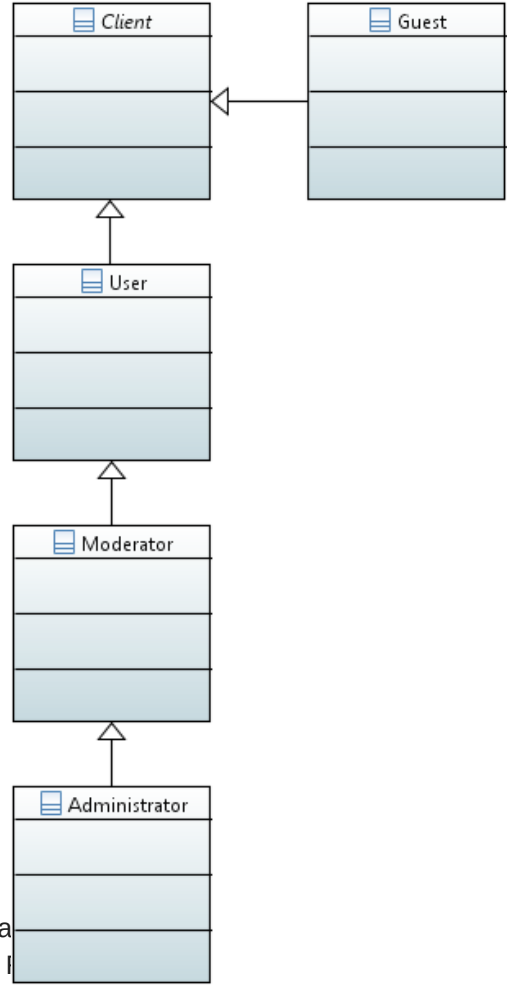


Simplifying a Class Hierarchy





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

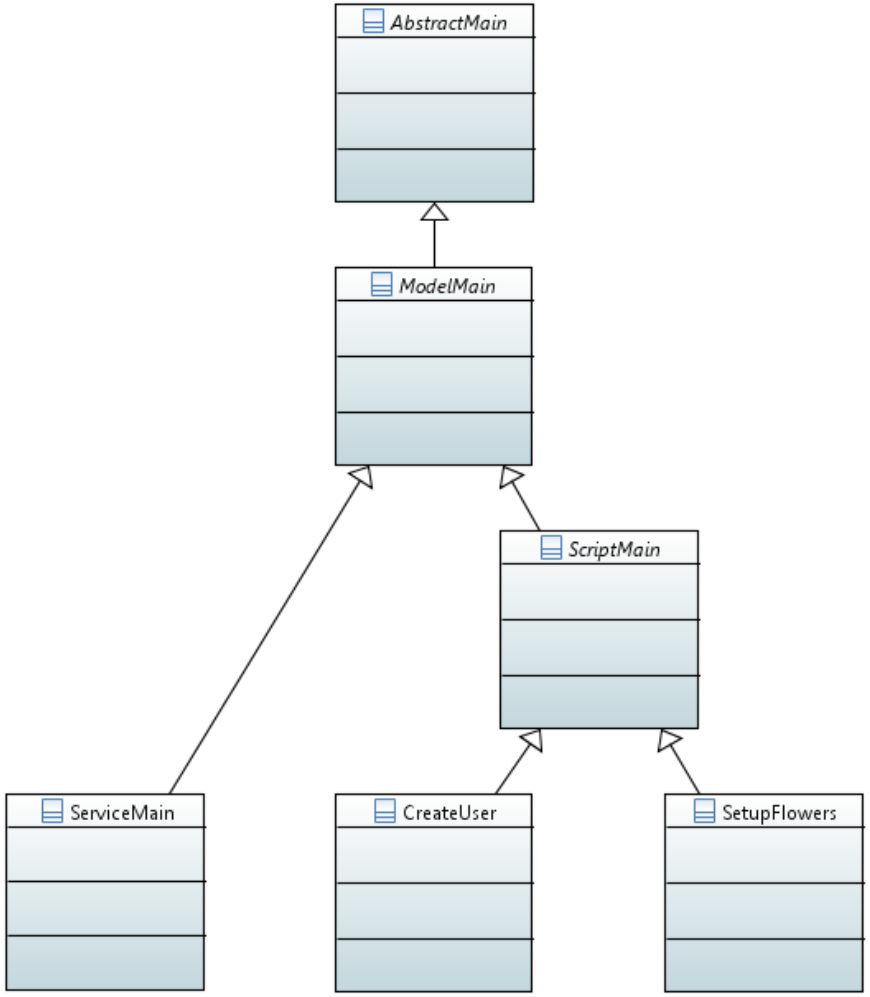


What to Use When?

- 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?

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