Object-Oriented Programming In Mechatronic Systems

Summer School

Module 1
Aachen, Germany, August 7th, 2018

Cybernetics Lab IMA & IfU
Faculty of Mechanical Engineering
RWTH Aachen University

Organization

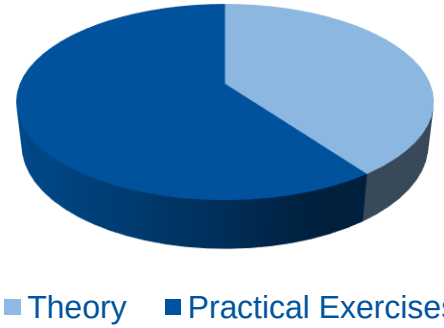
Organization

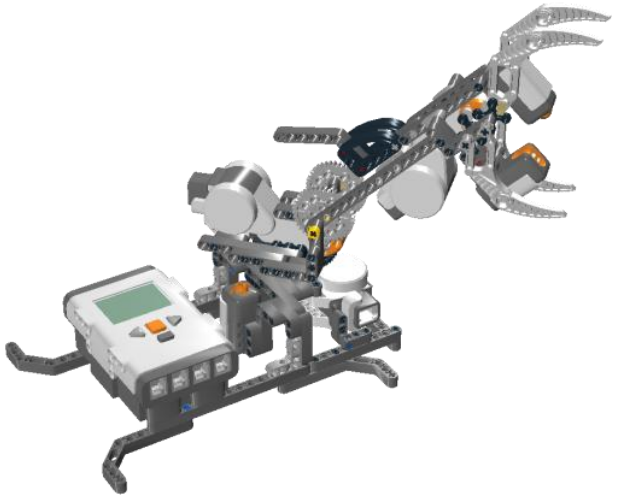
Synopsis

Today's mechanical engineering relies heavily on advanced software tools. Both industry and research expect you not only to use these tools but to design, develop and deploy them as well. During this course we teach you how.

Topics

- Java 101
- Object Oriented Software Engineering
- Software-Hardware Interaction





Organization

… at the Institute of Information Management in Mechanical Engineer (IMA)

Information Management for Mechanical Engineering

Prof. Dr.-Ing.
Tobias Meisen

Management
Director of IMA

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M.Sc.

Researcher
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Max Hoffmann

Research Leader
Industrial Big Data

Daniel Lütticke
Dipl.-Inform

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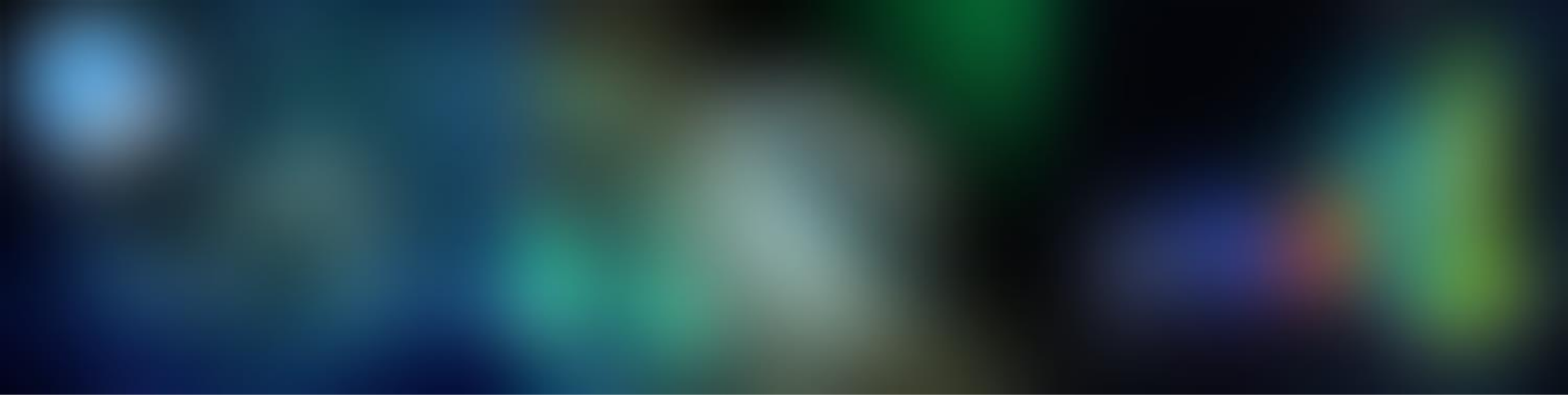

The Cybernetics Lab

Who are we?

IfU IMA RWTH AACHEN UNIVERSITY

Interdisciplinary at the Cybernetics Lab IMA & IfU

Univ.-Prof. Dr.-Ing.
Christian Hopmann (IKV)
Acting Head of Institute

apl.-Prof. Dr. habil.
Ingrid Isenhardt
Deputy Head of Institute

Dr. rer. nat.
Frank Hees
Vice Deputy Head of Institute

apl.-Prof. Dr. rer. nat.
Sabina Jeschke

Administration | **Public Relations** | **IT & Media Technology**

IMA
Inst. of Information Management in Mechanical Engineering

Information Management | Knowledge Management

Jun.-Prof. Dr.-Ing.
Tobias Meisen
Managing Director

Dr. phil.
Max Haberstroh
Managing Director

Ing. Industrial **Alexia Fenollar Solvay** Mobility and Logistics	Dr. rer. nat. **Stefan Schröder** Innovation- & Work Science
Dipl.-Inform. **Daniel Lütticke** Production Technology	Dr. phil. **Kathrin Schönefeld** Knowledge Engineering
Dipl.-Inform. **Christian Kohlschein** Cognitive Computing & eHealth	Dr. phil. **Valerie Stehling** Digital Learning Environments
Dr.-Ing. **Max Hoffmann** M.B.A. Industrial Big Data	

