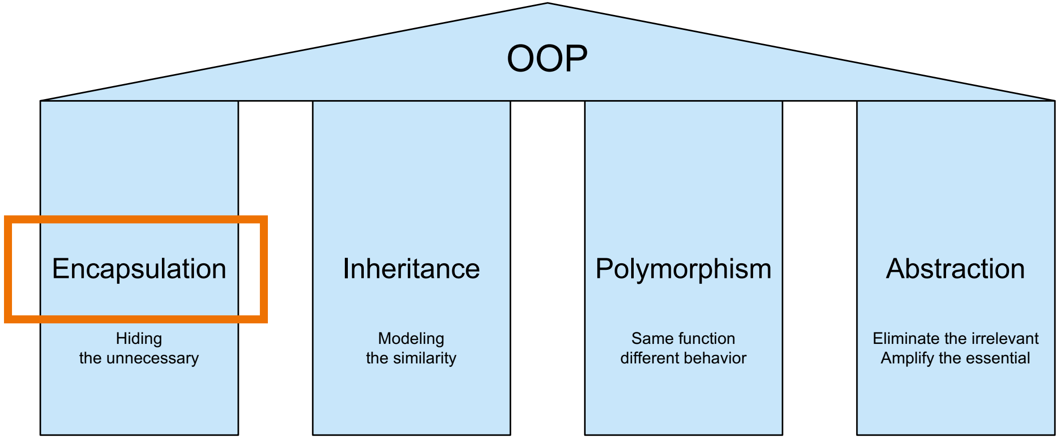

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Vorkurs Informatik

Vorlesung 4: Principles of Object-Oriented Programming I

Prof. Dr. Yannic Noller
Software Quality group

Agenda

- Software Quality research @ RUB
- Recap: Classes, Objects, Attributes, Methods
- UML Modelling
- Composition
- Four Principles of OOP
  - #1 Encapsulation

Software Quality research at RUB

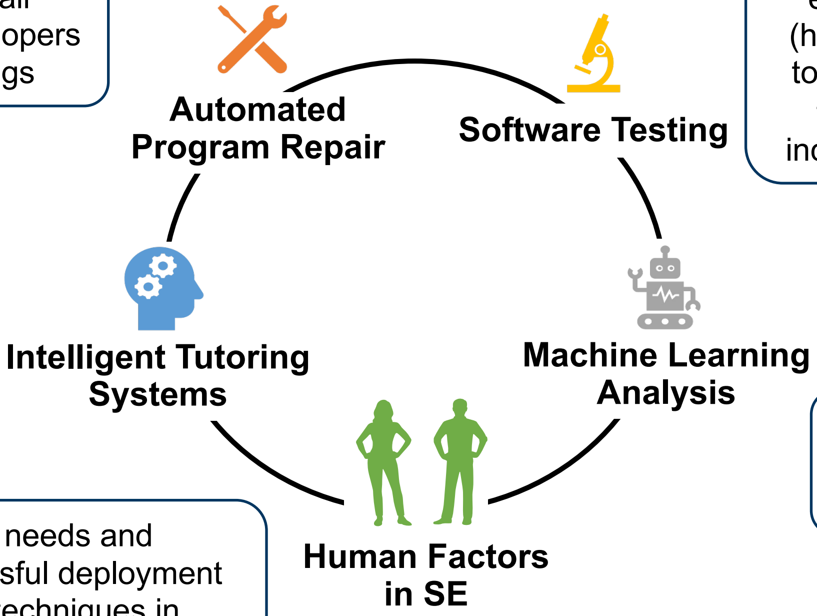
About Me

- since **July 2024**: Professor for Computer Science, Ruhr University Bochum
- **Before**:
  - 2023 – 2024: **Singapore** University of Technology and Design (Assistant Professor)
  - 2020 – 2023: National University of **Singapore** (PostDoc, Research Assist. Prof.)
  - 2016 – 2020: PhD student at HU **Berlin**
  - 2010 – 2016: Bachelor and Master in Software Engineering at University of **Stuttgart**
- **Research Interests:**
  - automated software engineering
  - software testing & verification (e.g., symbolic execution and fuzzing)
  - software repair (e.g., semantic-based)

