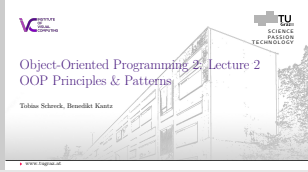
INSTITUTE OF VISUAL COMPUTING

TU Graz
SCIENCE
PASSION
TECHNOLOGY

Object-Oriented Programming 2: Lecture 2 OOP Principles & Patterns

Tobias Schreck, Benedikt Kantz



Which OOP principles do you know?

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- Ask students, write down relevant answers on blackboard

Why should we use OOP principles? [1]

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- our team can communicate more effectively $\implies$ easy to understand, concise
- we develop a common “language” - we can understand *any* code!

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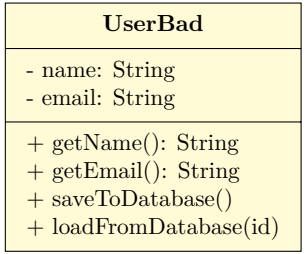
- This means a class should encapsulate a single, well-defined responsibility or concern.
- "Reason to change" often relates to a specific actor or stakeholder group that would request changes related to that responsibility.
- It's about cohesion - keeping related things together and unrelated things separate.

Single Responsibility Principle (SRP)
Example

Violation:



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Violation:

Problem: The `User` class handles both user data *and* data storage logic. Reasons to change: user attributes change OR database technology changes.

Solution: Separate concerns. `User` holds data. `UserRepository` handles persistence, depending on `User`.

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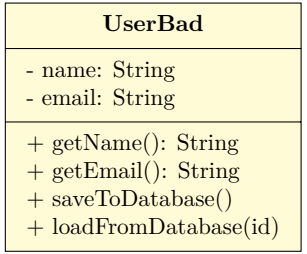
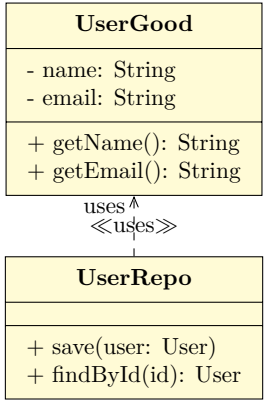
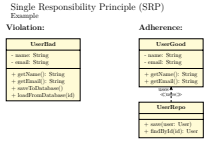


Adherence:





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Why?

- **Improved Readability & Understandability:** Classes are smaller and focused on one task.
- **Easier Maintenance:** Changes related to one responsibility are isolated to a single class, reducing the risk of unintended side effects.
- **Enhanced Testability:** Smaller classes with single responsibilities are easier to unit test in isolation.
- **Reduced Coupling:** Classes are less dependent on unrelated concerns.
- **Increased Reusability:** A class focused on one task is more likely to be reusable elsewhere.

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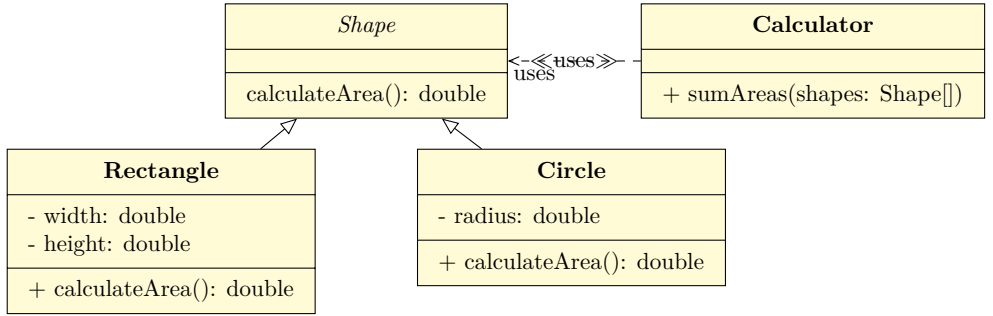
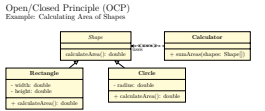
- You should be able to add new functionality without changing existing, working code.
- Often achieved through abstraction (abstract classes, interfaces) and polymorphism.
- Existing code (closed for modification) relies on abstractions, while new functionality (open for extension) is added by creating new concrete implementations of those abstractions.