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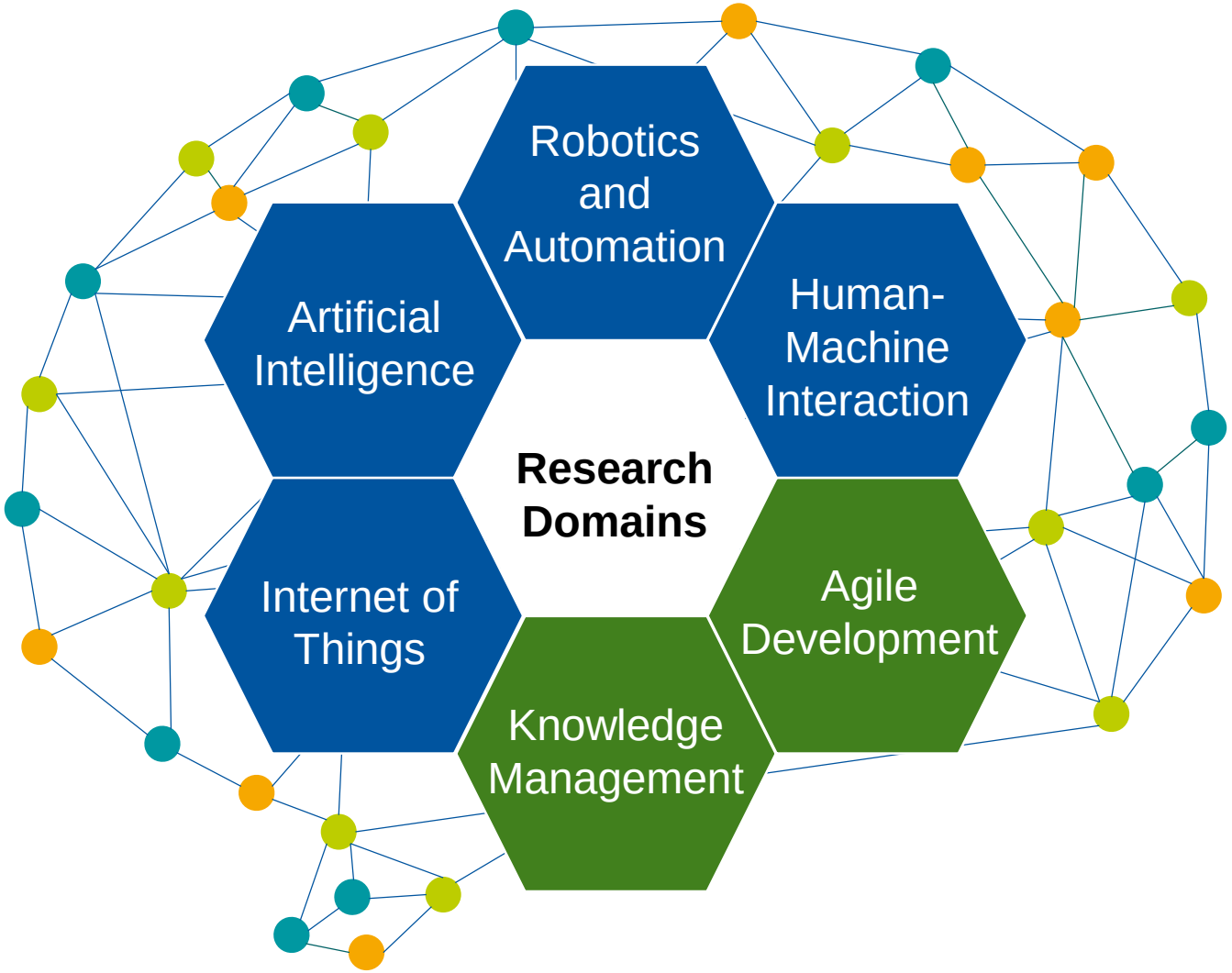
Managing Director

Dr. phil. **Daniela Janßen** Economic and Social Cybernetics
Dr. rer. nat. **Pia Bresenitz** Technical Cybernetics

Prof. Dr.-Ing. em.
Klaus Henning
Senior Advisor

What drives us

Research Domains

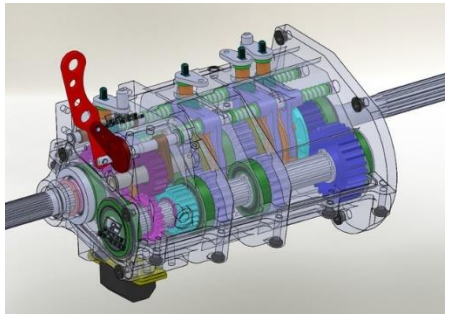


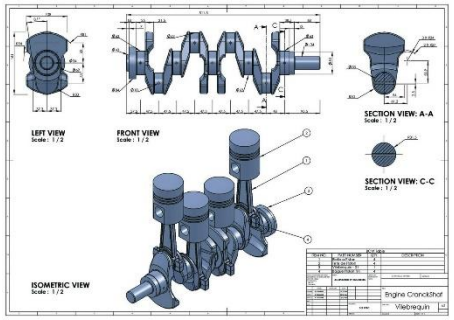
Motivation

Motivation

Mechatronic Systems rely on Advanced Software Tools!

From Computer Aided Design (CAD) to Robotics …

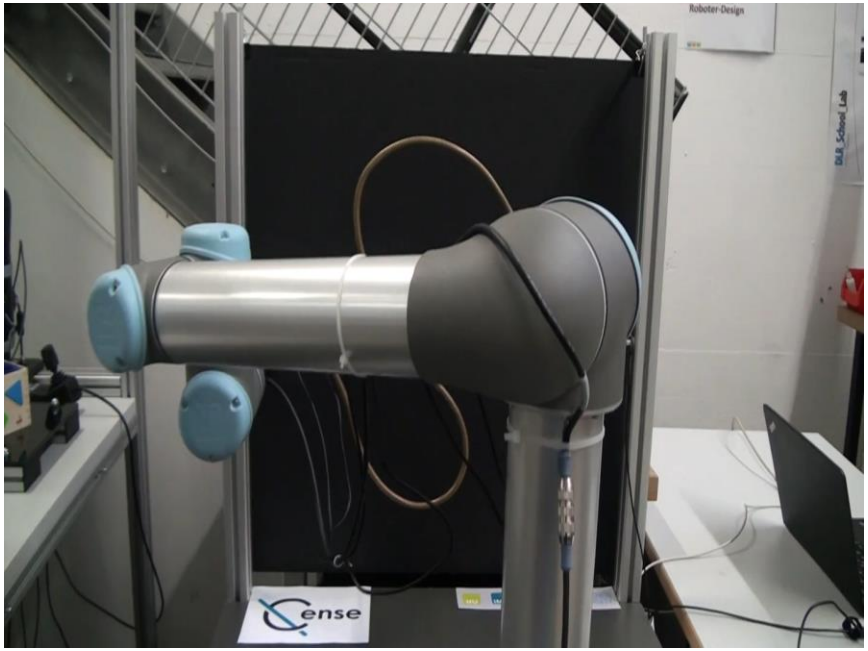




Motivation

Mechatronic Systems rely on Advanced Software Tools!

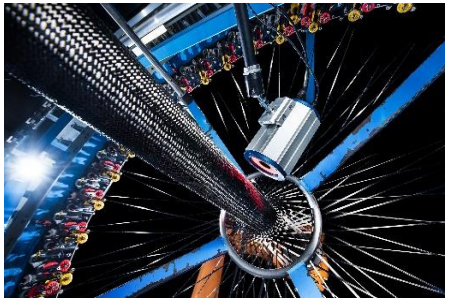
… to learning robots! (at our institute)

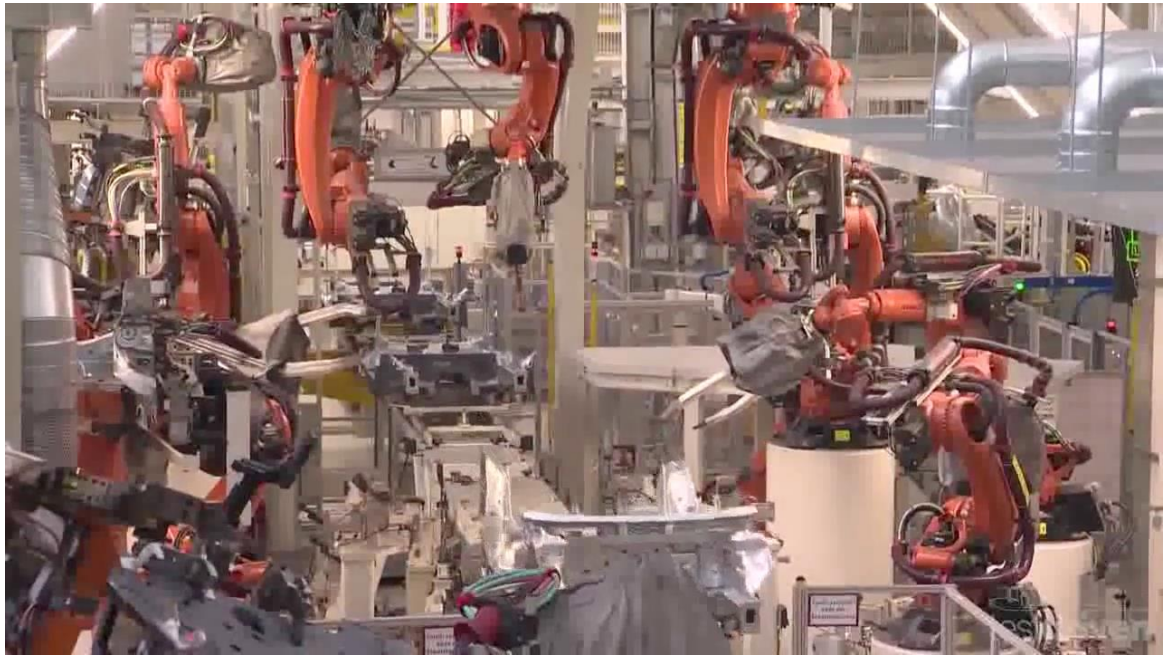


Motivation

Mechatronic Systems rely on Advanced Software Tools!