Software Quality Research @ RUB

developing new repair techniques to aid developers in fixing program bugs

exploring and designing (hybrid) testing techniques to systematically generate test inputs that expose incorrect program behavior



how to help CS students learn programming by applying concepts from automated testing and repair to guide the students toward the right solution

automated analysis, testing, and repairing of machine learning models

studying developer needs and requirements for successful deployment of testing and repair techniques in development practice

https://informatik.rub.de/en/sq/

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Just Accepted

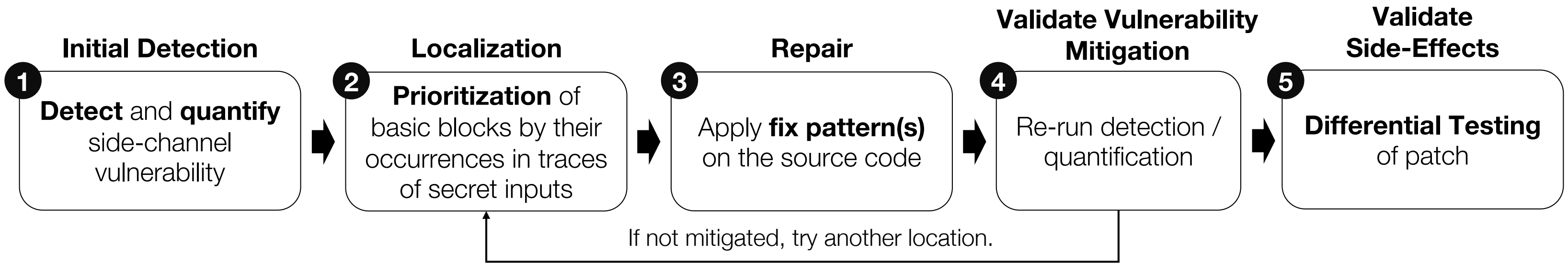
Timing Side-Channel Mitigation via Automated Program Repair

Authors: Haifeng Ruan, Yannic Noller, Saeid Tizpaz-Niari, Sudipta Chattopadhyay, Abhik Roychoudhury | Authors Info & Claims

ACM Transactions on Software Engineering and Methodology • Accepted on 19 June 2024 • https://doi.org/10.1145/3678169

Online AM: 16 July 2024 Publication History

Check for updates



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Evolutionary Testing for Program Repair

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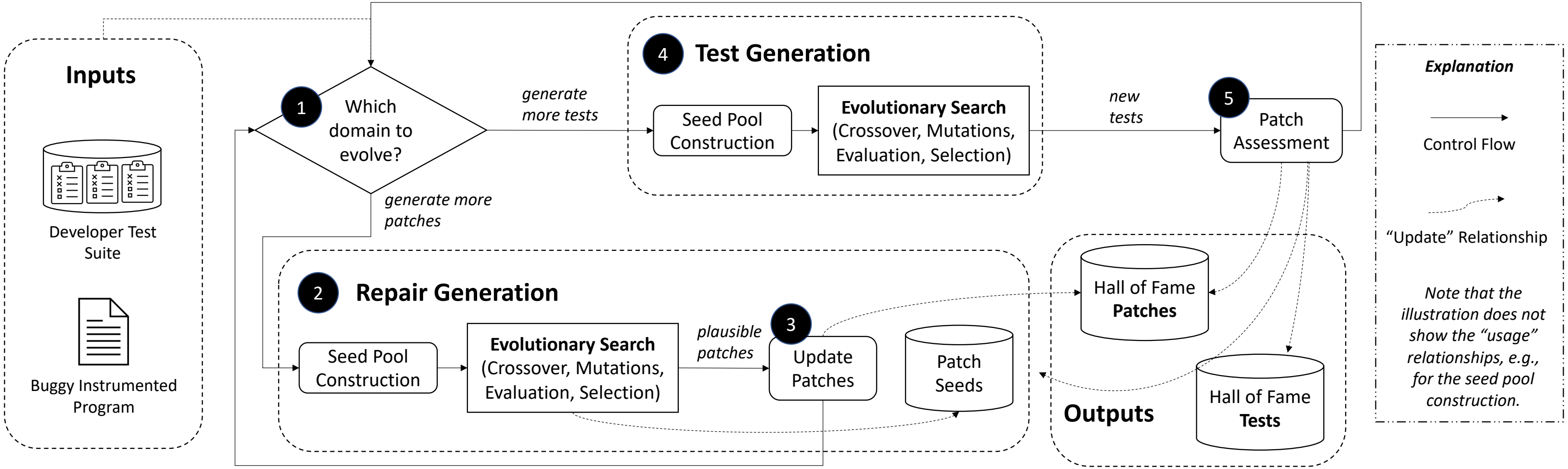

Recap

Classes, Objects, Attributes, Methods

Role of Programming

- **Programming**: Essential form of expression for a computer scientist
- **Programming Languages** (PL) determine what algorithms and ideas you can express
- **Learning** about Programming Languages
  - **choose right PL** for a specific purpose
  - make best use of tools (e.g., debuggers, IDEs, analysis tools)

→ **Learning the concepts**

Programming Languages

- **Broad Classification**
  - **Declarative** (“what to compute“): e.g., Haskell, SQL, spreadsheets
  - **Imperative** (”how to compute it”): e.g., C, Java, Perl
- **Various PL paradigms:**
  - Functional, Logic
  - Sequential, Shared-memory parallel, Distributed-memory parallel
  - Statically typed, Dynamically typed
- Most languages combine **multiple** paradigms
- **Types!**