Open/Closed Principle (OCP)
Example: Calculating Area of Shapes





Solution: The `Calculator` depends on the `Shape` abstraction. To add a new shape (e.g., `Triangle`), create a new class inheriting from `Shape` and implement `calculateArea()`. The `Calculator` does **not** need to be modified.

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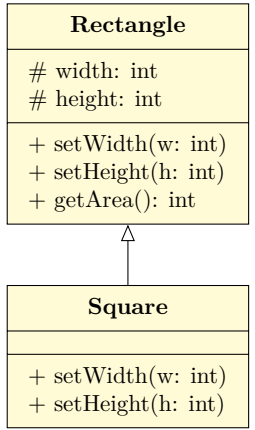
- If class S is a subtype of class T, then objects of type T in a program may be replaced with objects of type S without affecting the desired properties (correctness, task performed, etc.) of that program.
- Focuses on the "is-a" relationship based on *behavior*, not just structure or inheritance syntax.
- Subclasses should fulfill the contract (preconditions, postconditions, invariants) defined by their superclass.

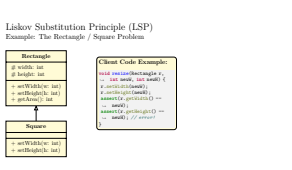
Liskov Substitution Principle (LSP)

Example: The Rectangle / Square Problem



Client Code Example:

```
void resize(Rectangle r,
 ↪  int newW, int newH) {
 r.setWidth(newW);
 r.setHeight(newH);
 assert(r.getWidth() ==
  ↪  newW);
 assert(r.getHeight() ==
  ↪  newH); // error!
}
```

Violation: A `Square` "is-a" `Rectangle` geometrically, but behaviorally it violates the implied contract. A client expecting to set width and height independently on a `Rectangle` will break if given a `Square`. `Square` is not substitutable for `Rectangle` here.

- What could one do to mitigate this issue?
- Solution: introduce a Geometry class above, or reduce "promised" functionality (i.e. width/height immutable!)

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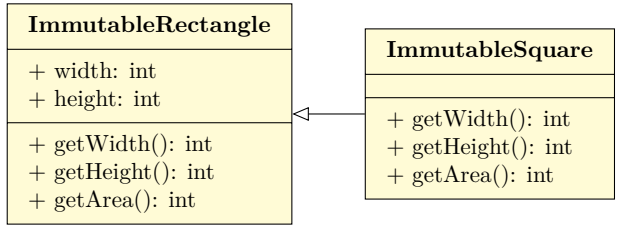
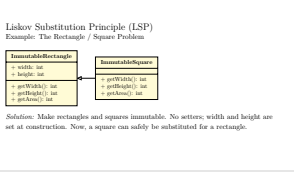


Solution: Make rectangles and squares immutable. No setters; width and height are set at construction. Now, a square can safely be substituted for a rectangle.



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- **Correct Inheritance Hierarchies:** Helps model true "is-a" behavioral relationships.
- **Reduced Runtime Errors:** Avoids unexpected behavior when substituting subtypes.
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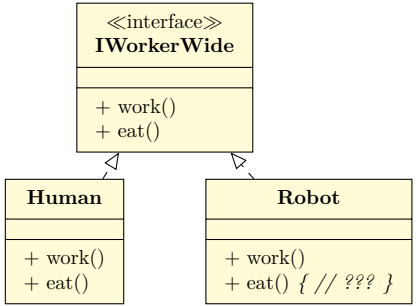
- Prefer many small, client-specific interfaces over one large, general-purpose interface.
- Classes should only need to implement methods that are relevant to them.
- If a class implements an interface with methods it doesn't need, it leads to empty implementations, exceptions, or unnecessary dependencies.

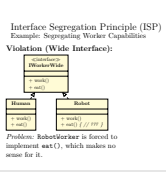
Interface Segregation Principle (ISP)

Example: Segregating Worker Capabilities

Violation (Wide Interface):



Problem: `RobotWorker` is forced to implement `eat()`, which makes no sense for it.