… to self-optimizing production systems!





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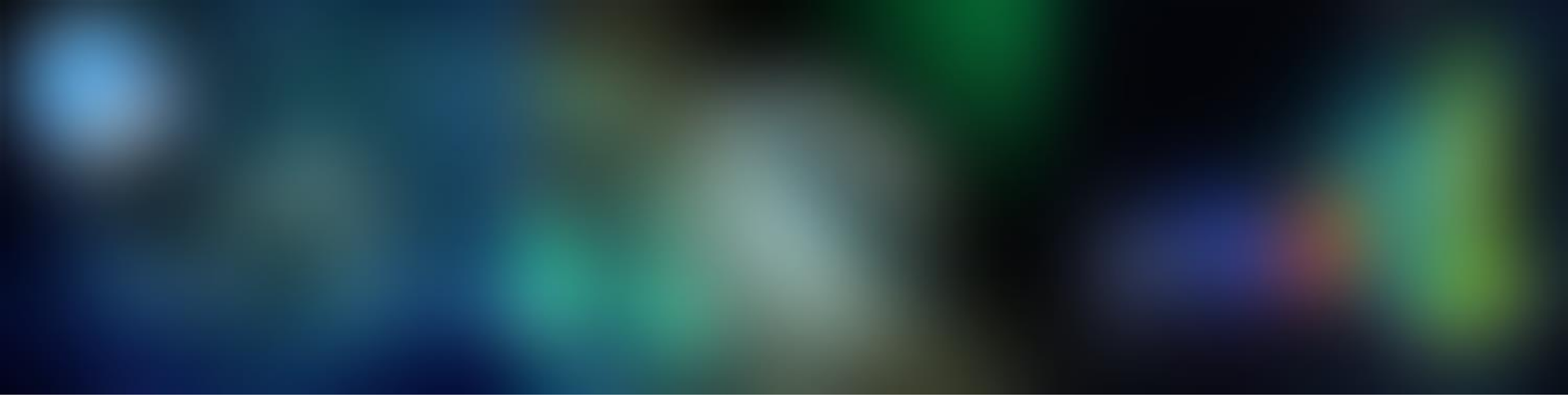
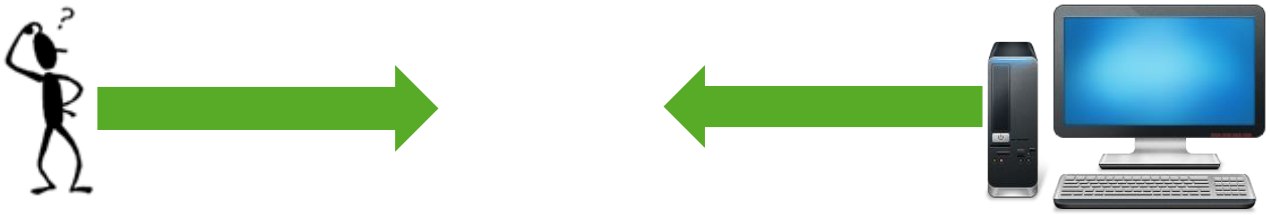


Algorithms and Programming Languages

Algorithms and Programming Languages

We need an interface between human and computer



Both have different requirements:

Human:

- Analog world
- Visual, haptic and auditory signals
- Comprehensive integration in contextual knowledge
- Fluent, “natural” language

Computer

- Digital World
- Electronic signals
- Majority: no information “outside”
- Structured statements: Algorithms

How do we formulate a problem for the computer?

An **algorithm** is an unambiguous rule of action for solving a problem or a class of problems.

Colloquially:

- Algorithms are "somehow clever" methods that efficiently help to solve specific problems
- Not only arithmetic problems such as efficient addition or multiplication, but also everyday questions:
  - How do I find the exit from a labyrinth?
  - How do I calculate the shortest connection between two cities?
  - How do I search my warehouse shelf as quickly as possible?

Example of an algorithm:

1. Put a filter in the filter container
2. Fill the filter with coffee powder
3. Pour water into the tank provided for this purpose
4. Check whether empty coffee pot is ready
5. If **yes**: Go to step 7 ← Branch
6. If **not**: empty the coffee pot and place it under the filter
7. Press the start button
8. Wait until the coffee is ready (typically: machine "gurgles", steam rises)

← Termination Condition

Properties of algorithms:

Finiteness:

- Formulated in a finite text (static finiteness)
- Finally needs a lot of memory (dynamic finiteness)
- Finished in finally many steps (scheduling)

Executability:

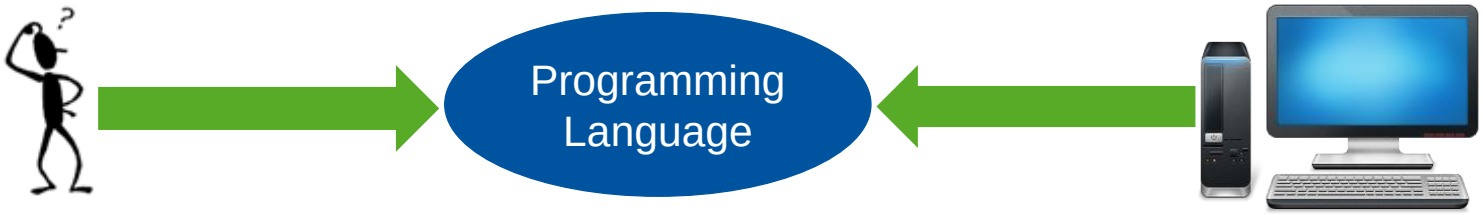
- Each step must actually be executable

Uniqueness:

- Always the same result under the same conditions (Determinacy)
- Only ever exactly one possibility of continuation (Determinism)

Algorithms and Programming Languages

Interface between Human and Computer



Still, both have different requirements:

Human:

- Natural language
- Legibility
- Expressiveness

Computer

- Simple translation into machine code
- Efficiency of the generated code

Algorithms and Programming Languages

Learning programming languages comparable to "natural" foreign languages

Syntax:

- Defines permitted strings (= vocabulary) and grammar
- In each language there are defined keywords

Semantics:

- Defines the meaning of the syntax
- Builds on syntax

Syntactically correct, semantic nonsense:
"A banana speculates purple the sunset."

Syntactically incorrect, semantically correct:
"A banana is fruit yellow."

Syntactically correct, semantically correct:
"A banana is a yellow fruit."