Types in Java

What is the other category of types?

two categories of types

- **primitive data types:** 8 essential built-in data types

Typ	Size (Byte)	Values
`boolean`	1	`true` or `false`
`char`	2	16-Bit Unicode Character
`byte`	1	$-2^7 \ldots 2^7-1$ (i.e., $-128 \ldots 127$)
`short`	2	$-2^{15} \ldots 2^{15}-1$ (i.e., $-32768 \ldots 32767$)
`int`	4	$-2^{31} \ldots 2^{31}-1$
`long`	8	$-2^{63} \ldots 2^{63}-1$
`float`	4	$+/-3.40282347 * 10^{38}$
`double`	8	$+/-1.79769313486231570 * 10^{308}$

Object types
(also known as
class data types)

Quiz

What values do these JavaScript expressions evaluate to?

```
''      == 'zero'

''      == 0

'0'     == 0

false   == 'false'
```

https://forms.gle/RCpTizYcKkuHcWGk6

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Quiz

What values do these JavaScript expressions evaluate to?

```
''      == 'zero'   // false
''      == 0        // true
'0'     == 0        // true
false   == 'false'  // false
```

Two strings that are not the same

String and number: String is coerced into a number (here: 0)

Boolean and another type:

- Boolean gets coerced to a number (here: 0)
- String also get coerced to a number (here: NaN)
- The two numbers differ

Why do we need types?

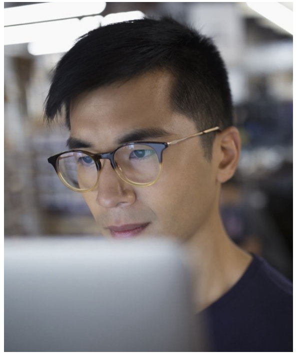
- **Reason 1:** Provide **context** for operations
- **Reason 2: Limit valid operations**
- **Reason 3: Code readability** and **understandability**
- **Reason 4:** Compile-time **optimizations**

*» **Object-oriented programming** is a method of implementation in which programs are organized as **cooperative collections** of **objects**, each of which represents an **instance** of some **class**, and whose classes are all members of a hierarchy of classes united via **inheritance** relationships. «*

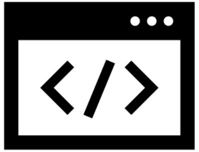
Grady Booch, “Object-oriented Analysis and Design with Applications”, 1991.

Examples for Objects

Manager



Programmer

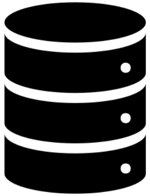


Window

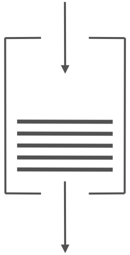
“Coffee”

