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Object-oriented programming
Chapter 11 – Abstract base classes

Prof. Dr Kai Höfig

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Abstract classes – what for?

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- Abstract classes are an important technical concept of object-oriented software development
- They are used to define the interfaces of future subclasses (for example, if we cannot or do not want to specify an implementation yet)
- They are a kind of pattern (template method pattern) that specifies which methods must be implemented in subclasses
- Only the subclasses know exactly how the methods should behave
- An abstract class works like a slot into which objects of the subclasses are inserted
- Software that provides such slots = framework
- Often the topmost or root element of an inheritance hierarchy

Abstract classes (1)

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- Definition:
  - Class that **cannot be instantiated**

- Two different types are possible:
  (1) All operations are fully implemented – as with specific classes
  (2) At least one operation is not implemented (**abstract operation**)
    - Only defines the method signature – the method body is empty
    - Only specifies the interface
    - Derived classes must implement all abstract operations of the base (top-level) class

Abstract classes (2)

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- Notation in UML
  - Keyword `<<abstract>>`
  - Italic font
  - Better with keyword for handwritten representation!

<<abstract>> **Person**
drive() {abstract}

Person
drive()

Calling inherited methods

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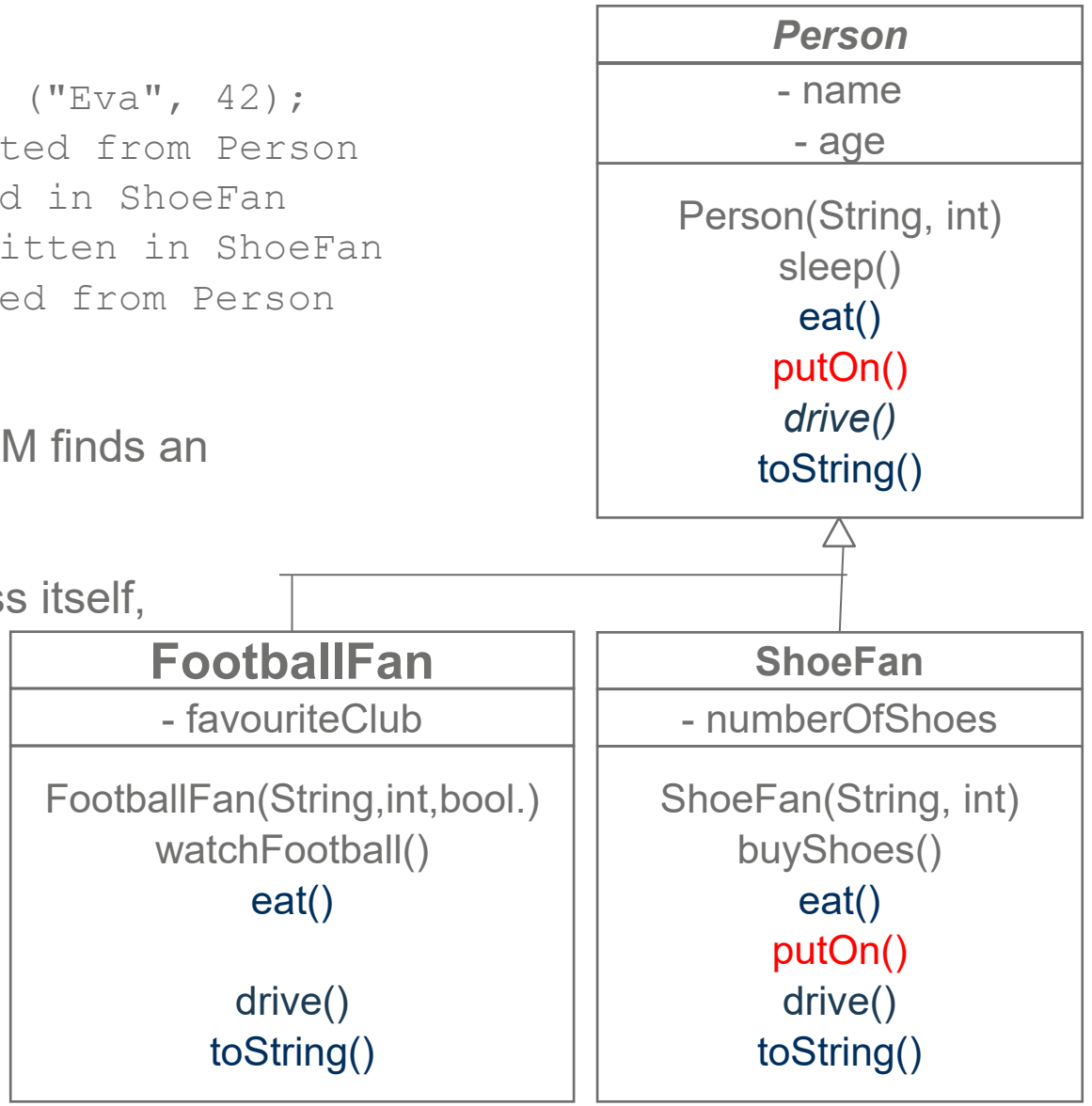
- Example:
  - `ShoeFan eva = new ShoeFan ("Eva", 42);`
  - `eva.sleep();  // inherited from Person`
  - `eva.buyShoes();// defined in ShoeFan`
  - `eva.putOn();  // overwritten in ShoeFan`
  - `eva.drive();  // realised from Person`
- Processing:
  - Compiler ensures that the JVM finds an implementation at runtime
  - JVM first searches in the class itself, then in the base class, then in its base class, and so on.



