Subtyping and Inheritance

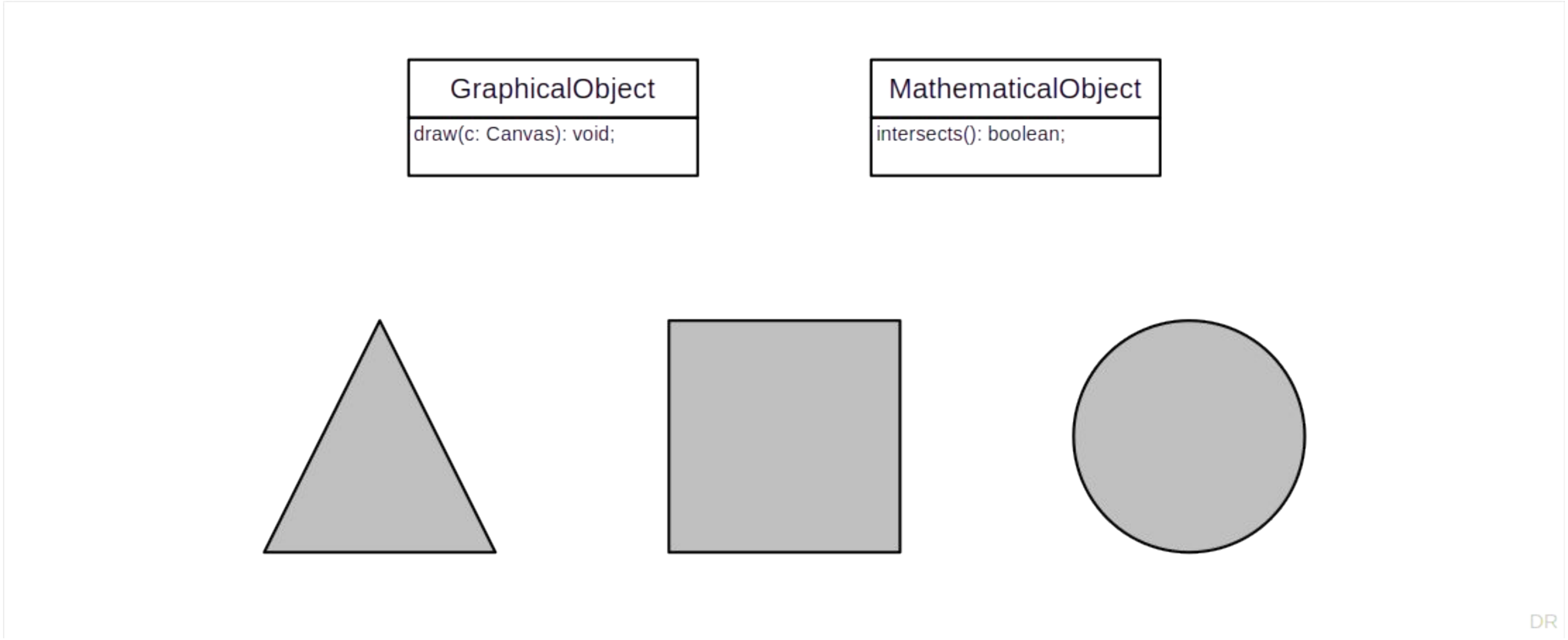
Dirk Riehle, FAU Erlangen

ADAP B03

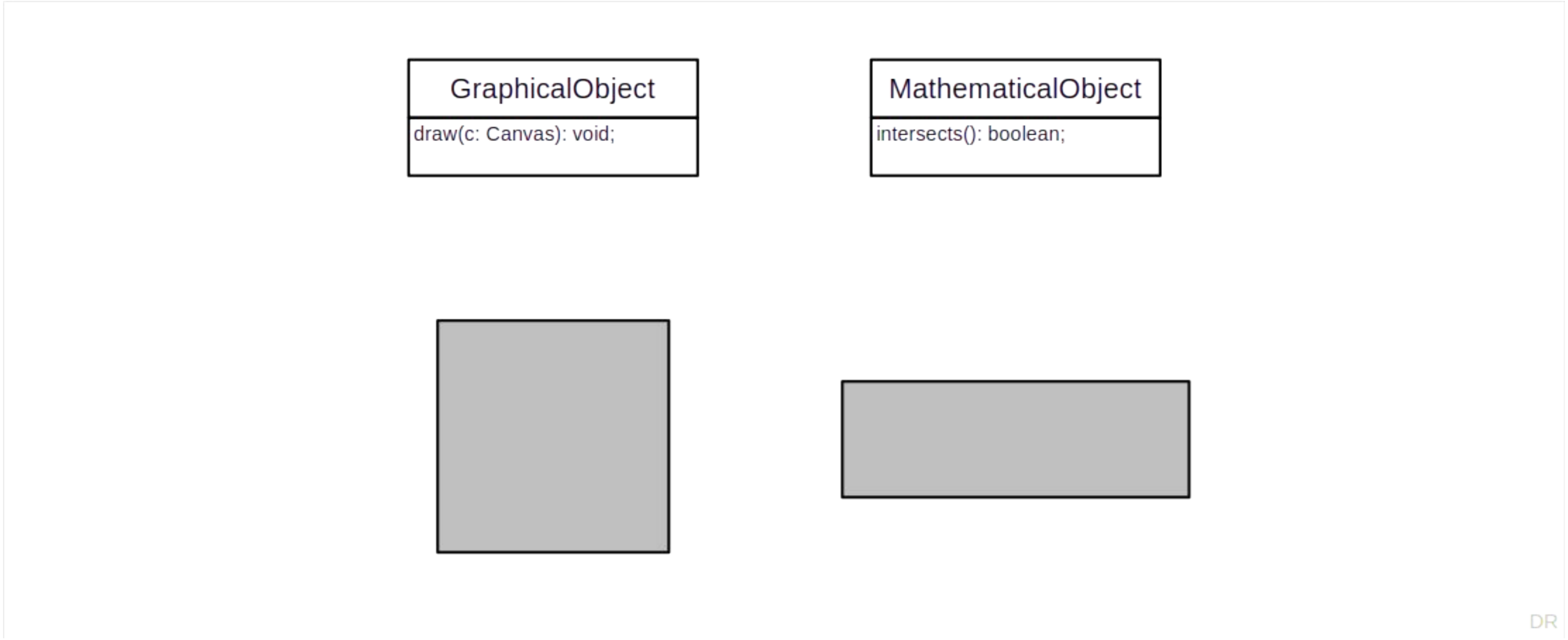
Agenda

1. What is Subtyping?

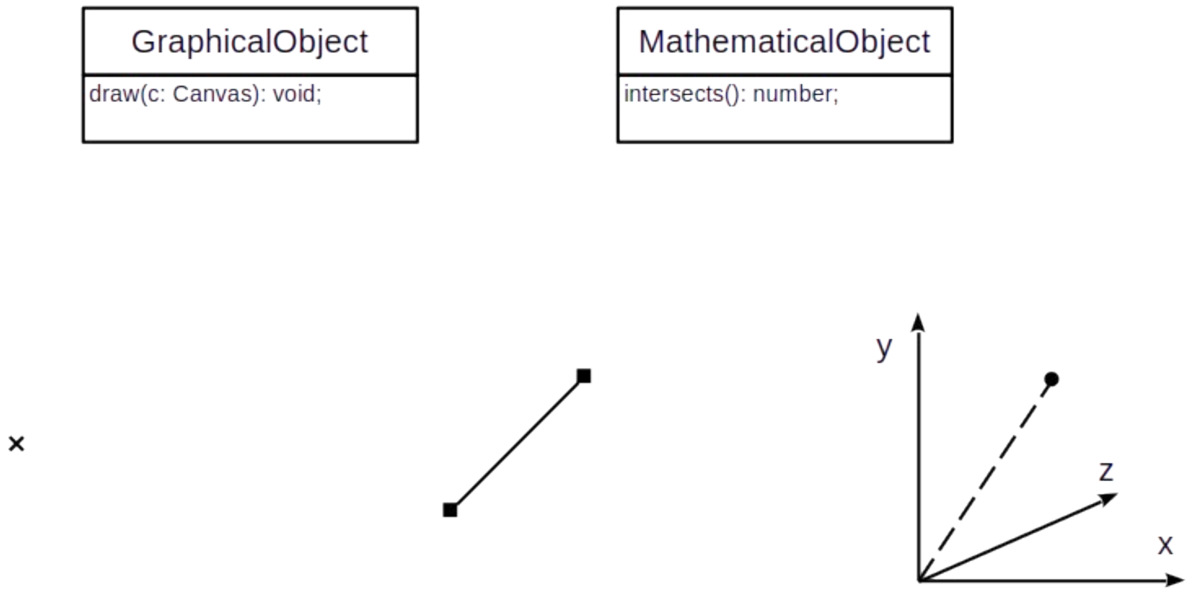
Subtyping Example 1 / 3



Subtyping Example 2 / 3



Subtyping Example 3 / 3



2. Liskov Substitutability Principle

The Subtype Requirement [1]

Let $\varphi(x)$ be a property provable about objects x of type T.

Then $\varphi(y)$ should be provable for objects y of type S, where S is a subtype of T.

[1] A.k.a. the Liskov Substitutability Principle (LSP) [LW94]

In Simpler Words

All properties that hold for instances of a supertype should also hold for instances of a subtype [DR]

Even Simpler

Don’t surprise use-clients

Quiz: What’s the Surprise?

If you make Rectangle a subtype of Square?

If you make Square a subtype of Rectangle?

If you make 2DLine a subtype of Point?