String

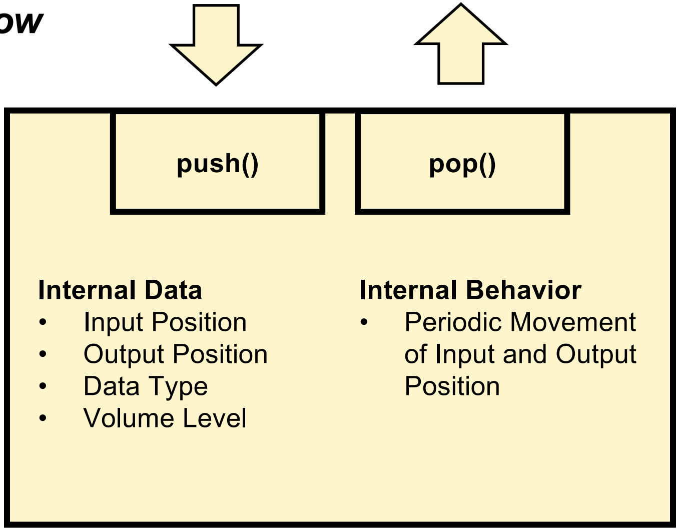
Contract



Database



Queue



Interface

Encapsulated data and functionality

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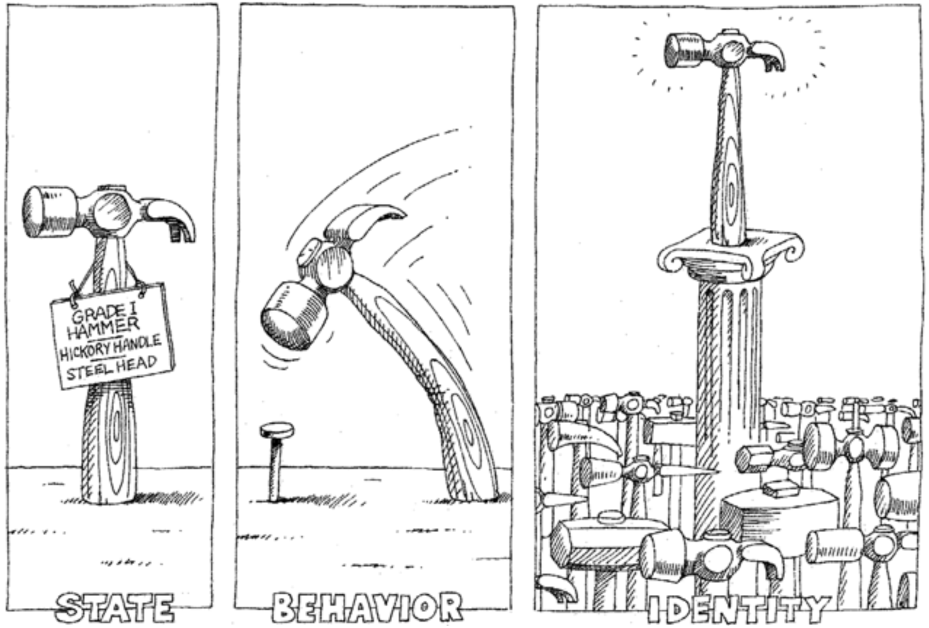
Objects



*» An **object** has **state**, exhibits some well-defined **behavior**, and has a unique **identity**.«*

- are **self-contained** units
- provide specific **service** or solve a specific task
- have a **state** and manage their **data**
- can be **instantiated** and **destroyed**

Grady Booch, "Object-oriented Analysis and Design with Applications", 1991.

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Classes

- A **class** is the **abstraction** (i.e., the data type) of an object and defines its **structure** (the attributes and methods).
- We **implement** the **class**, not the object.
- Objects are instances of **exactly** one class.
- Classes can have their own (class) methods and (class) attributes. A class attribute only exsists once per class (for all its objects).

- Examples:
  - Professor → Nils Jansen, Yannic Noller, …
  - University → RUB, TU Dortmund, HU Berlin, …
  - Airline → Lufthansa, Singapore Airline, …

Advantages

- Any relevant information (attributes, methods) linked to a concept is contained within a class.
- The object-oriented philosophy is that every object is a **blackbox** with a defined set of methods
  - We do not know or need to know how the data is stored inside the class
  - It is fine to use attributes within the class, but avoid doing so outside

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Example

- `RobotTurtle` as a game character

  - name
  - speed
  - position

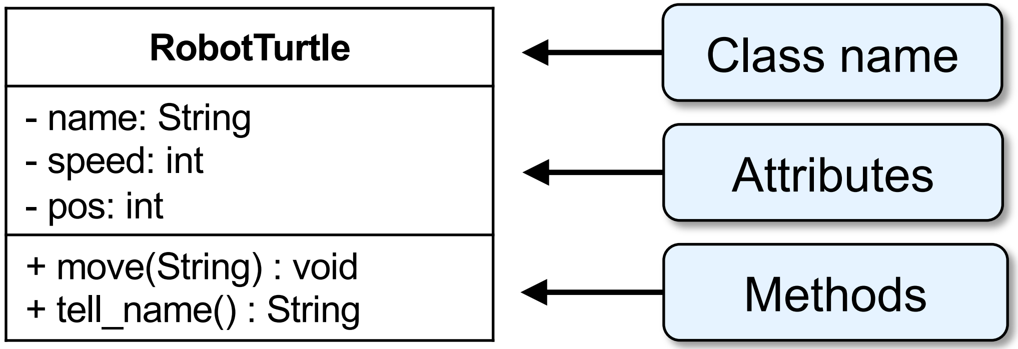
Attributes

  - tell name
  - move

Methods

UML Class Diagram

- Unified Modeling Language (UML) gives some specifications how to represent the classes visually



Attributes and Methods

- **Attributes**: define the characteristic of the object
  - usually a *noun*
  - variables defined within the object
- **Methods**: define what the object can do
  - usually a *verb*
  - functions that apply to our user-defined data type
- Attributes and methods **define** your object