Modifying the subclasses

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- **Extend**
- Add something completely new
- ***Overload*** an existing method
- Subclass extends the top-level base class with additional attributes, operations and/or relationships

- **Redefine**
- Behave in a similar way
- If required, ***overwrite*** methods inherited in the subclass from the top-level base class with own specific implementation
- If necessary, use inherited implementations

- **Define**
- ***Realise*** something promised
- Implement abstractly declared operations of the top-level base class in the subclass

Extend properties in subclass

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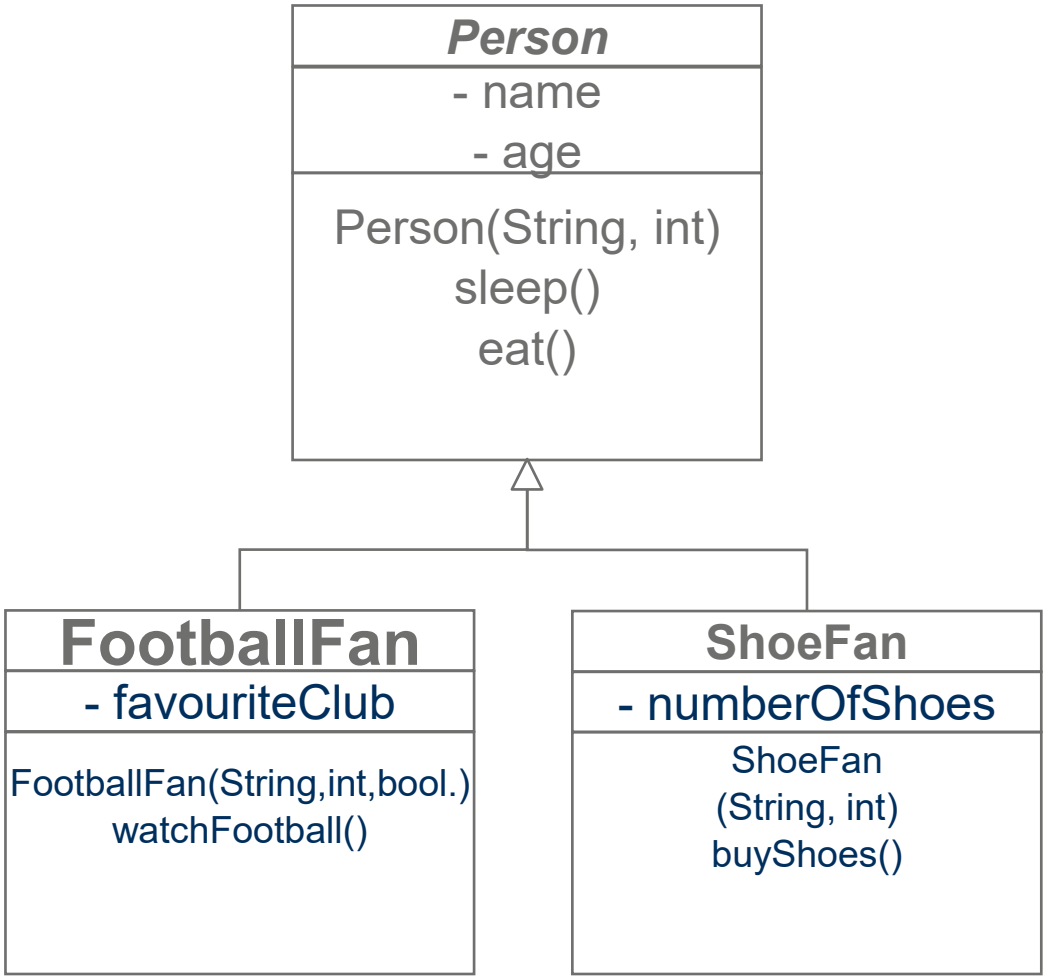
- **Starting point**
  - Base class Person
  - Common attributes
  - Basic common methods
  - Constructor
- **Extension in subclasses**
  - Specific attributes
  - Specific methods
  - In particular, own constructors



Overloading methods

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- When **overloading** a method, we consider methods of the same name within a single class

- A method is specified by three properties:
  - Method name
  - Parameter list
  - Return value

- If we overload a method, it means that we have at least two methods of the same name within one class.

- **A differentiation using the return value does not work.**
- Therefore, we only have the parameter list for differentiation

Overloading methods: example

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```
public static void foo(int x,double y,double z){
        System.out.println("foo 1");
}

public static void foo(int x,double y){
        System.out.println("foo 2");
}

public static void foo(double x,int y){
        System.out.println("foo 3");
}
```

- What happens now?