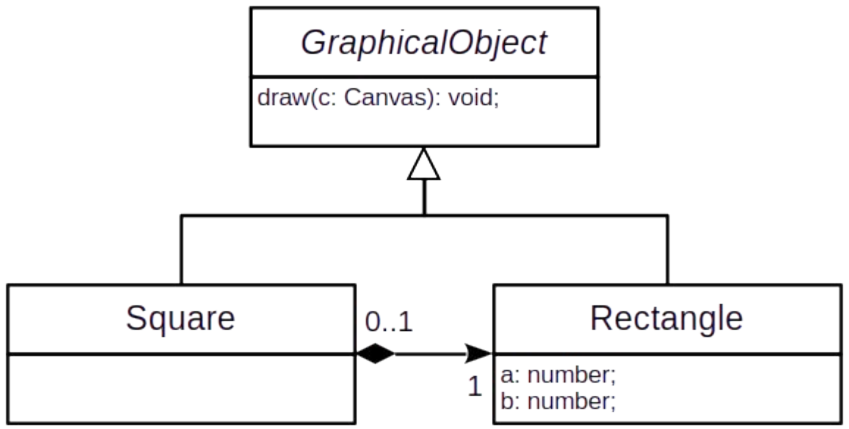
If you make Point a subtype of 2DLine?

3. Applied to Class Hierarchies

Subclasses as Extended Subtypes

Subclasses

- Add methods and state
- Do not constraint superclasses



DR

Subclasses as Constrained Subtypes

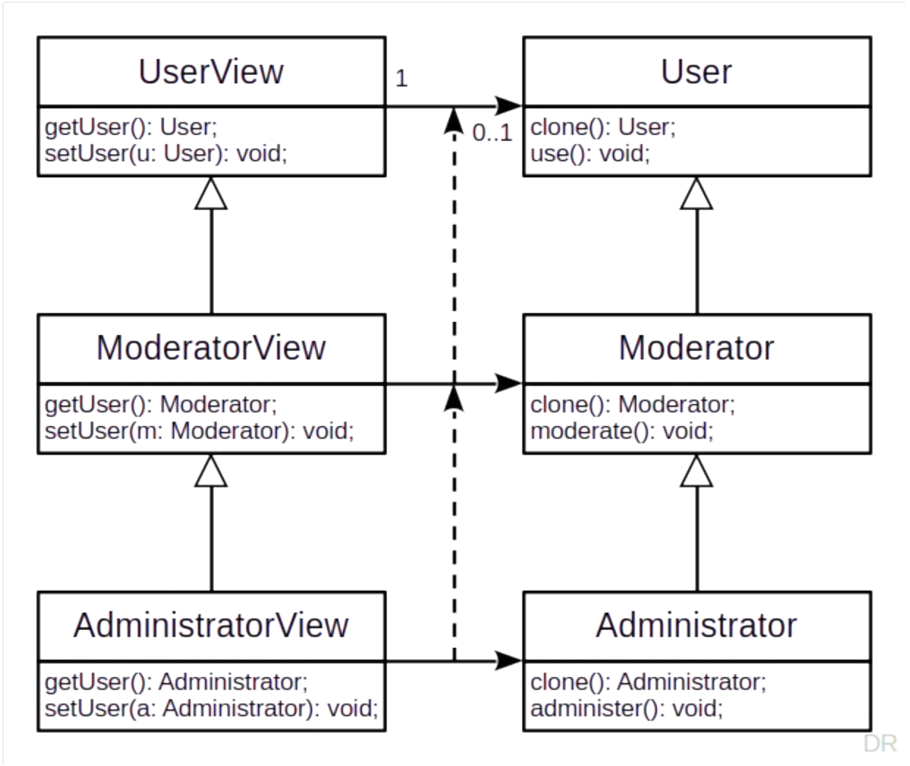
Subclasses

- Constrain behavior in defined space

In method signatures

- Using covariant redefinition

Leads to parallel class hierarchies



Extract Superclass Refactoring

A refactoring is a

- Behavior-preserving transformation of existing code

The goal is to improve readability, remove redundancy, etc.

The extraction of an abstract superclass is a common refactoring

Fowler’s catalog [1] lists Extract Superclass (without “Abstract” though)

[1] Martin Fowler. Refactoring (2nd Edition). Addison Wesley, 2018.

4. Co- and Contravariance

Covariant Redefinition of Return Types

A return type has been covariantly redefined in a method definition, if

- The return type of the subtype's method is a subtype of the supertype's

Example of covariant redefinition of return type

- UserView.getUser(): **User** → ModeratorView.getUser(): **Moderator**

The subtype's method "returns less" than what the supertype's method promises

- Does not violate the LSP (is within expectations)