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```java
public class RobotTurtle {

    private String name;
    private int speed;
    private int[] pos;

    public RobotTurtle(String name, int speed) {
        this.name = name;
        this.speed = speed;
        this.pos = new int[2];
    }

    public void move(String direction) {
        if (direction.equals("up")) {
            this.pos[1] = this.pos[1] + this.speed;
        …
    }

    public void tell_name() {
        System.out.println("My name is " + this.name);
    }
}
```

Class Definition

Attribute(s)

Constructor(s)

Method(s)

Object Instantiation

- Object instantiation refers to the **creation** of an object
  - an instantiated object is named and created in **memory**

RobotTurtle
- name: String - speed: int - pos: int
+ move(String) : void + tell_name() : String

<u>luigi : RobotTurtle</u>
name = “Luigi” speed = 1 pos = [0 , 0]

<u>mario : RobotTurtle</u>
name = “Mario” speed = 5 pos = [3 , 0]

<u>toad : RobotTurtle</u>
name = “Toad” speed = 2 pos = [1 , 0]

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The Constructor

- A **constructor** is a special (optional) **method**, which is called for the **initialisation** of an object.
- Constructors
  - have the same **name** as the class
  - do **not** have any **return value** (also not void!)
  - can have an arbitrary number of **parameters**, and can be **overloaded**.

Will be generated by **default** if no other constructor is defined.

```
public class Person {
   private int age;

   Person() {...}

   Person(int age) { this.age = age; }
}
```

```
Person donald = new Person();

Person dagobert = new Person(60);
```

```
    Person() {
       this(1);
    } ...
```

Constructor Chaining

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```java
RobotTurtle luigi = new RobotTurtle("Luigi", 1);

luigi.tell_name();

System.out.println(Arrays.toString(luigi.getPos()));

luigi.move("up");
System.out.println(Arrays.toString(luigi.getPos()));

luigi.move("right");
System.out.println(Arrays.toString(luigi.getPos()));

luigi.move("down");
System.out.println(Arrays.toString(luigi.getPos()));

luigi.move("left");
System.out.println(Arrays.toString(luigi.getPos()));
```

Instantiate Object

Usage of object's methods

Output:

```
My name is Luigi
[0, 0]
[0, 1]
[1, 1]
[1, 0]
[0, 0]
```

Quiz

How do we destroy an object?

Quiz

How do we destroy an object?

- **Java Virtual Machine** and its **Garbage Collector** will handle it.

```
protected void finalize() {
    ... // clean up
}
```

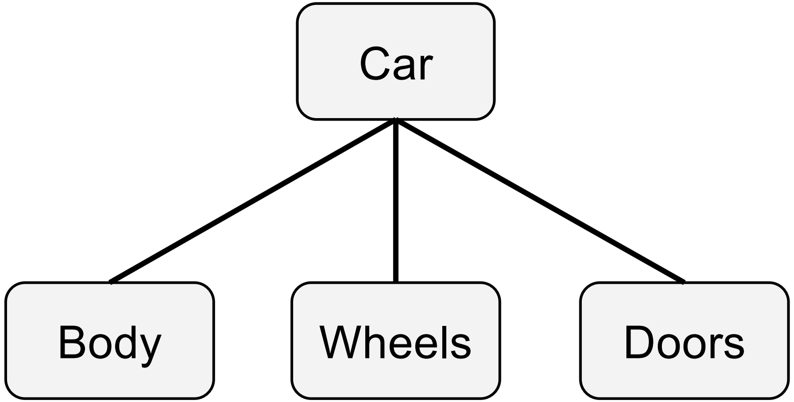
deprecated since Java 9

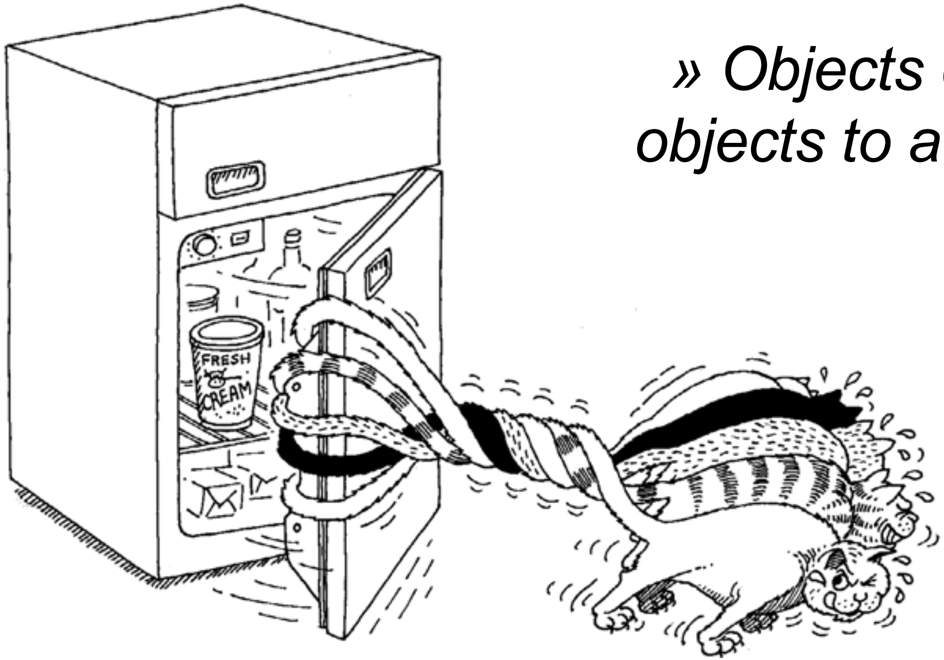
- housekeeping tasks, releasing of locks, closing of database/network connections, …

Relationship between classes: **Composition**

Composition

- Composition: an object can be **composed** of other objects.