```
> foo(6,7.0,6.7);
> foo(3.1,5);
> foo(5,3.1);
> foo(5.0,5.0);
```

Overwriting methods

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- **Overwriting** methods involves methods of the same name that are distributed among different classes within an inheritance hierarchy
- As with **overloading**, when **overwriting** methods the parameter list is also the decisive criterion for the unique assignment of a call to a method.

```
class Circle {
   ...
 void draw() {
  for( .... )
        drawPoint( x1, y1 );
   }
}

class ColouredCircle extends
Circle{
    ...
    @Override
  void draw() {
   for( .... )
    drawColourPoint(x1,y1,c);
    }
}
```

Overwriting vs. overloading

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- **Overloading**: two methods have the same name, but different parameters. Calling is differentiated at compile time.
- **Overwriting**: two methods with the same name and parameters, but one of them is in the base class and one in the derived class. Only ***at runtime*** is the type of the object checked and the correct method selected.
- The binding of overloaded methods is **static binding**. The binding of overwritten methods is **dynamic binding** (or late binding).

Shadowing (1)

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- Already known from "normal" classes
  - Local variables and/or parameter names shadow attributes
- New type of shadowing with inheritance
  - Subclass attribute shadows base class attribute
  - Subclass method shadows base class method
- Access
  - To shadowed element `x` of the base class: `super.x`
  - To shadowed element `x` of the current class: `this.x`

Shadowing (2)

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- Base class

```
public abstract class Person {
   …
 public String eat() {
 return "eat  : Mmmmh, delicious.\n";
 }
}
```

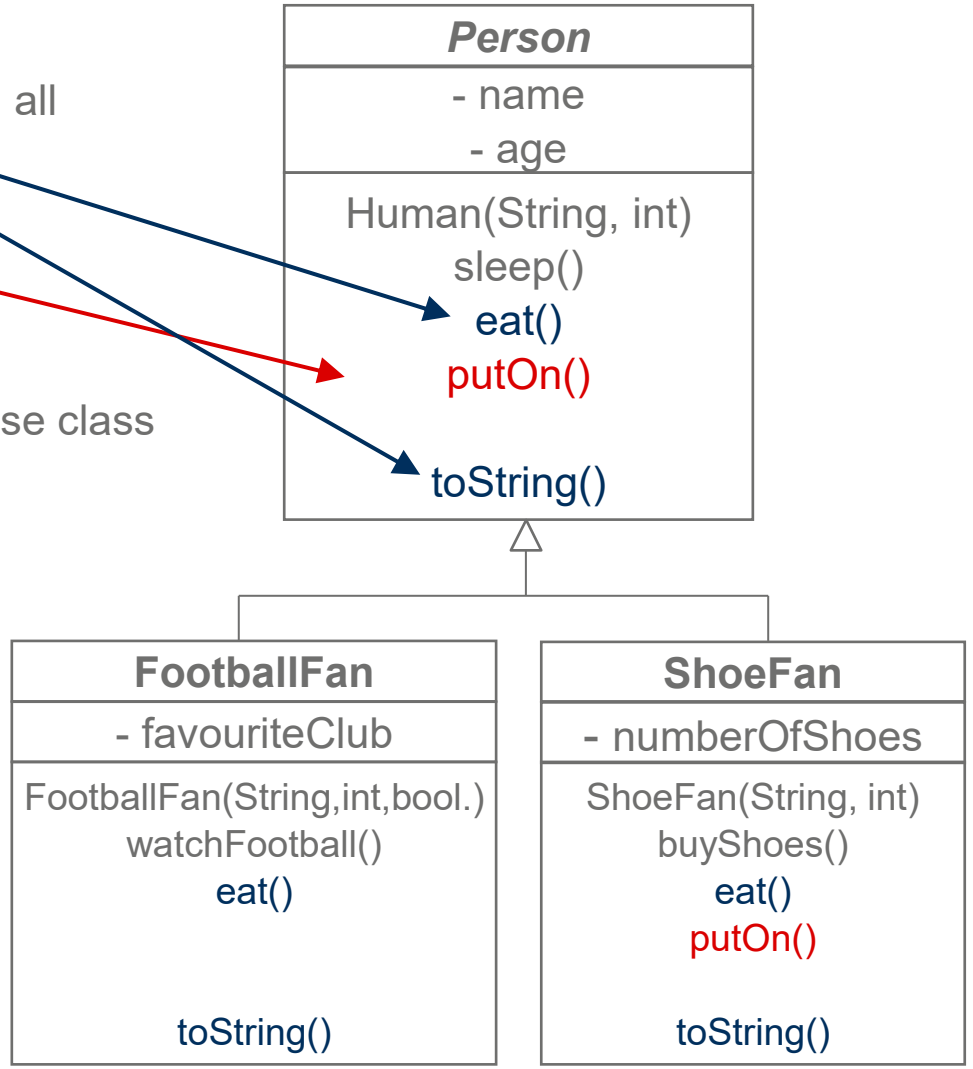
- Subclass