Algorithms and Programming Languages

```java
1. class HelloWorld{
2.   public static void main(String[] args){
3.     System.out.println("Hello World!");
4.   }
5. }
```

Java

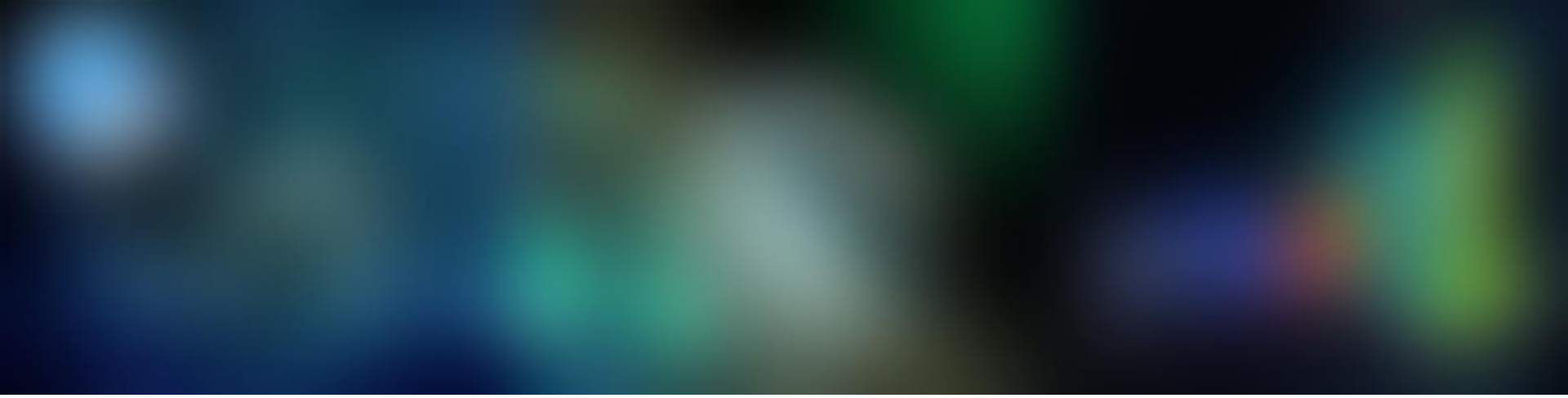
```fortran
1.Program Hello
2.Print *, "Hello World!"
3.End Program Hello
```

Fortran

```python
1.class HelloWorld(object):
2.    def __init__(self, args):
3.          print(„Hello World!“)
```

Python

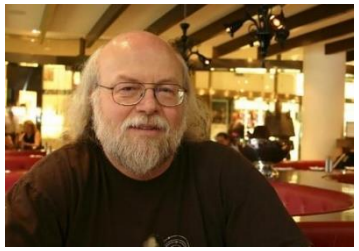
Different syntax, identical semantics!



The Java Programming Language

Brief History

- Java invented June 1991 by James Gosling at Sun (2010 acquired by Oracle)



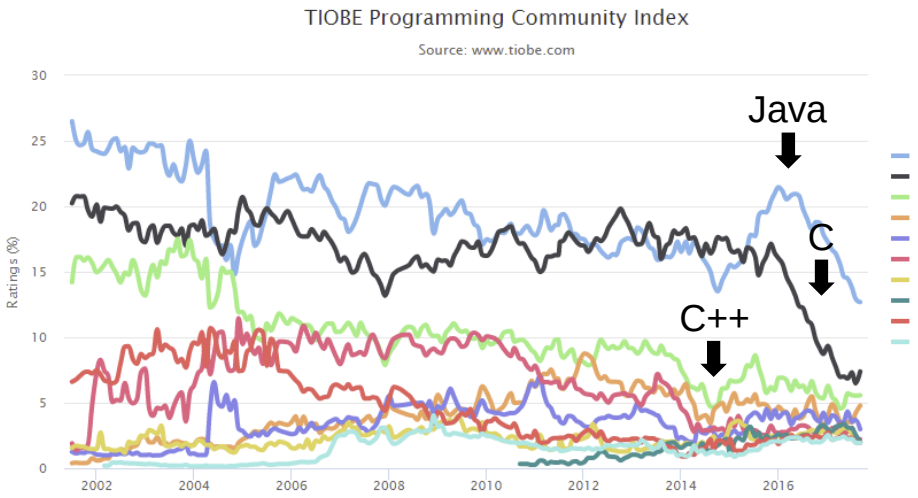
- **Five** Design Goals:
  - *“Simple, Object Oriented, and Familiar”*
  - *“Robust and Secure”*
  - *“Architecture Neutral and Portable”*
  - *“High Performance”*
  - *“Interpreted, Threaded, and Dynamic”*

- Current Version: Java 8 Update 144

The Java Programming Language

It’s widely spread!

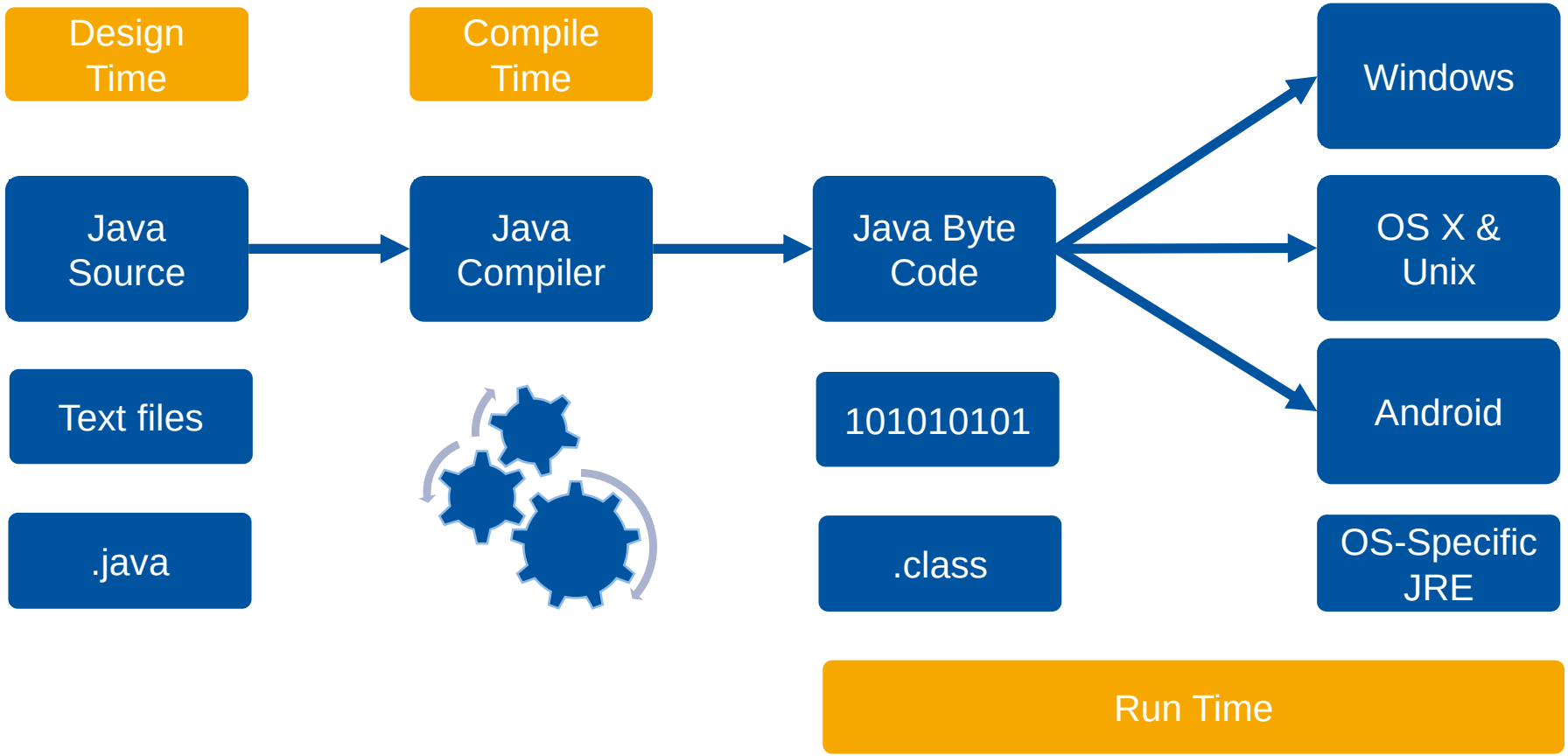
TIOBE 2015 (Popularity Index)