*» Objects **collaborate** with other objects to achieve some behavior.«*

Grady Booch, “Object-oriented Analysis and Design with Applications”, 1991.

Composition

- Composition: an object can be **composed** of other objects.

```
public class RobotTurtle {

    private String name;
    private int speed;
    private int[] pos;

    public RobotTurtle(String name, int speed) {
        this.name = name;
        this.speed = speed;
        this.pos = new int[2];
        this.pos = new Coordinate(0, 0);
    }
…
}
```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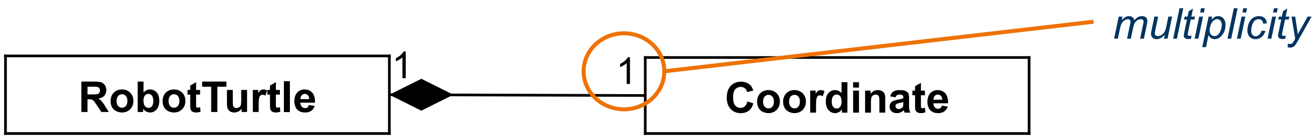
UML Class Diagram

- UML allows to specify the **relationship** between different classes



- The **black diamond** shows a **composition** relationship, i.e., an instance of RobotTurtle contains an instance of Coordinate
- **Multiplicity**: the “1” on both sides show that 1 instance of RobotTurtle is associated with exactly 1 instance of Coordinate

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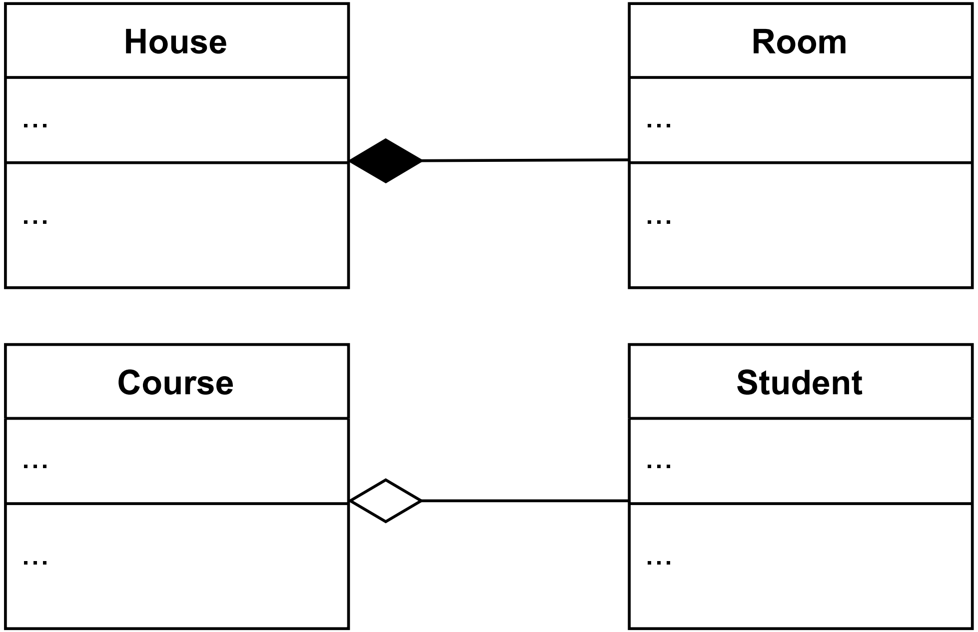
UML: Relationships between Classes

Composition
implies a relationship where the child cannot exist independent of the parent

Aggregation
implies a relationship where the child can exist independently of the parent