```
 public class FootballFan extends Person {
    …
  public String eat() {
   return super.eat() +
      "Can I have some more?";
  }
 }
```

Redefining properties in subclass

- **Starting point**
- Method with basic functionality that occurs in all subclasses, but is supplemented
- Method with standard functionality that is sufficient as is for some subclasses

- **Redefinition in subclasses**
- Overwriting the method from the top-level base class by specific implementation
- Integrating the implementation from the top-level base class via `super.<methodName>()`



Example: Redefining

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- Extending the `Person` class with the `putOn()` method

```
public abstract class Person { …
 public String putOn() {
  return "put on: underwear and socks";
 } …
}
```

- Redefining the `ShoeFan` class

```
public class ShoeFan extends Person { …
 public String putOn() {
  return "put on: underwear, socks and shoes";
  } …
}
```

Example: Redefining, using basic function (1)

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- Changes compared to the above example
  - `Person` class unchanged
  - Overwrite `eat()` method in both `ShoeFan` and `FootballFan` classes

- Redefining the `ShoeFan` class

```
public class ShoeFan extends Person {
  …
 public String eat() {
    String result = super.eat();
  result = result + "\n        Such a shame
      that this has so many calories...";
  return result;
  }…
}
```

Example: Redefining, using basic function (2)

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- Redefining the `FootballFan` class

```
public class FootballFan extends Person {
  …
 public String eat() {
    String result =      .eat();
  result = result + "\n Can I have
      some more?";
  return result;

  }
  …
}
```

Defining properties in subclass

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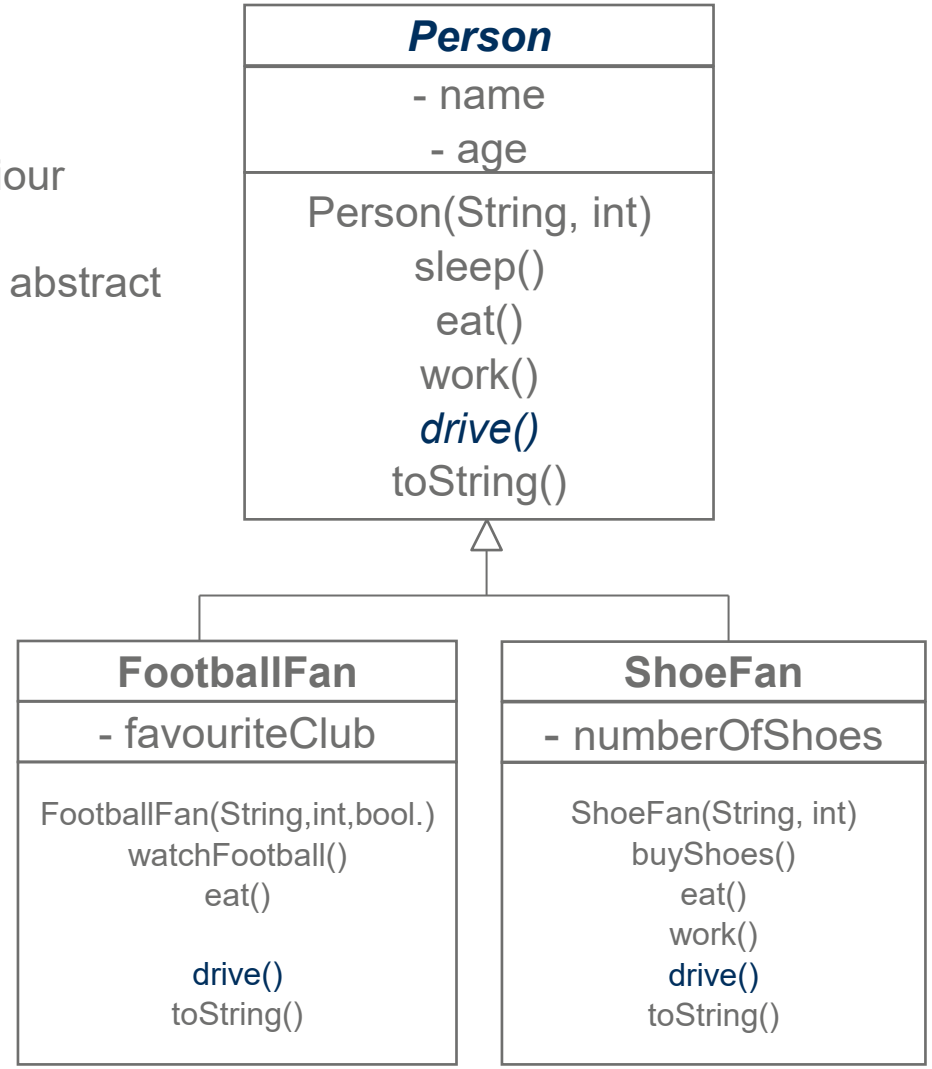
- **Starting point**
- Operation `drive()` is abstract, i.e. defines only the signature
- This ensures the existence of this behaviour
- No implementation!
- This also makes the top-level base class abstract

- **Definition in subclasses**
- Define specific implementations for the abstract operations

- Required in every non-abstract subclass



Example: Defining (1)

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- Changes compared to the above example
  - `Person` class only defines the interface of the `drive()` method; thus becomes abstract class
  - `ShoeFan` and `FootballFan` classes both extended by implementation of the `drive()` method

- New version of the `Person` class