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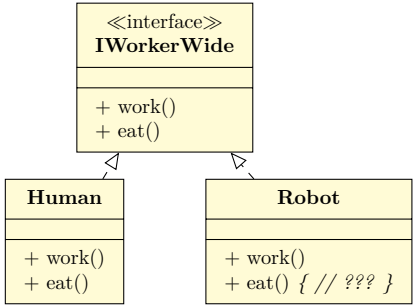

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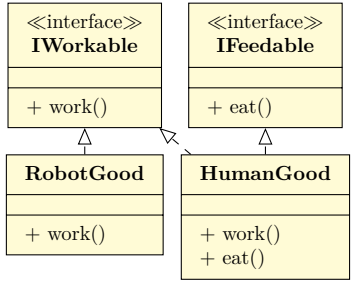
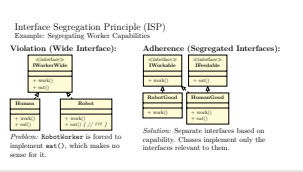


Solution: Separate interfaces based on capability. Classes implement only the interfaces relevant to them.



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- **Reduced Coupling**
- **Improved Cohesion**
- **Increased Flexibility & Reusability**
- **Easier Implementation**
- **Better Design Clarity**

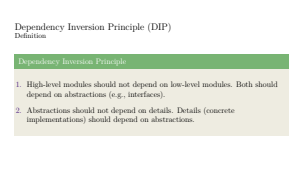
Interface Segregation Principle (ISP)
Why?
- Reduced Coupling
- Improved Cohesion
- Increased Flexibility & Reusability
- Easier Implementation
- Better Design Clarity

- **Reduced Coupling:** Clients only depend on the methods they actually call. Changes to unused methods in an interface won't affect unrelated clients.
- **Improved Cohesion:** Interfaces are more focused and represent specific roles or capabilities.
- **Increased Flexibility & Reusability:** Smaller interfaces are easier to implement and combine.
- **Easier Implementation:** Classes don't need to provide dummy implementations for irrelevant methods.
- **Better Design Clarity:** The roles and capabilities in the system are

Dependency Inversion Principle (DIP)
Definition

Dependency Inversion Principle

1. High-level modules should not depend on low-level modules. Both should depend on abstractions (e.g., interfaces).
2. Abstractions should not depend on details. Details (concrete implementations) should depend on abstractions.

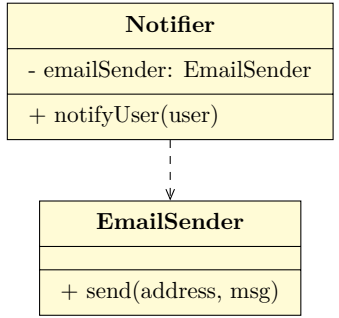


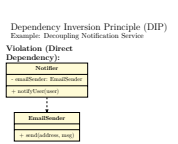
- "Inversion" refers to inverting the traditional dependency direction (High-level → Low-level) to (High-level → Abstraction ← Low-level).
- Decouples policy (high-level logic) from implementation details (low-level specifics).
- Often implemented using Dependency Injection (DI) patterns.

Dependency Inversion Principle (DIP)

Example: Decoupling Notification Service

Violation (Direct Dependency):





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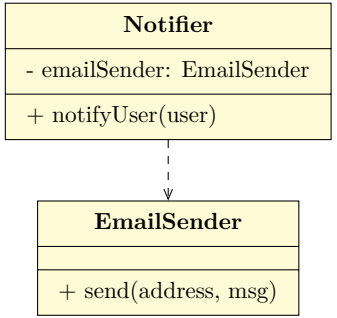
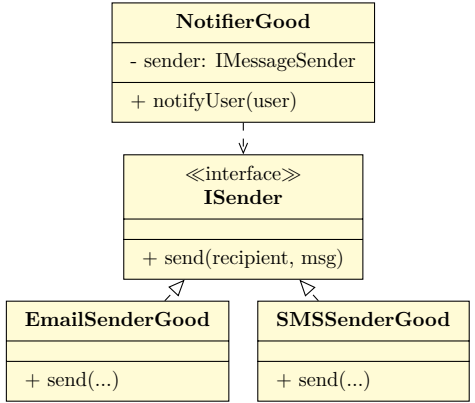
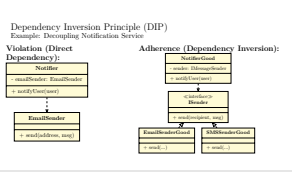


Adherence (Dependency Inversion):





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Solution: Both high-level and low-level depend on the abstraction.