Sep 2017	Sep 2016	Change	Programming Language	Ratings	Change
1	1		Java	12.687%	-5.55%
2	2		C	7.382%	-3.57%
3	3		C++	5.565%	-1.09%
4	4		C#	4.779%	-0.71%
5	5		Python	2.983%	-1.32%

Industry use (to name a few)

Motto: “Write Once, Run Anywhere”



Terminology

- JVM: **J**ava **V**irtual **M**achine. Executes Java byte code.
- JRE: **J**ava **R**untime **E**nvironment. Contains the JVM + set of libraries
- JDK: **J**ava **D**evelopment **K**it. Contains the JRE + Development tools (e.g. *javac*)

JVM Features

- **Automatic Garbage Collector**
- JIT Compiler
- Byte Code Verifier
- **Supports other languages:**

What are the basic requirements for writing a Java program?

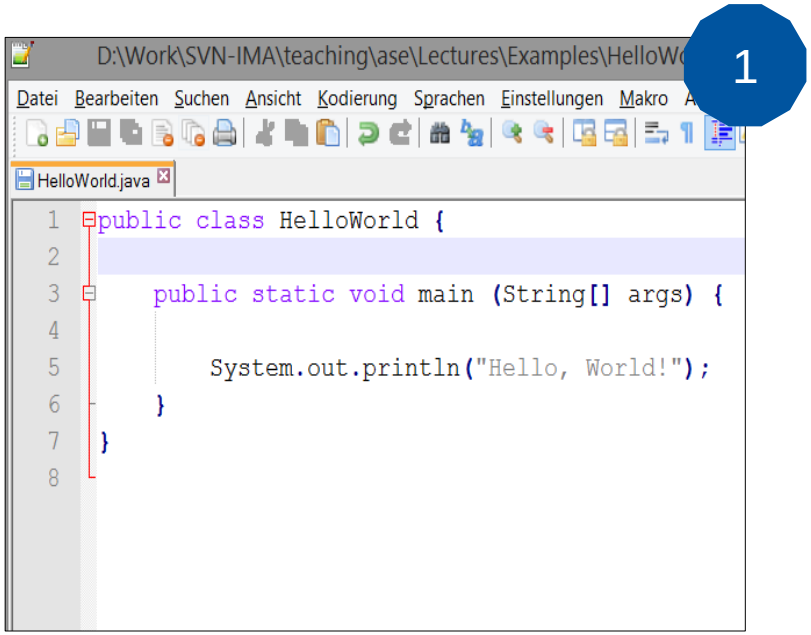
- A computer with a Java supported OS (e.g. Windows or OS X)
- A text editor, e.g. notepad++ (but we'll use 

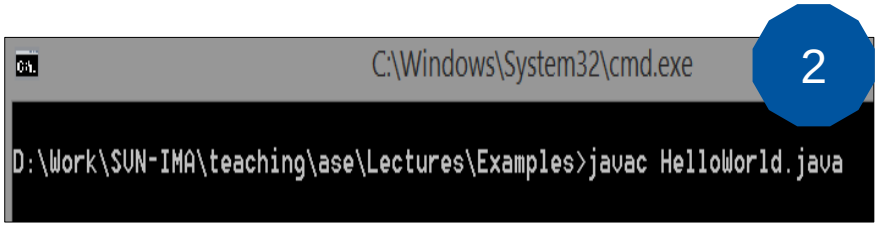
IDE during this course)
- The Java JDK: http://www.oracle.com/technetwork/java/javase/downloads/jdk10-downloads-4416644.html

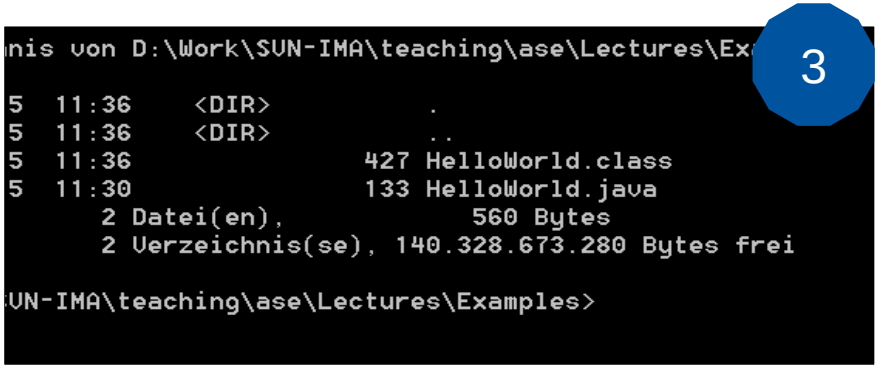
Five steps to run a Java program

1. Create a Java source file, i.e. write some code.
2. Save it to a .java file (e.g. `HelloWorld.java`)
3. Compile the Code (using `javac`, e.g. `javac HelloWorld.java`).
4. The compilation yields a class file (e.g. `HelloWorld.class`)
5. Run the program (e.g. `java HelloWorld`)