```
public abstract class Person {
   …
 public abstract String drive();
}
```

Example: Defining (2)

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- Extension of `FootballFan` with definition of `drive()`

```
public class FootballFan extends Person {
  …
 public String drive() {
  return "Please start driving, I want to go to the game!";
}…}
```

- Extension of `ShoeFan` with definition of `drive()`

```
public class ShoeFan extends Person {
  …
 public String drive() {
  return "Then off to the shoe shop!";
}…}
```

Interface – meaning

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- Definition: **interface**
- Special form of class
- No objects can be derived directly from the interface

- **Behaviour**
- Only defines abstract operations, no implementations
  Exception: `default` implementations
- Thus only sets requirements
- No executable statements (since Java8: `static` and `default` possible)
- No constructors

- **Properties**
- Contains no modifiable attributes
- Publicly visible constants are possible as attributes

- **All methods / data elements have implicit public visibility!**

Interface – implementation in Java

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- Significance of Java
  - Enables clear separation of implementation and interface
  - Multiple inheritance of specific classes is not allowed in Java
  - However, implementation of multiple interfaces is possible!!!

- Implementation in Java:
  - Reserved keyword `interface` (instead of `class`)
  - Each interface has its own `.java` file which is translated into a `.class` file

Interface in UML

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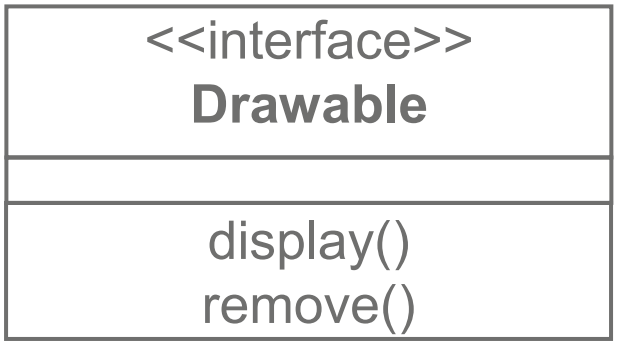
- Interface in UML
  - Symbol analogous to class
  - Stereotype `<<interface>>` above the class name