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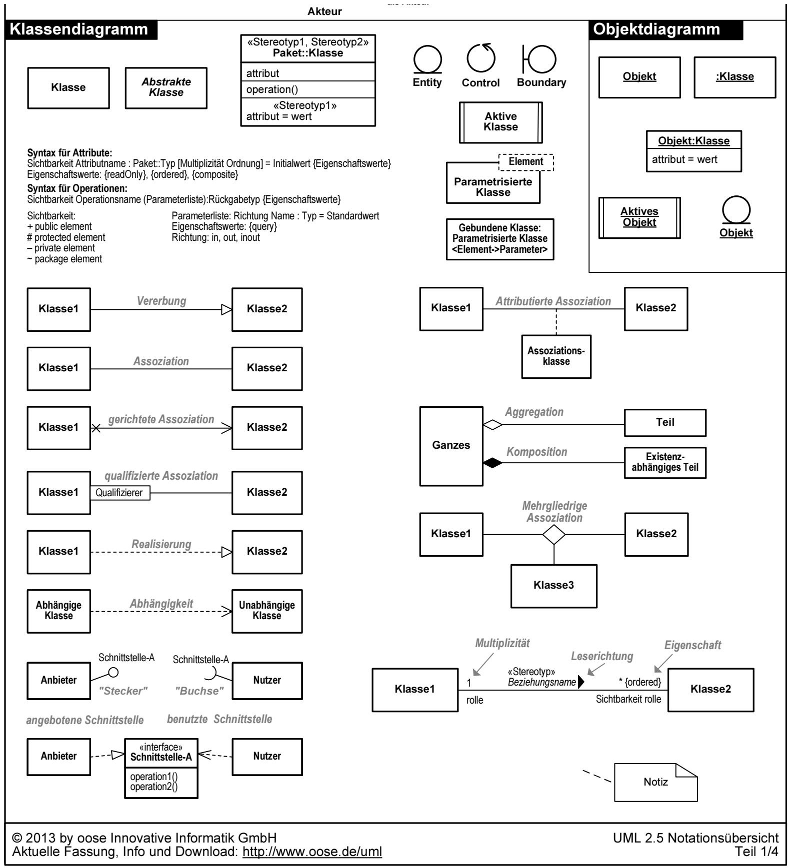
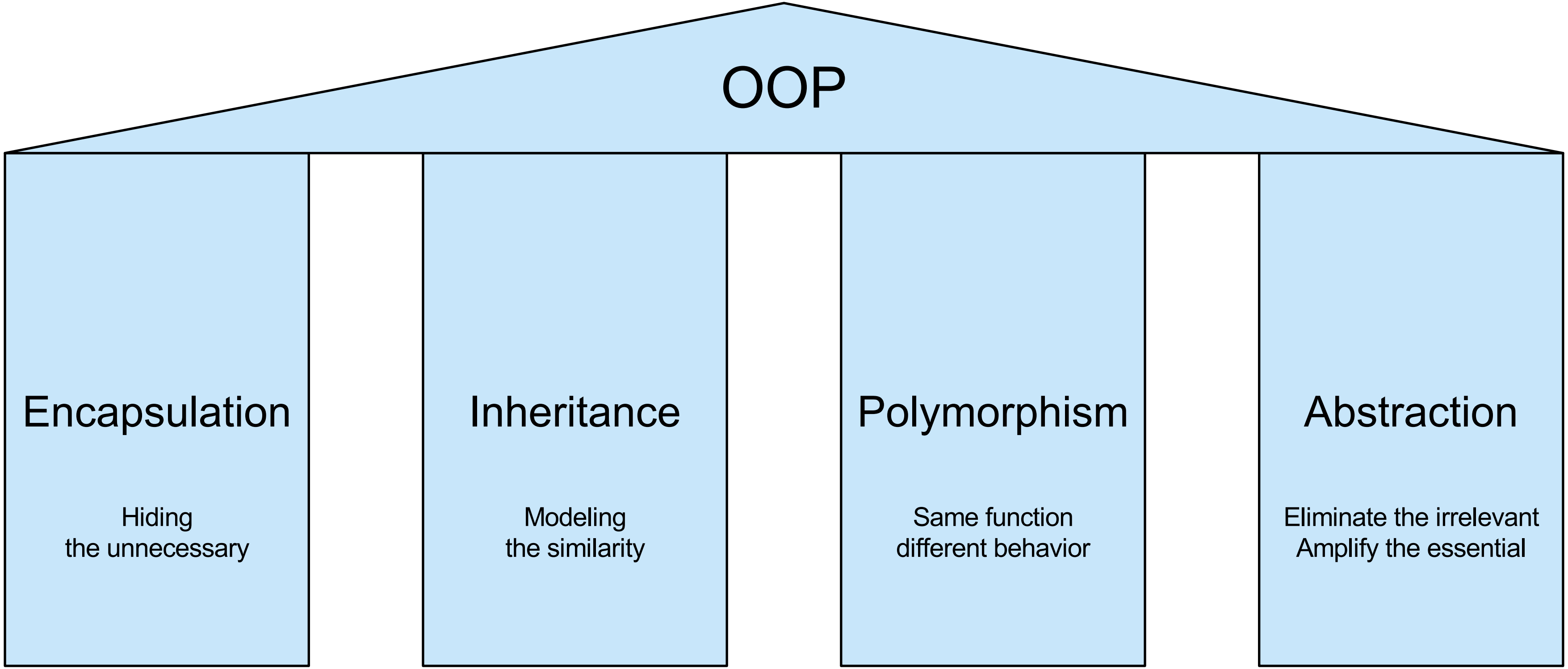
UML Notation Overview



Four Principles of OOP

Four Principles of OOP



#1 Encapsulation

Encapsulation refers to the bundling of data with the methods that operate on that data, or the restricting of direct access to some of an object's components.