- High-Level: `NotifierGood`
- Low-Level: `EmailSender`, `SMSSender`
- Intermediate: `ISender`

Dependency Inversion Principle (DIP)
Why?

- Decoupling
- Flexibility & Extensibility
- Testability
- Reusability
- Parallel Development

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Summary

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- **LSP:** Subtypes must be substitutable for base types. (Behavioral Contract)
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- Instructions:
  - Groups of 3-4
  - Select a tool of your choice (ChatGPT, Mistral,...)

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Definition

Principle

Favor composing objects (HAS-A relationship) over extending classes (IS-A relationship) to achieve polymorphic behavior and code reuse.

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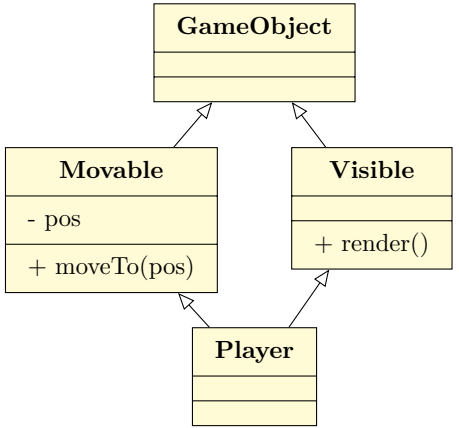
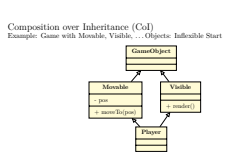
- Inheritance is a powerful tool, but can lead to rigid hierarchies and the "fragile base class" problem.
- Combines DIP and ISP
- Composition allows for more flexible designs where behavior can be changed at runtime by composing with different objects.
- Often used in conjunction with Dependency Inversion (depending on interfaces of composed objects).

Composition over Inheritance (CoI)

Example: Game with Movable, Visible, . . . Objects: Inflexible Start





Problem:

Attributes tied to base class $\implies$ hard to compose Visible and Movable Objects.

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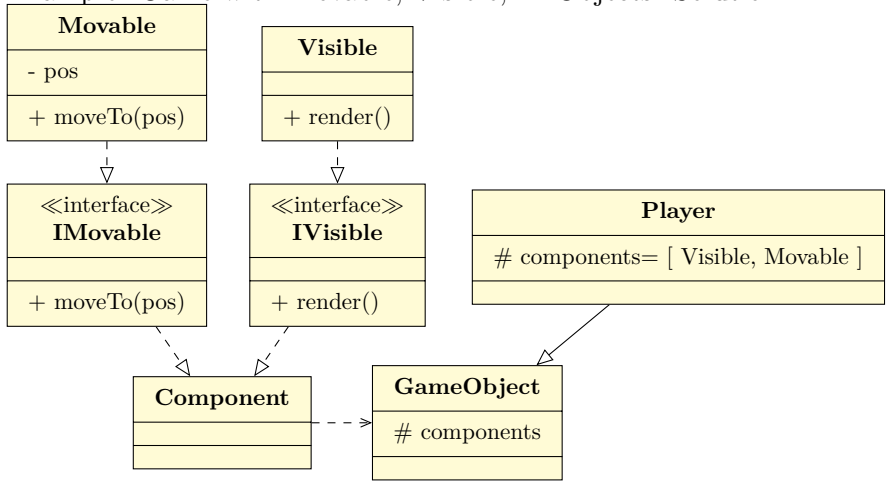
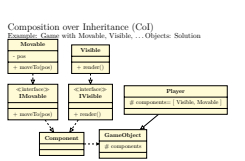
Example: Game with Movable, Visible, . . . Objects: Solution





Solution:

Composable attributes $\implies$ easy to combine Visible and Movable & expand!