  - Interface is always also abstract, doesn't have to be explicitly marked as abstract



Terms – supplier and client

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- Supplier of an interface
  - Realises the interface, i.e. implements the operations
- Client of an interface
  - Uses the interface, i.e. calls the operation
  - Does not know specific implementation!

Suppliers and clients in UML

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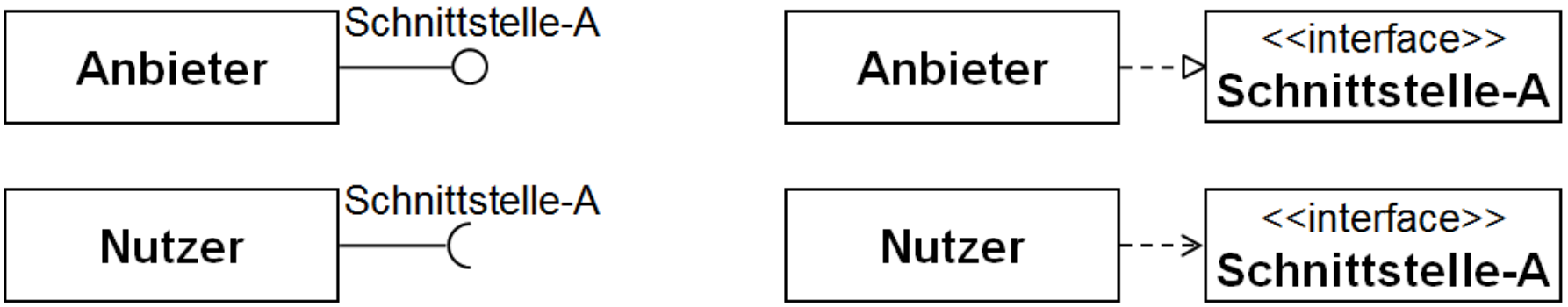
Provision and use of interface A



Interaction via interface A

Terms – realisation and inheritance

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- Realisation
  - Interface not executable on its own
  - Specific class is derived from interface
  - Simply put: "Specific class implements the interface"
  - In doing so, implements all defined operations of the interface

- Inheritance between interfaces
  - New interface extends old interface
  - In doing so, only adds abstract operations
  - In Java: interface can extend multiple interfaces
  - i.e. multiple inheritance between interfaces is possible!

Example: realisation and inheritance

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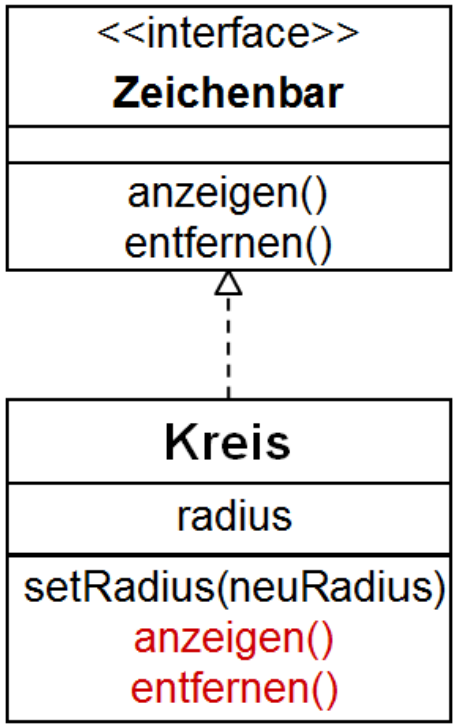
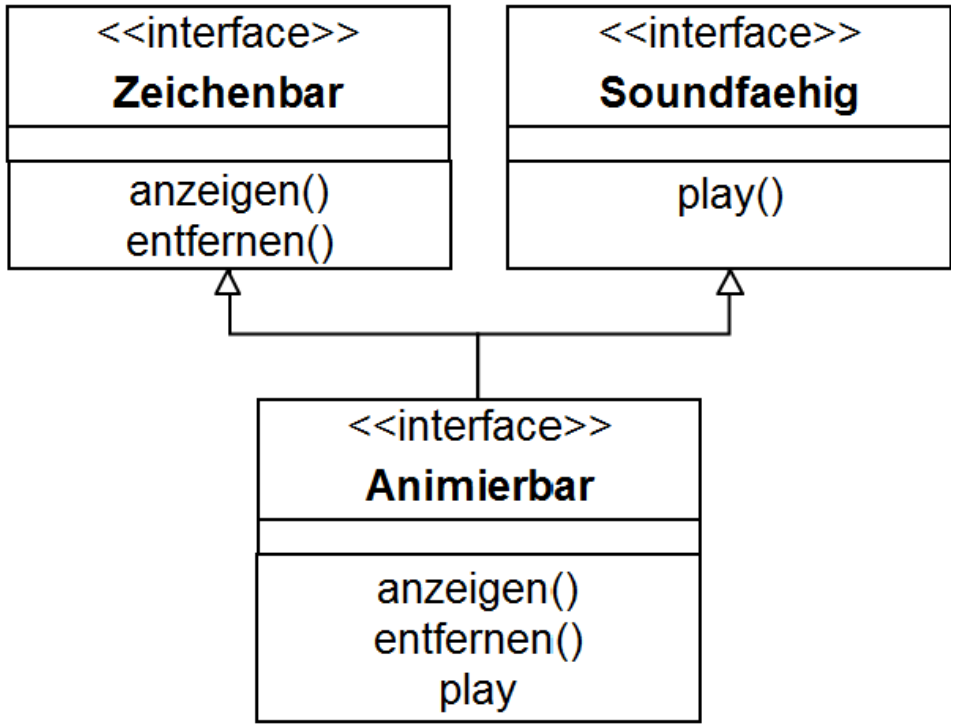


Realisation



Inheritance

Example

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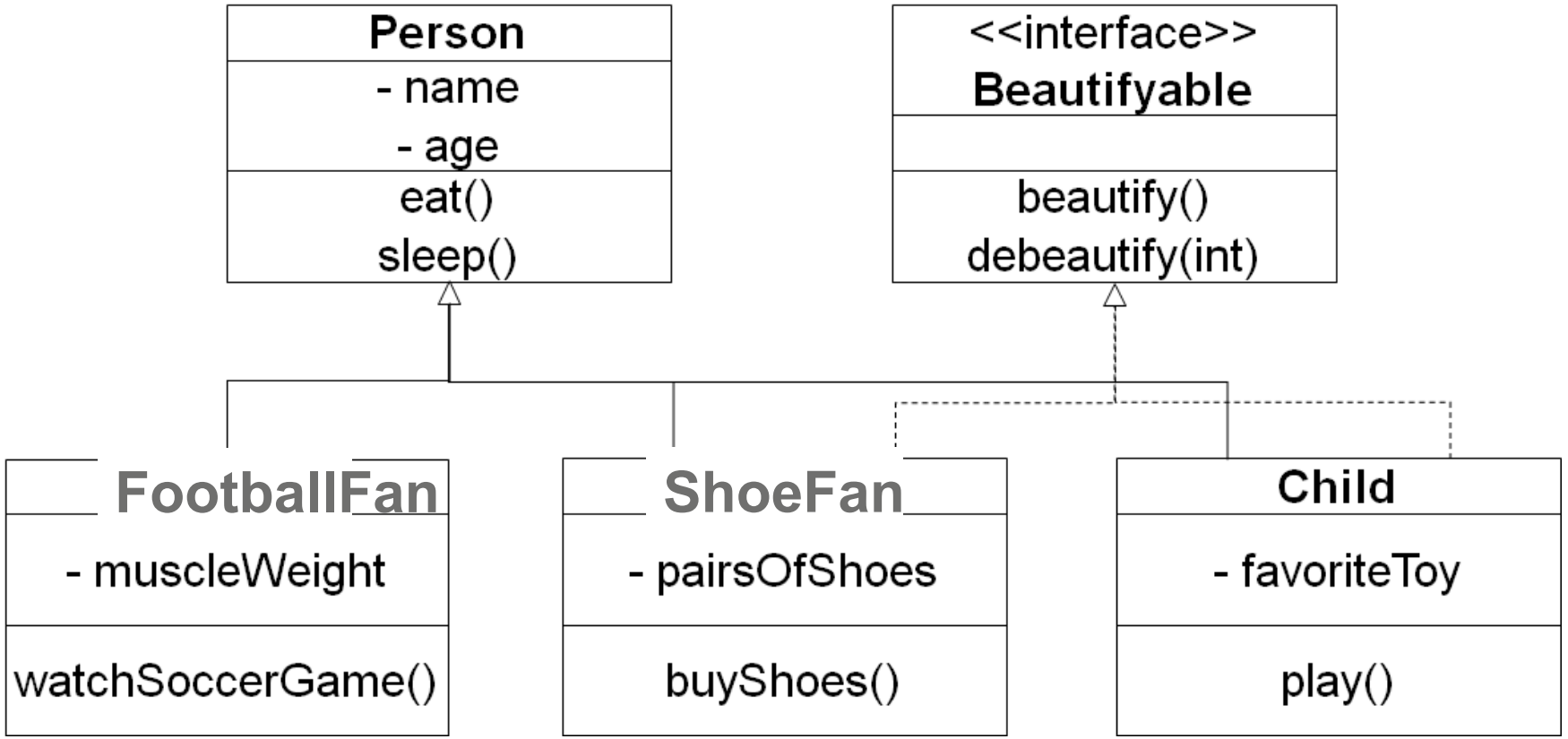

Implementation of the interface

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- Changes compared to the above example
  - `FootballFan` and `Person` classes unchanged
  - Extension of the `Main` class
  - New `Beautifyable` interface
  - `ShoeFan` class implements `Beautifyable` interface
  - New `Child` class implements `Beautifyable` interface

- New `Beautifyable` interface