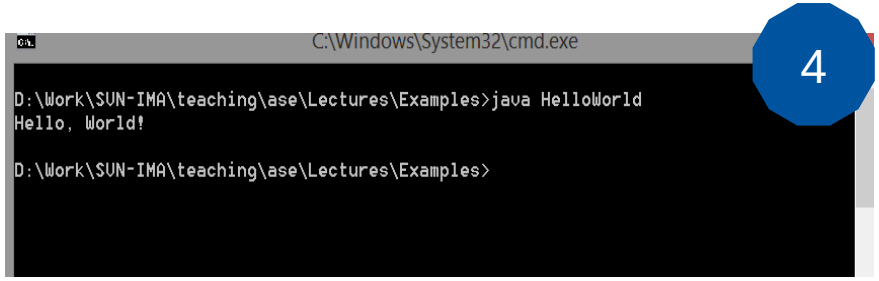
Writing, Compiling and Executing







1. Write
2. Compile
3. Yields a `.class` file
4. Execute



Structure of a Java Program

Structure of a Java Source File

Class Definition

```
public class Foo {



}
```

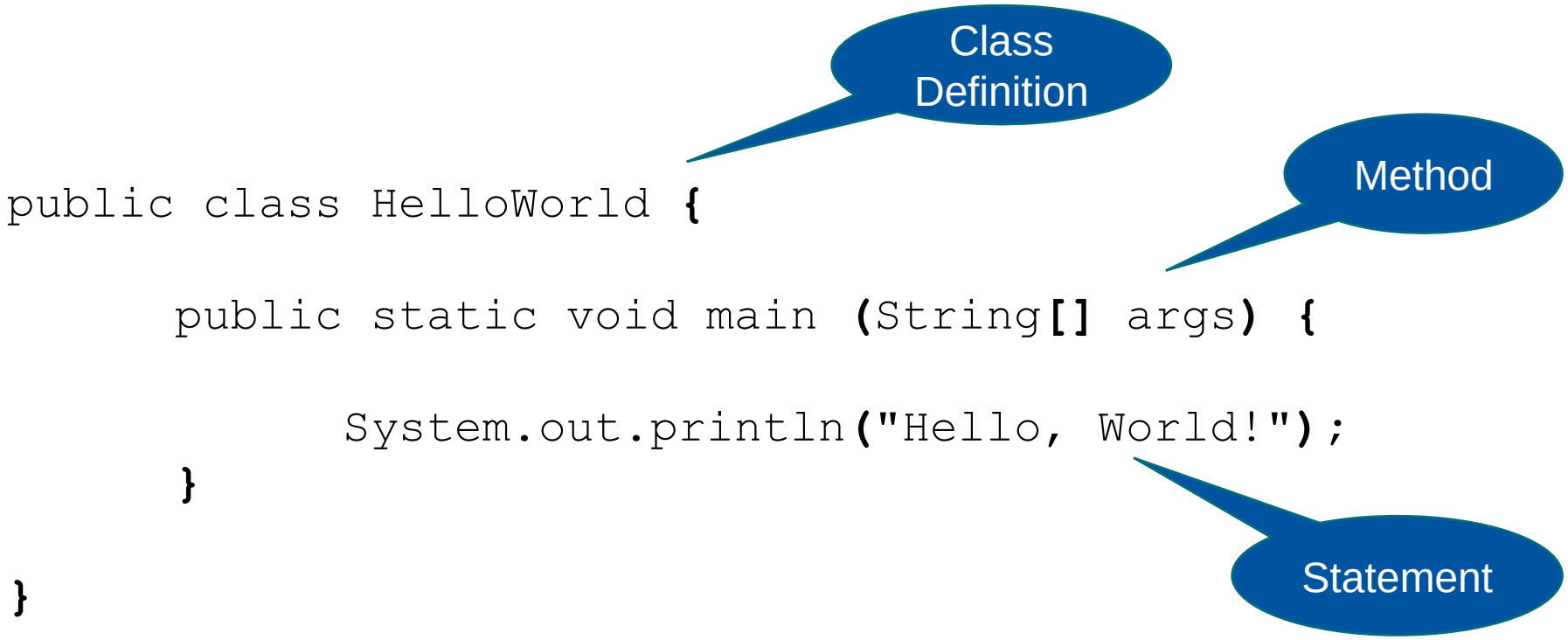
Methods

```
public class Foo {

    void bar() {



    }

}
```

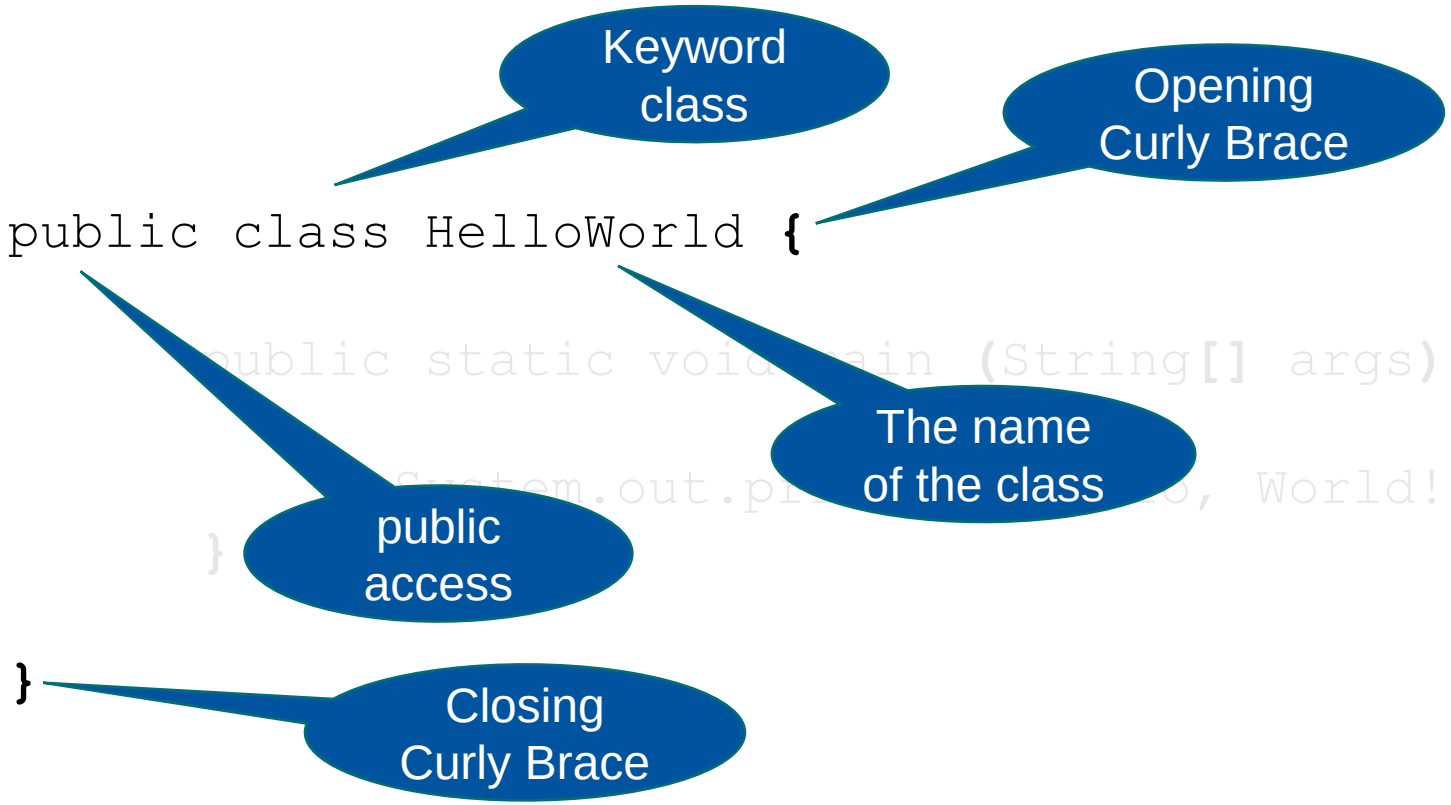
Statements

```
public class Foo {

    void bar() {

        statement1;

        statement2;

        statement3;
    }

}
```