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Why?

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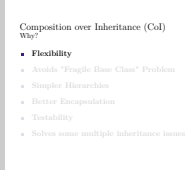

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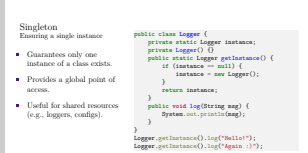
Singleton

Ensuring a single instance

- Guarantees only one instance of a class exists.
- Provides a global point of access.
- Useful for shared resources (e.g., loggers, configs).

```
public class Logger {
    private static Logger instance;
    private Logger() {}
    public static Logger getInstance() {
        if (instance == null) {
            instance = new Logger();
        }
        return instance;
    }
    public void log(String msg) {
        System.out.println(msg);
    }
}
Logger.getInstance().log("Hello!");
Logger.getInstance().log("Again :)");
```

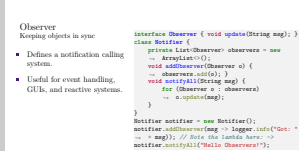



Observer

Keeping objects in sync

- Defines a notification calling system.
- Useful for event handling, GUIs, and reactive systems.

```
interface Observer { void update(String msg); }
class Notifier {
    private List<Observer> observers = new
    ↪  ArrayList<>();
    void addObserver(Observer o) {
    ↪  observers.add(o); }
    void notifyAll(String msg) {
        for (Observer o : observers)
        ↪  o.update(msg);
    }
}
Notifier notifier = new Notifier();
notifier.addObserver(msg -> logger.info("Got: "
↪  + msg)); // Note the lambda here: ->
notifier.notifyAll("Hello Observers!");
```

Builder

Pattern with Lombok's `@Builder`

- The `@Builder` annotation from Lombok generates a builder for your class.
- Simplifies object creation, especially for classes with many fields.
- No need to write boilerplate builder code manually.

```java
import lombok.Builder;
import lombok.ToString;
@Builder
@ToString
public class User {
    private String username;
    private int age;
    private String email;
}
User user = User.builder()
    .username("alice")
    .age(30)
    .email("alice@example.com")
    .build();
```

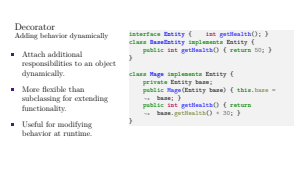

Decorator

Adding behavior dynamically

- Attach additional responsibilities to an object dynamically.
- More flexible than subclassing for extending functionality.
- Useful for modifying behavior at runtime.

```
interface Entity {    int getHealth(); }
class BaseEntity implements Entity {
    public int getHealth() { return 50; }
}

class Mage implements Entity {
    private Entity base;
    public Mage(Entity base) { this.base =
    ↪  base; }
    public int getHealth() { return
    ↪  base.getHealth() + 30; }
}
```

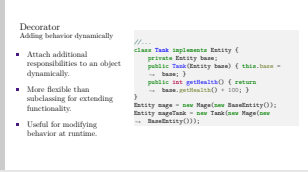



Decorator

Adding behavior dynamically

- Attach additional responsibilities to an object dynamically.
- More flexible than subclassing for extending functionality.
- Useful for modifying behavior at runtime.

```
//...
class Tank implements Entity {
    private Entity base;
    public Tank(Entity base) { this.base =
    ↪  base; }
    public int getHealth() { return
    ↪  base.getHealth() + 100; }
}
Entity mage = new Mage(new BaseEntity());
Entity mageTank = new Tank(new Mage(new
↪  BaseEntity()));
```