Contravariant Redefinition of Return Types

A return type has been contravariantly redefined in a method definition, if

- The return type of the subtype's method is a supertype of the supertype's

Example of contrvariant redefinition of return type

- ModeratorView.getUser(): **Moderator** → AdministratorView.getUser(): **User**

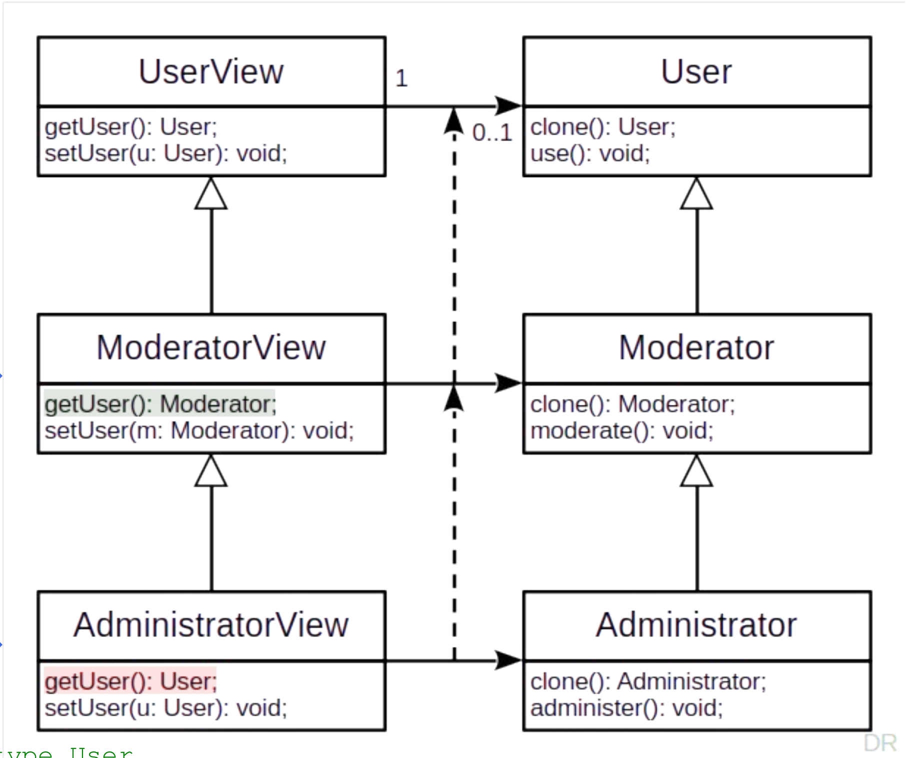
The subtype's method "returns more" than what the supertype's method promises

- Violate the LSP, because clients of the supertype's methods might be surprised

Users / Views Example 1 / 2

```
let modView1: ModeratorView =
      new ModeratorView(new Moderator());
let modAsUserView1: UserView =
      modView1 as UserView;
let mod1: Moderator =
      modAsUserView1.getUser() as Moderator;
mod1.moderate(); // should work, no problem
```

```
let adminView: AdministratorView =
      new AdministratorView();
let adminViewAsModView1: ModeratorView =
      adminView as ModeratorView;
let mod3: Moderator =
      adminViewAsModView1.getUser();
mod3.moderate() // will fail because mod3 is of dynamic type User
```



Covariant Redefinition of Argument Types

An argument type has been covariantly redefined in a method definition, if

- The argument type of subtype's method is a subtype of the supertype's

Example of covariant redefinition of argument type

- User.setUser(u: **User**): void → Moderator.setUser(m: **Moderator**): void

The subtype's method "accepts less" than what the supertype's method promises

- This violates the LSP and only makes sense if you think in relationships

Contravariant Redefinition of Argument Types

An argument type has been contravariantly redefined in a method definition, if

- The argument type of the subtype's method is a supertype of the supertype's

Example of contravariant redefinition of argument type

- ModeratorView.getUser(): **Moderator** → AdministratorView.getUser(): **User**

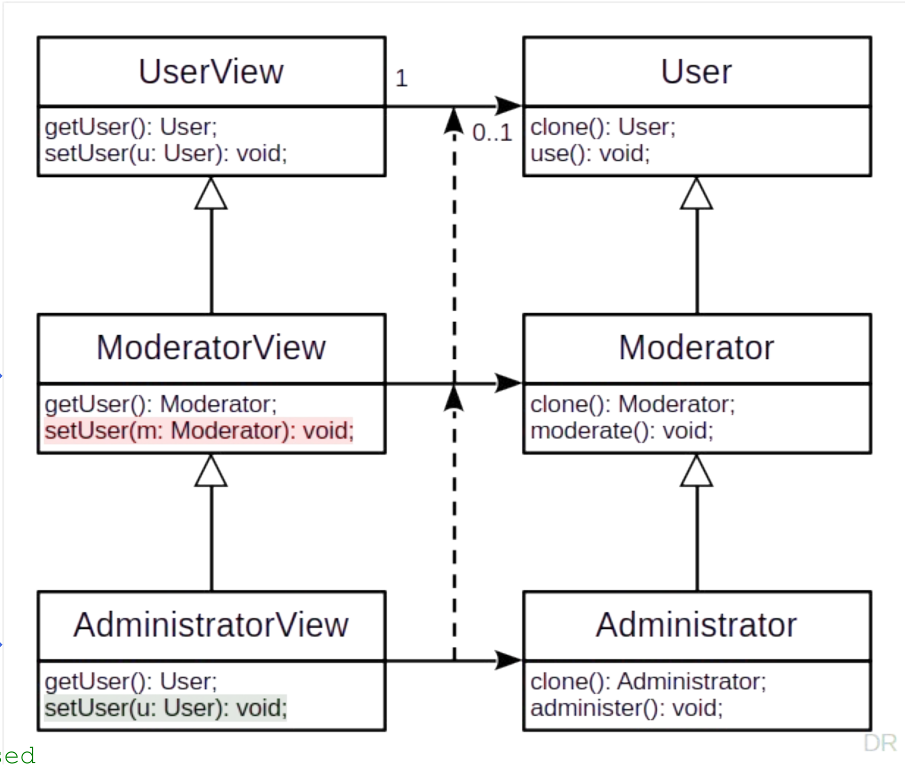
The subtype's method "accepts more" than what the supertype's method promises