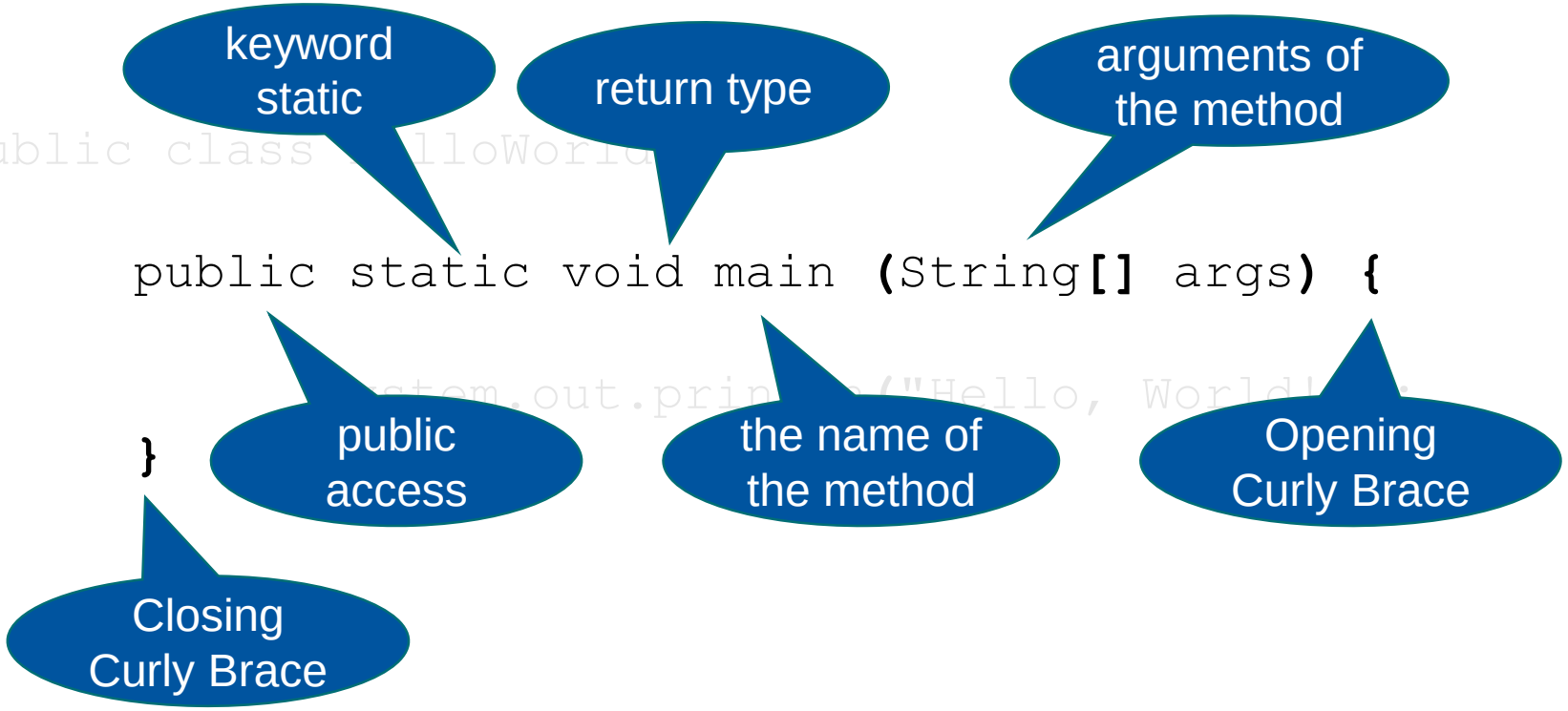
Structure of a Java Source File



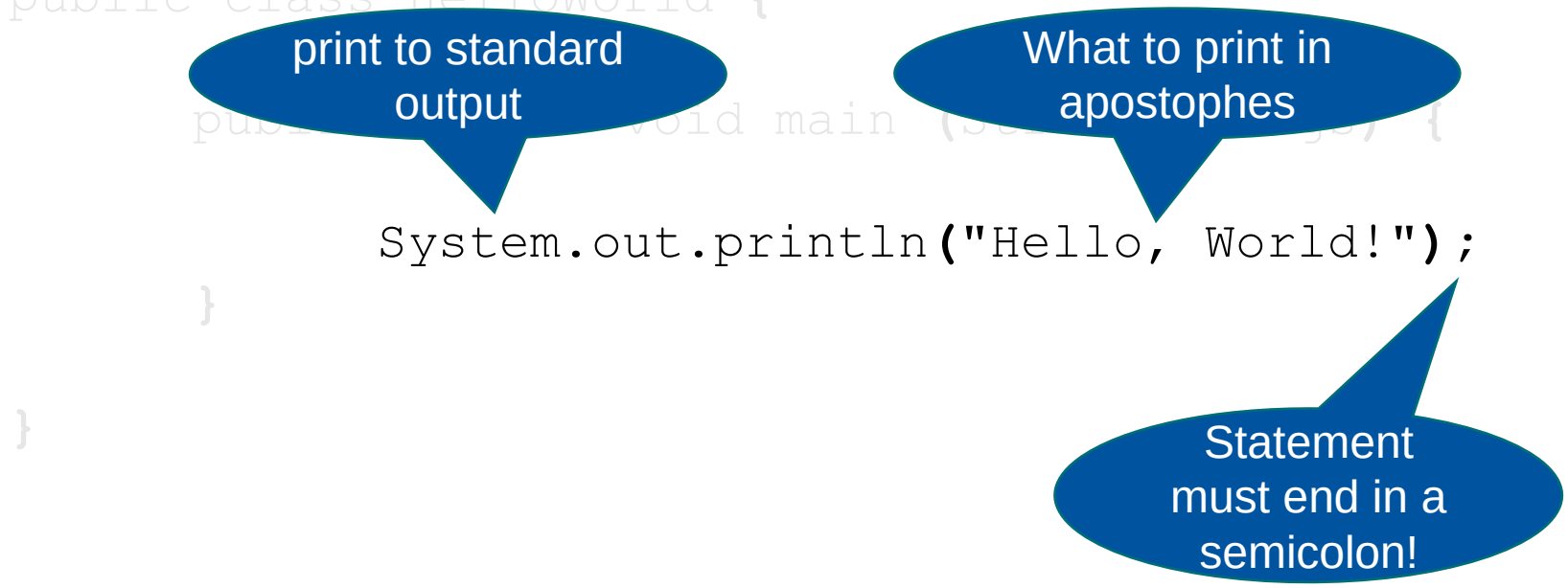
Structure of a Java Source File. A closer look at the class.



Structure of a Java Source File. A closer look at the method.



Structure of a Java Source File. A closer look at the statement.



What are comments?

- Document the code and keep it readable
- Single line comment: `// myComment`
- Multiple line comment: `/* myMultiLineComment */`

Examples

```
public class HelloWorld { // It's my first class!
  public static void main (String[] args) {
    /* I want to
    print on the command line */
    System.out.println("Hello, World!");
  }
}
```

Variables

Variables

What are variables?

- A container, a box or a cup. It contains something.
- They come in different kinds
- They got a name

Examples

```
short numberOfEngines = 5;
double temperature = 23.7;
boolean engineStarted = true;
char c = 'e';
int depth = -343535;
```

Two ways of “constructing” variables

- **First**, declare, than initialize: `int length; length = 5;`
- **Second**, define them in one single statement: `int length = 5;`

Examples

- `short numberOfEngines = 5;`
- `double temperature = 23.7;`
- `boolean engineStarted = true;`
- `char c = 'e';`
- `int depth = -343535;`

Four Primitive Data Types in Java

- boolean, char, integer and floating point
- They got a default value
- They only hold one value

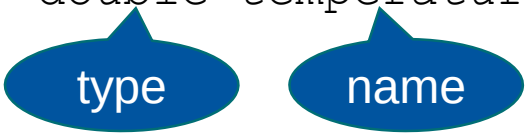
Data Type	Example	Keyword
Logical value	true, false	`boolean`
Single character	a, b, …	`char`
Whole number	1, -3, 87, …	`byte, short, int, long`
Real number	-2.6, 9.4, …	`float, double`

For details (e.g. max or min values) see:
https://docs.oracle.com/javase/tutorial/java/nutsandbolts/datatypes.html

Rules I

- Variables must have a **type**, e.g. `double`!
- Variables must have a **name**, e.g. `temperature`!

```
double temperature;
```