```
public interface Beautifyable {
 public String beautify();
 public String debeautify(int minutes);
}
```

Interfaces vs. abstract classes

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- During the design phase of a complex software system: often difficult to choose one of the two variants
- **In favour of interfaces**: greater flexibility through the ability to be used in different class hierarchies
- **In favour of classes**: possibility to realise already formulatable parts of the implementation, and the ability to accommodate static components and constructors
- Combination of both approaches: first provide an interface, then simplify its application by using a helper class

Interfaces vs. abstract classes

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- Example: subsequent changes
  - Subsequent changes to interfaces are also not easy: an abstract class can be given a specific method, which does not result in any source code adaptation for subclasses.

- What should we do if we want to implement a `getTimeInSeconds()` helper function ?
- In the interface → all implementing classes must reimplement this implementation.
- In the abstract base class → simply insert into the abstract class, no changes necessary in the class users.

```
abstract class Timer {
 abstract long getTimeInMillis();

 long getTimeInSeconds() {
  return getTimeInMillis() / 1000;
  }
}
```

Combination of interfaces and abstract classes

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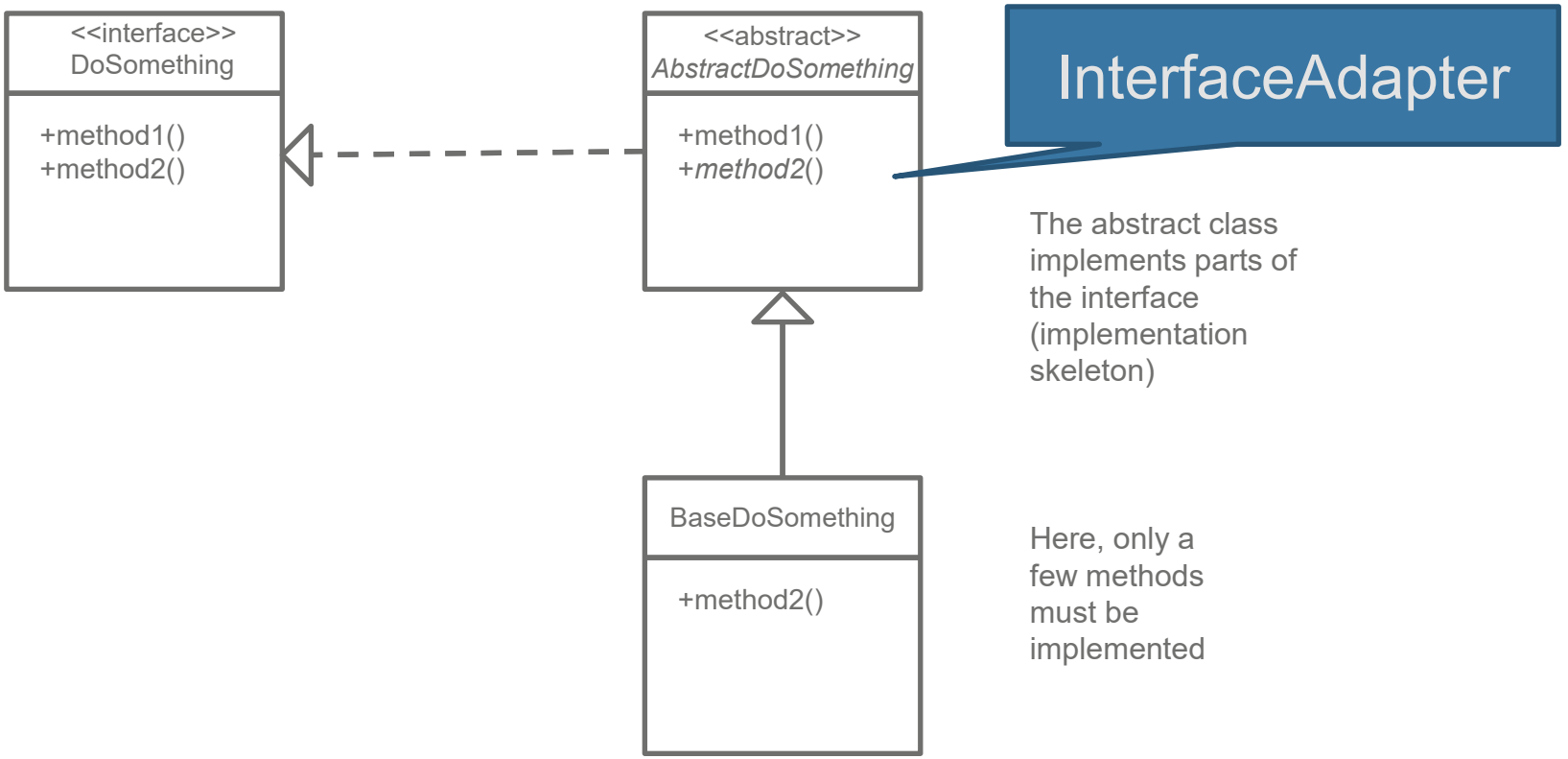
- Adapters provide a basic implementation of an interface



Type information at runtime

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```
AbstractBasis ab1 = new NormalBasis();
AbstractBasis ab2 = new SpecificA();
NormalBasis nb1 = new SpecificB();
SpecificA sa1 = new SpecificA();
SpecificB sb1 = new SpecificB();
```