- Does not violate the LSP but also makes little sense in practice

Users / Views Argument Type Example

```
let modView2: ModeratorView =
      new ModeratorView(new Moderator());
let modAsUserView2 =
      modView2 as UserView;
modAsUserView2.setUser(new User()); // setup
let mod2: Moderator =
      modView2.getUser(); // creates failure point
mod2.moderate(); // should fail
```

```
adminView.setUser(new User());
let user1: User = adminView.getUser();
user1.use(); // no problem
let admin1: Administrator = user1 as Administrator;
admin1.administer(); // will fail but also was not promised
```



Co- and Contravariance in Typescript

	Covariant Redefinition	Contravariant Redefinition
Return type	● is allowed	● is not allowed
Argument type	● is allowed [2] ● should not be allowed [1]	● is allowed

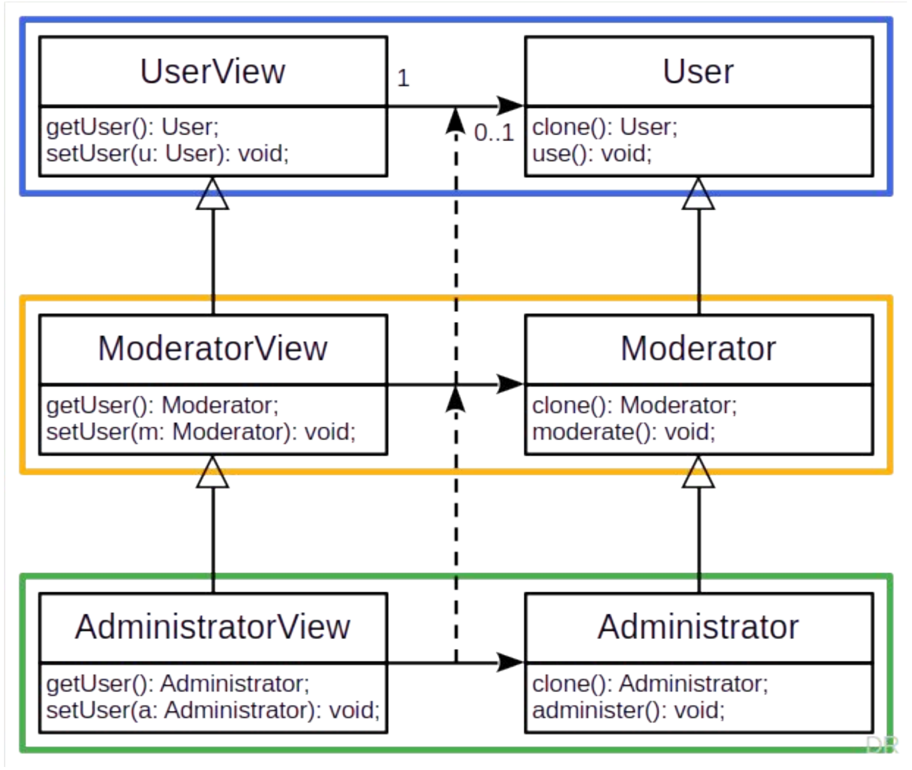
[1] Should not be allowed because it violates the LSP
[2] Only makes sense if class (role type) is part of a collaboration

Parallel Class Hierarchies

Parallel class hierarchies are

- Two related class hierarchies, subclassed in parallel
- Often using covariant redefinition of both return and argument types