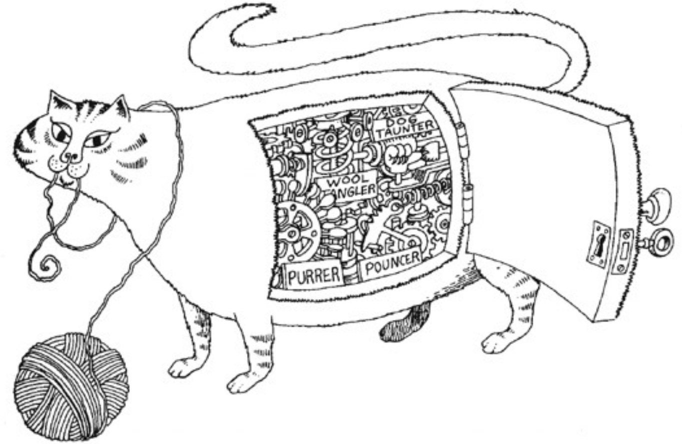
Without encapsulation

With encapsulation

Encapsulation in Java

- 1. Limit access to internal data by providing the methods that operate on the data
  - e.g., getter/setter methods, and other methods for the behavior
- 2. Restrict the direct access to the internal data of an object
  - Use the modifiers properly

» ***Encapsulation** hides the details of the implementation of an object.*«



Grady Booch, “Object-oriented Analysis and Design with Applications”, 1991.

Access Modifiers in Java

- **Modifiers** change the properties of classes, attributes and methods.
- **Accessability** of attributes and methods:

Attribute/Method visible in …	`public`	`protected`	`(default)`	`private`
own **class**	yes	yes	yes	yes
same **package**	yes	yes	yes	no
subclass	yes	yes	no	no
any other class	yes	no	no	no

- By default, classes are only visible within their own package (“implicit friendly”). The modifier `public` means that a class is also visible in visible in other packages.

Information Hiding & Hyrums Law

- **information hiding** — A software development technique in which each module's interfaces **reveal as little as possible** about the **module's inner workings**, and other modules are **prevented** from using information about the module that is not in the module's interface specification. *IEEE Std 610.12 (1990)*

- **Hyrum's Law** (an observation from software engineering practice):

  "With a sufficient number of users of an API,
  it does not matter what you promise in the contract:
  all observable behaviors of your system
  will be depended on by somebody."

Modifier `final` – Changeability

- The modifier **`final`** restricts the **changeability** of the affected program elements:
  - **no subclasses** may be derived from **`final`**-classes
  - **`final`**-methods may **not be overriden**
  - **`final`**-attributes **may not be changed**, i.e. they are **constants**
  - **parameters** of methods and **local variables** declared as **`final`** may not be changed after initialization.

```
void increaseSalary(final double amount){
    amount = 2 * amount; // not allowed!
    ...
}
```

Modifier `static` – Lifetime

- The modifier **`static`** influences the **lifetime** and is used to define static attributes and methods.
- In contrast to “normal” attributes and methods, static attributes and methods are not bound to specific objects.
- static attributes (class attributes) are only created once per class: all objects of the class “share” the attribute.

```
public class void Person {
   public static int counter = 0;
   Person() { counter++; // counts instances}
   ...
}
```

- External access to static attributes: **`ClassName.attribute`**

```
int numberofPersonObjects = Person.counter;
```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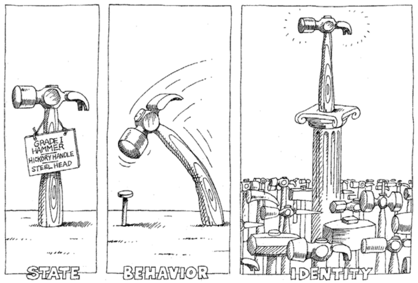
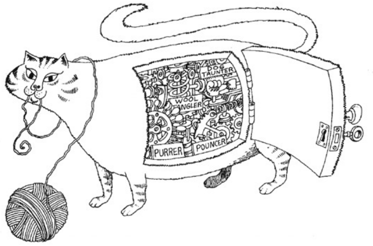
Summary

- **Programming Languages** (PLs) determine what algorithms and ideas you can express
- **Typesystems** are an essential part of PLs
- **Object-Orientation**
  - Objects: construct classes based on object abstraction
  - **Instantiation** of objects with constructors
  - Four **Principles** of OOP
    - #1 **Encapsulation**: internal data and behavior, information hiding
  - Access modifiers in Java, final, static





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