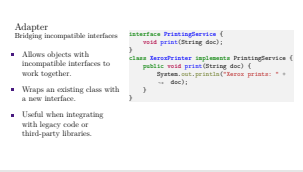



Adapter

Bridging incompatible interfaces

- Allows objects with incompatible interfaces to work together.
- Wraps an existing class with a new interface.
- Useful when integrating with legacy code or third-party libraries.

```java
interface PrintingService {
    void print(String doc);
}
class XeroxPrinter implements PrintingService {
    public void print(String doc) {
        System.out.println("Xerox prints: " +
        ↪  doc);
    }
}
```

Adapter

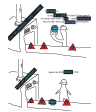
Bridging incompatible interfaces

- Allows objects with incompatible interfaces to work together.
- Wraps an existing class with a new interface.
- Useful when integrating with legacy code or third-party libraries.

```
//...
interface AirPrint {
    void airPrint(String doc);
}
class AirPrintAdapter implements
↪  PrintingService {
    private AirPrint airPrinter;
    public AirPrintAdapter(AirPrint airPrinter)
    ↪  {
        this.airPrinter = airPrinter;
    }
    public void print(String doc) {
        airPrinter.airPrint(doc);
    }
}
```


Factories

Factories

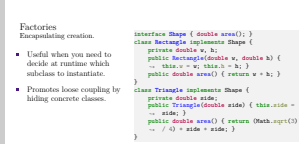


Factories

Encapsulating creation.

- Useful when you need to decide at runtime which subclass to instantiate.
- Promotes loose coupling by hiding concrete classes.

```
interface Shape { double area(); }
class Rectangle implements Shape {
    private double w, h;
    public Rectangle(double w, double h) {
    ↪  this.w = w; this.h = h; }
    public double area() { return w * h; }
}
class Triangle implements Shape {
    private double side;
    public Triangle(double side) { this.side =
    ↪  side; }
    public double area() { return (Math.sqrt(3)
    ↪  / 4) * side * side; }
}
```

Factories

Encapsulating creation.

- Useful when you need to decide at runtime which subclass to instantiate.
- Promotes loose coupling by hiding concrete classes.

```
//...
class ShapeFactory {
    public static Shape create(String type,
    ↪  double side) {
        switch (type) {
            case "square": return new
            ↪  Rectangle(side, side);
            case "circle": return new
            ↪  Circle(side);
            default: throw new
            ↪  IllegalArgumentException("Unknown
            ↪  type: " + type);
        }
    }
}
```


Factories

Encapsulating creation.

- Useful when you need to decide at runtime which subclass to instantiate.
- Promotes loose coupling by hiding concrete classes.

```
//...
Shape s1 = ShapeFactory.create("square", 3);
Shape s2 = ShapeFactory.create("circle", 2);
```


Factories
Encapsulating creation.
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//...
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Shape s2 = ShapeFactory.create("circle", 2);
```

Generics

Type-safe code reuse

- Generics can be limited to subclasses of a base class.
- Example: `findFirst` only works for arrays of `Animal` or its subclasses.

```
class Animal {
    void speak() { System.out.println("..."); }
}
class Dog extends Animal {
    void speak() { System.out.println("Woof!");
    ↪  }
}
```


Generics

Type-safe code reuse

- Generics can be limited to subclasses of a base class.
- Example: `findFirst` only works for arrays of `Animal` or its subclasses.

```
static <T extends Animal> T getFirst(T[] array)
↪  {
    if (array.length > 0) {
        return array[0];
    }
    return null;
}
```


Examples I

- Code examples on Gitlab.
- We will discuss them, looking into different aspect.
- Feel free to expand/go through it at your own pace at home!

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1.? 2. logger 3. observer

Examples II

- Questions:
  - Any further insights for you?
  - What is a typical application of a singleton?
  - Which Pattern is very useful in reactive systems?

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Feedback

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Bibliography I

References

[1] R. Martin, **Clean Architecture: A Craftsman's Guide to Software Structure and Design** (Robert C. Martin Series), eng, 1st ed. Hoboken: Pearson Education, Limited, 2017, ISBN: 0134494164.

[2] R. C. Martin, **Agile principles, patterns, and practices in c,** eng, 2007.

[3] S. Stelting, **Applied java patterns,** eng, 2002.

Books give good overview, if you want more theory - they are even translated to German if you feel the need to read about Software in German ;)