The design focus is on the collaboration



5. Multiple Inheritance

Multiple Inheritance

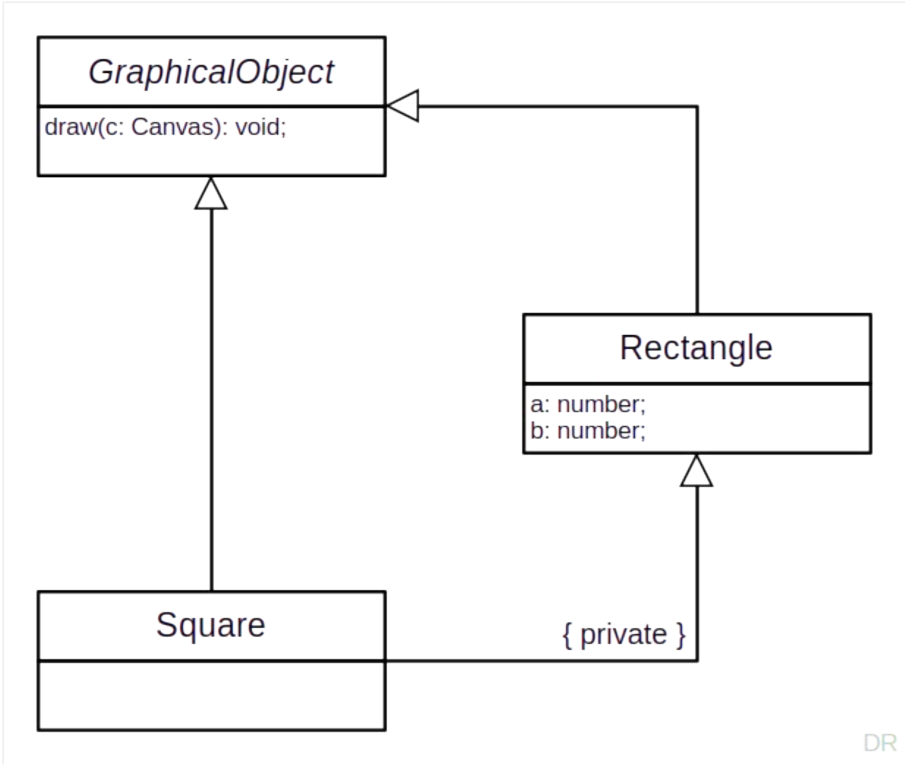
Multiple inheritance is when

- A class has 2+ superclasses

Does not imply substitutability

- Cf. C++'s private inheritance

Not a Typescript feature



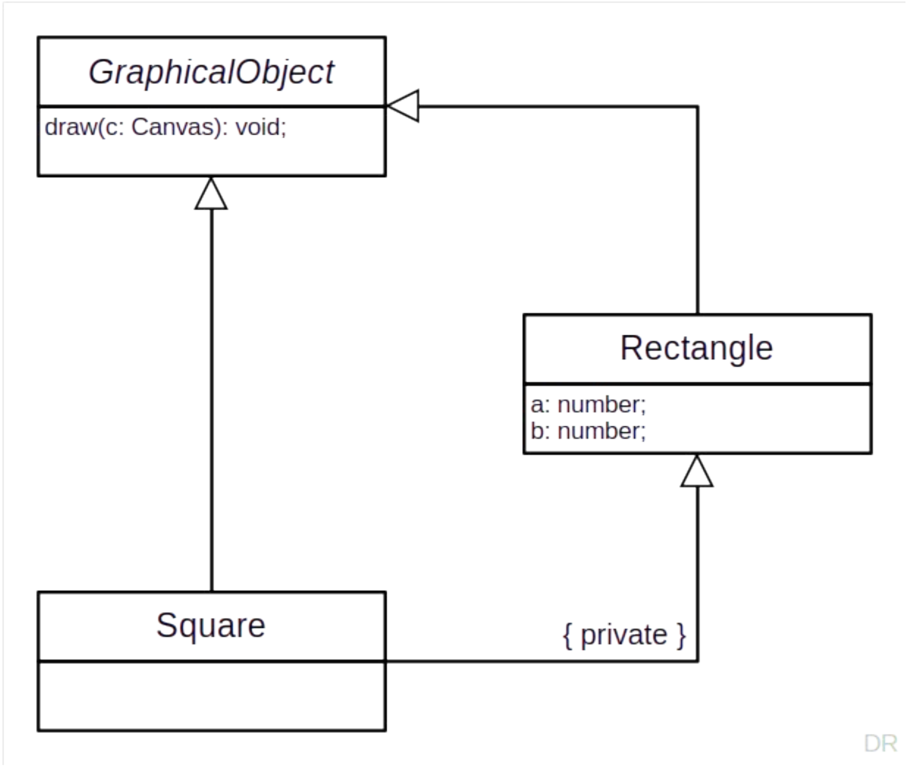
Implementation Delegation

Implementation delegation is when

- A class delegates its implementation

Generally better than multiple inheritance

- Choose delegation over inheritance



Composition over Inheritance

The composition over inheritance principle states that

- You should favor object composition over class inheritance

A.k.a. delegation over inheritance (principle)

6. Abstract Superclass Rule

Inheritance vs. Abstractness

Inheritance is

- A relationship between two classes

Abstractness / concreteness

- A relationship between a class and its instances

Abstract Superclass Rule (ASR)

All superclasses must be abstract

Corollary: Never subclass a concrete class

ASR in Framework vs. Application

In a framework

- Leaf classes may be abstract (awaiting subclassing)
- Leaf classes may be concrete (if ready to use)

In an application (based on a framework)

- Framework leaf classes may be abstract if unused
- Application leaf classes must be concrete