- Instances of subclasses can be stored in base classes
- Runtime information through
  - **`instanceof`**: e.g. `if(ref instanceof MyClass){ … }`
  - Via `Object.getClass()`

Deadly Diamond of Death

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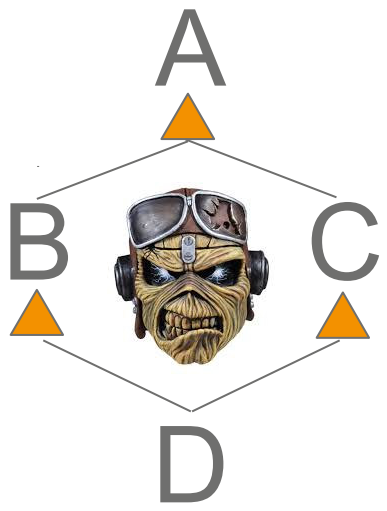
Problems that occur with such an inheritance structure

1. If class `A` provides an attribute `a`, do type `D` objects then have two `a` attributes, one through inheritance from `B` and one through inheritance from `C`?

2. If classes `B` and `C` both provide the method `public void foo()` with different implementations, which method then applies in `D`?



Multiple inheritance is shown here. Class D inherits from B and C (and twice from A). This is not possible without restrictions in Java.

How are these problems handled in Java?

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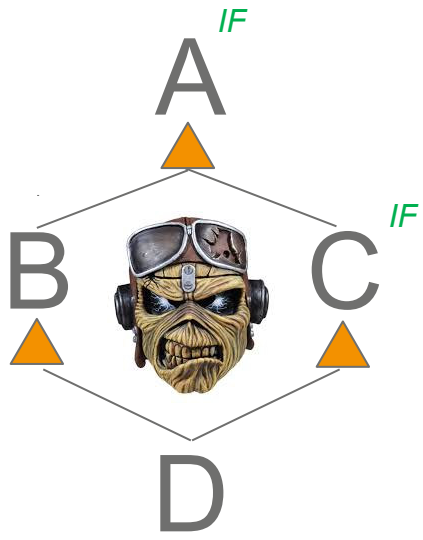
There is still no multiple inheritance of classes in Java. This means that exactly one class always comes after `extends`. It follows that either `B` or `C` must be an interface. Since interfaces cannot inherit from classes, then `A` is also an interface.

1. An attribute `a` in `A` must be `static final` because `A` is an interface. This means that `a` cannot be overwritten by `B` or `C`. Consequently, `D` has exactly one `a`, which is defined by `A`, and that's all!

2. If `B` provides a `void foo()` method and `C` (as an interface) provides a `default void foo()` method, then the method of `B` applies.
   a) if `A` and `C` provide `default void foo()`, then `C` applies (similar to overwriting)
   b) if `B` and `C` are both interfaces and provide `default void foo()`, then it must be explicitly specified which applies, otherwise a compiler error will occur.




```
public class D implements B,C{

    public void foo(){
        B.super.foo();
    }
}
```