ASR and LSP

The ASR helps to comply with the LSP

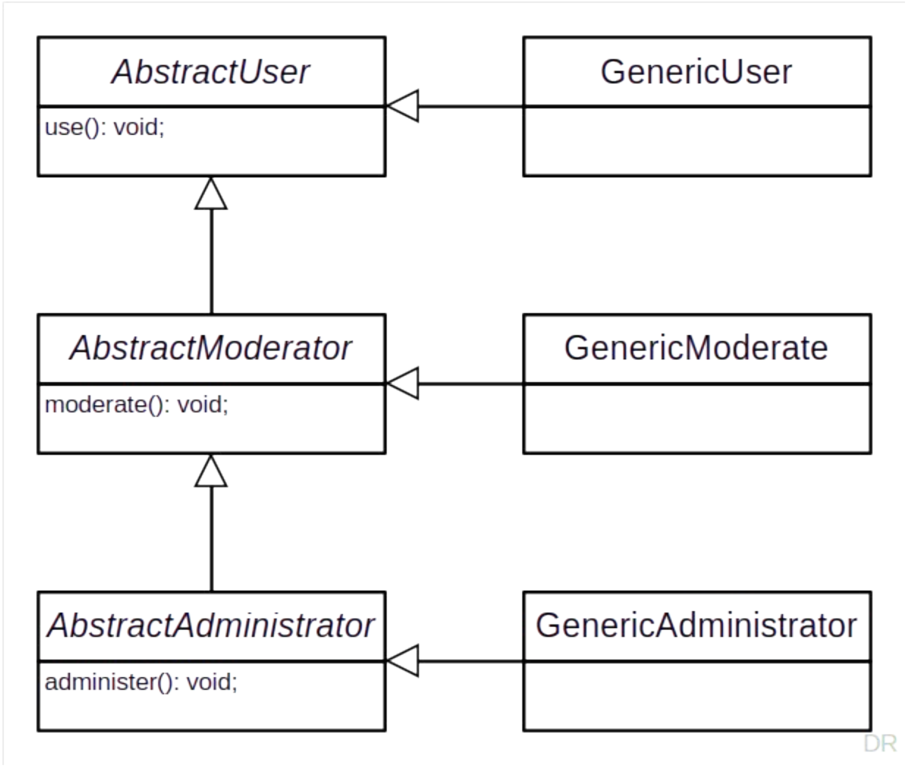
- The ASR automatically casts subclasses as constrained subtypes

Pragmatics of ASR

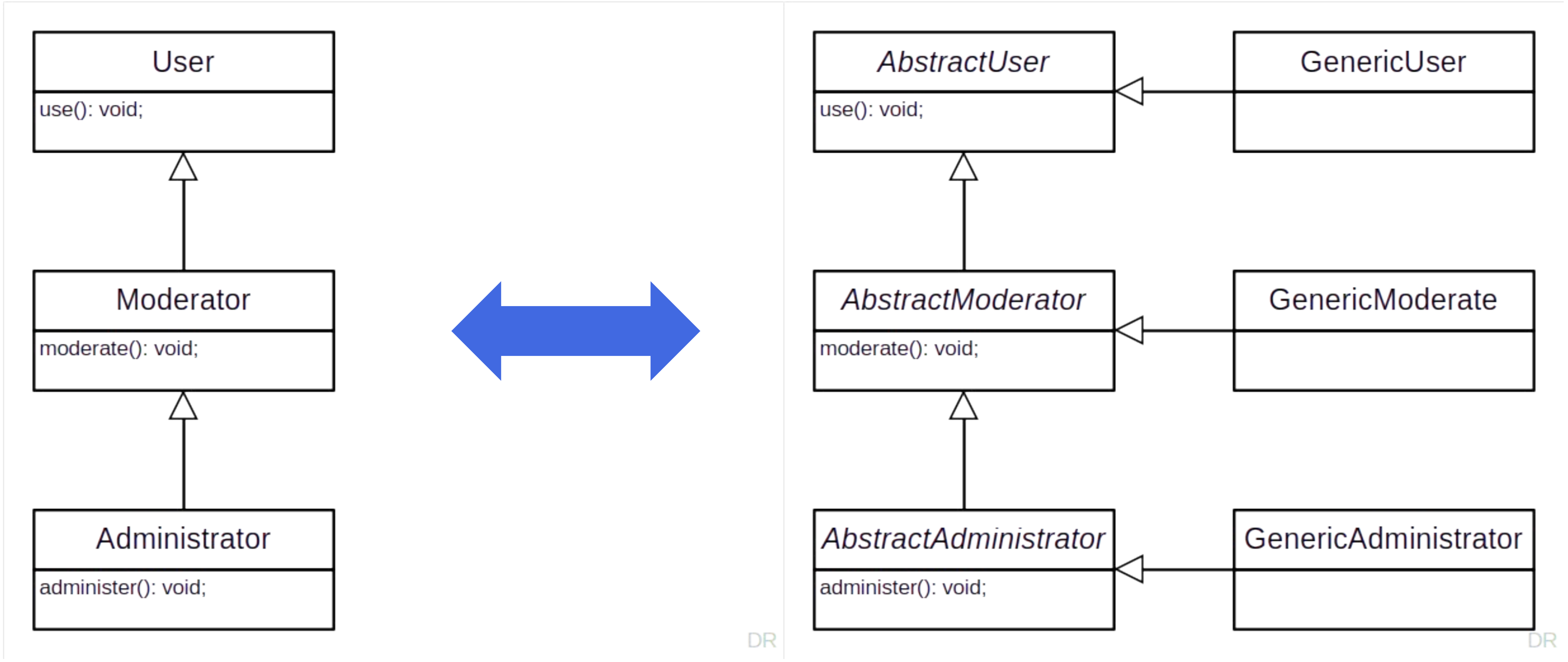
Logically separate abstract class from generic implementation subclass

Pragmatically, merge implementation class into abstract class

Make abstract class concrete but maintain inheritance interface



Class Hierarchy Evolution



7. Cascading Class Hierarchies

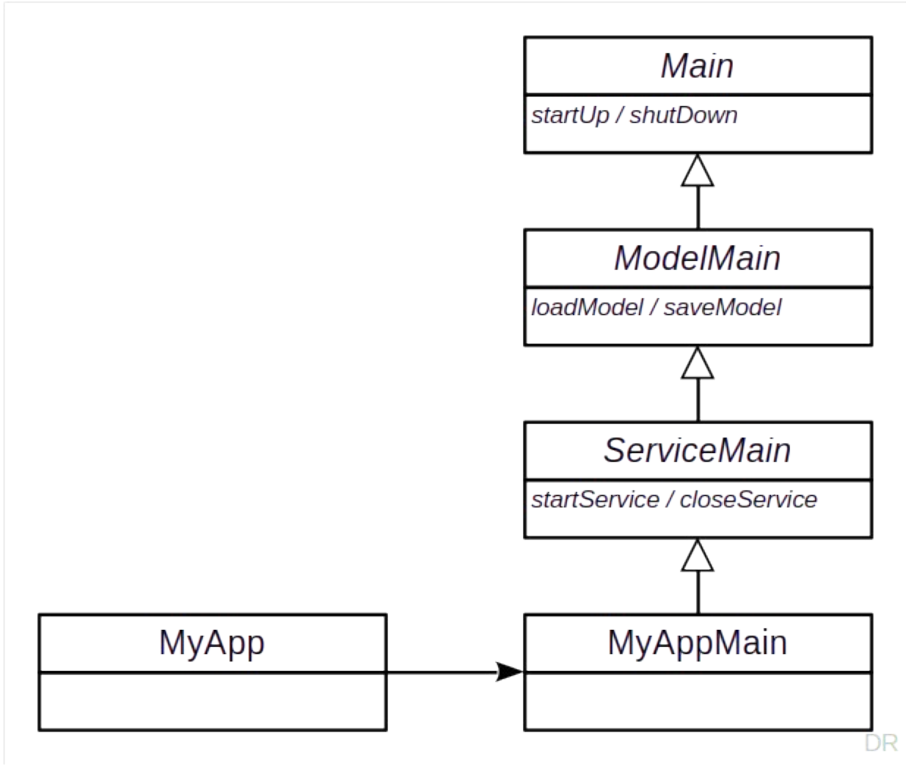
Before and After Methods

Before and after methods wrap a method’s main body

They typically come in pairs and are about a meta issue

- The before method sets something up
- The after method tears it down

App with Service Example



```
import { MyAppMain } from "./MyAppMain";

function main(args: string[]) {
    let appMain: MyAppMain = new MyAppMain();
    appMain.run(args);
}

let args: string[] = process.argv;
args = args.slice(2);
main(args);
```

Cascading Inheritance Interfaces 1 / 2

```
export abstract class Main {

   public run(args: string[]): void {
       this.parseArgs(args);
       this.startUp();
       this.execute();
       this.shutDown();
   };

   protected parseArgs(args: string[]): void {
       // do nothing (expect subclass to override)
   }

   protected startUp(): void {
       // do nothing (expect subclass to override)
   }

   protected abstract execute(): void;

   protected shutDown(): void {
       // do nothing (expect subclass to override)
   }

}
```

```
import { Main } from "./Main";

export abstract class ModelMain extends Main {

   protected startUp(): void {
       super.startUp();
       this.loadModel();
   }

   protected loadModel(): void {
       // do nothing (expect subclass to override)
   }

   protected shutDown(): void {
       this.saveModel();
       super.shutDown();
   }

   protected saveModel(): void {
       // do nothing (expect subclass to override)
   }

}
```

Cascading Inheritance Interfaces 2 / 2

```
import { ModelMain } from "./ModelMain";

export abstract class ServiceMain extends ModelMain {

    protected startUp(): void {
        super.startUp();
        this.startService();
    }

    protected startService(): void { /* ... */ }

    protected execute(): void {
        // start main event loop
    }

    protected shutDown(): void {
        this.closeService();
        super.shutDown();
    }

    protected closeService(): void { /* ... */ }

}
```

```
import { ServiceMain } from "./ServiceMain";

export class MyAppMain extends ServiceMain {

    protected loadModel(): void {
        // do something
    }

    protected startService(): void {
        // do something
    }

    protected saveModel(): void {
        // do something
    }

    protected closeService(): void {
        // do something
    }

}
```

Summary

1. What is subtyping?
2. Liskov substitutability principle
3. Applied to class hierarchies
4. Co- and contravariance
5. Multiple inheritance
6. Abstract superclass rule
7. Cascading class hierarchies

Thank you! Any questions?

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

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

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