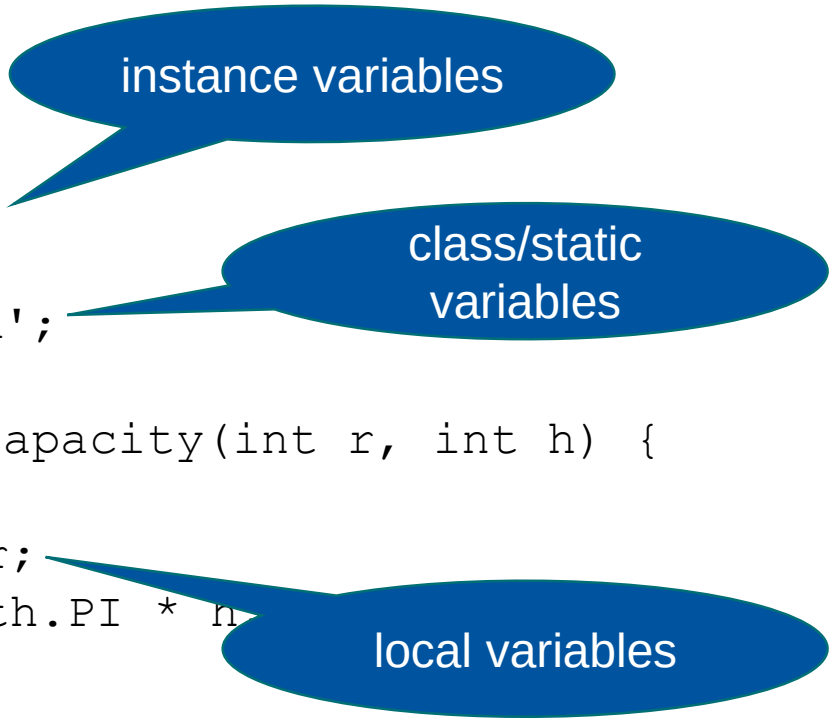


Rules II and Good Practice

- No keywords are allowed as names, e.g. `class` or `while` are prohibited! https://en.wikipedia.org/wiki/List_of_Java_keywords
- Names must start with a letter, underscore (_) or a dollar sign ($)
- No special characters, e.g. `§`.
- **Choose meaningful names**, e.g. `currentVelocity` (as opposed to `cV`);

Three kinds of variables in Java

```
public class Cylinder {

    public double cylinderCap = 0;

    public static char vendor = 'A';

    public double computeCylinderCapacity(int r, int h) {

            double rSquare = r*r;
            return rSquare * Math.PI * h

    }
}
```



Defining Constants Variables

- Are all-round in Mathematics, physics, engineering ...
- Are declared with the keyword `final`
- Convention for naming of constants: UPPERCASE, e.g. PI or E

Examples (the bad and the good)

```
double circumf = 2 * 3.1415 * r;
double area = r * r * 3.1415;
```

- Typing errors
- Changing code in different places
- Bad Readability

```
final double PI = 3.1415;
double circumf = 2 * PI * r;
double area = r * r * PI;
```

- Good readability
- DRY principle (don’t repeat yourself)

Operators and Variables

- **Allocation (=)**
- **Arithmetic (+, -, *, /, %)**
- Comparison (==, !=, <, >)
- Unary (++, --)
- Logical (! (not), &&, ||)

Allocation and Arithmetic Operator Examples

- ```
  int number; number = 5;
  ```
- ```
  int x = 5;
  int y = 7;
  int sum = x + y;
  int diff = 40 - y;
  double div = 30 / 4.3;
  ```

Operators and Variables

- Allocation (=)
- Arithmetic (+, -, *, /, %)
- **Comparison (==, !=, <, >)**
- **Unary (++, --)**
- **Logical (! (not), &&, ||)**

Comparison, Unary and Logical Operator Examples

- ```
  boolean isSmaller;
  int one = 1; int two = 2;
  isSmaller = one < two;
  ```
- ```
  int i = 3;
  int j = i++;
  ```
- ```
  boolean result = !true || false;
  ```
  ```

Operators Priorities

- How does Java evaluate an complex expression? E.g.:
- ```
  int a = 5;
  int b = 7;
  int c = 2
  a = a – b – c % (a * c++); // (a is –4)
  ```
- With an internal priority table! Excerpt from: https://docs.oracle.com/javase/tutorial/java/nutsandbolts/operators.html

Priority	Operator
1	Unary, e.g. ++
4	Additive, e.g. +
12	Logical OR e.g. ||
14	Allocation, e.g. =
  ```

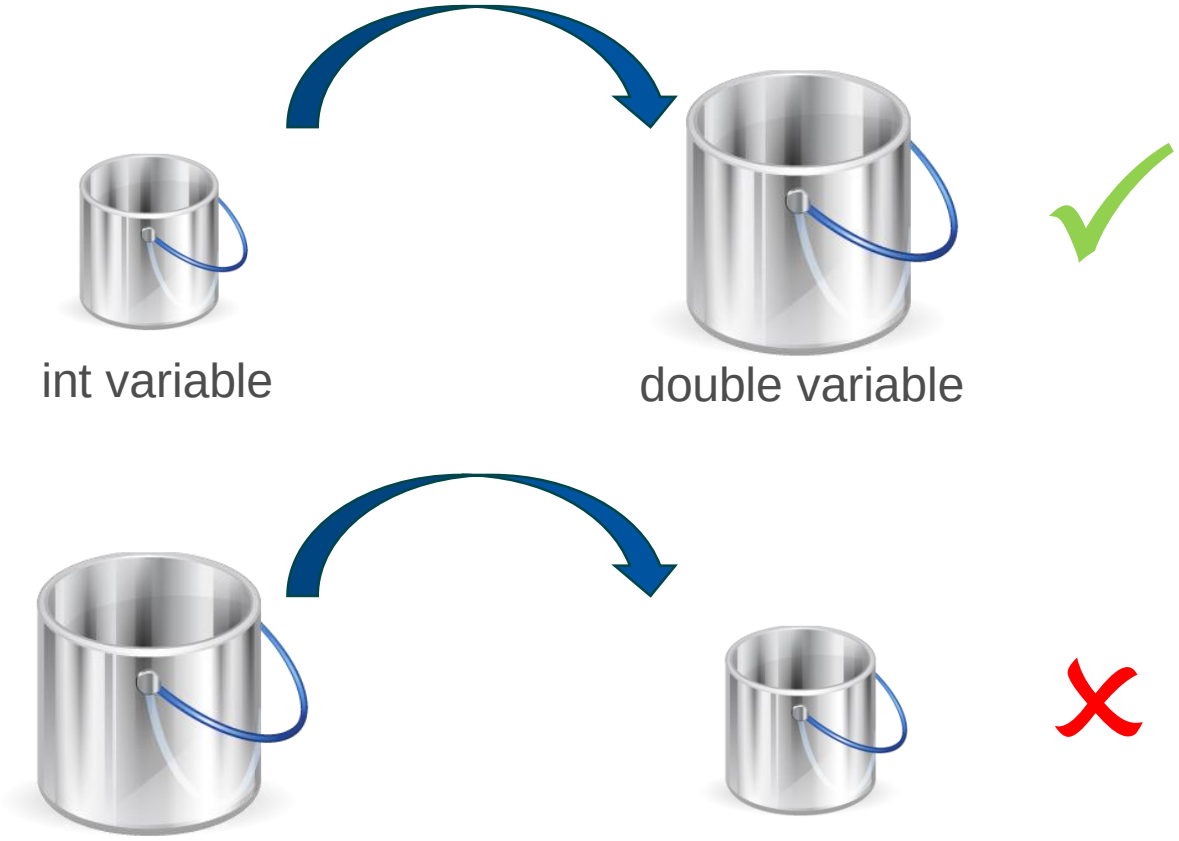
Type Casts

- It can be necessary to convert one type of data into an other one
- There are two types of casts
- **Implicit** type casts. Target type is computed **automatically** via context. “Upgrading”.
- **Explicit** type casts. Target type **has to be explicitly defined**. “Downgrading”. Target type has to be defined in “(“ and “)” brackets

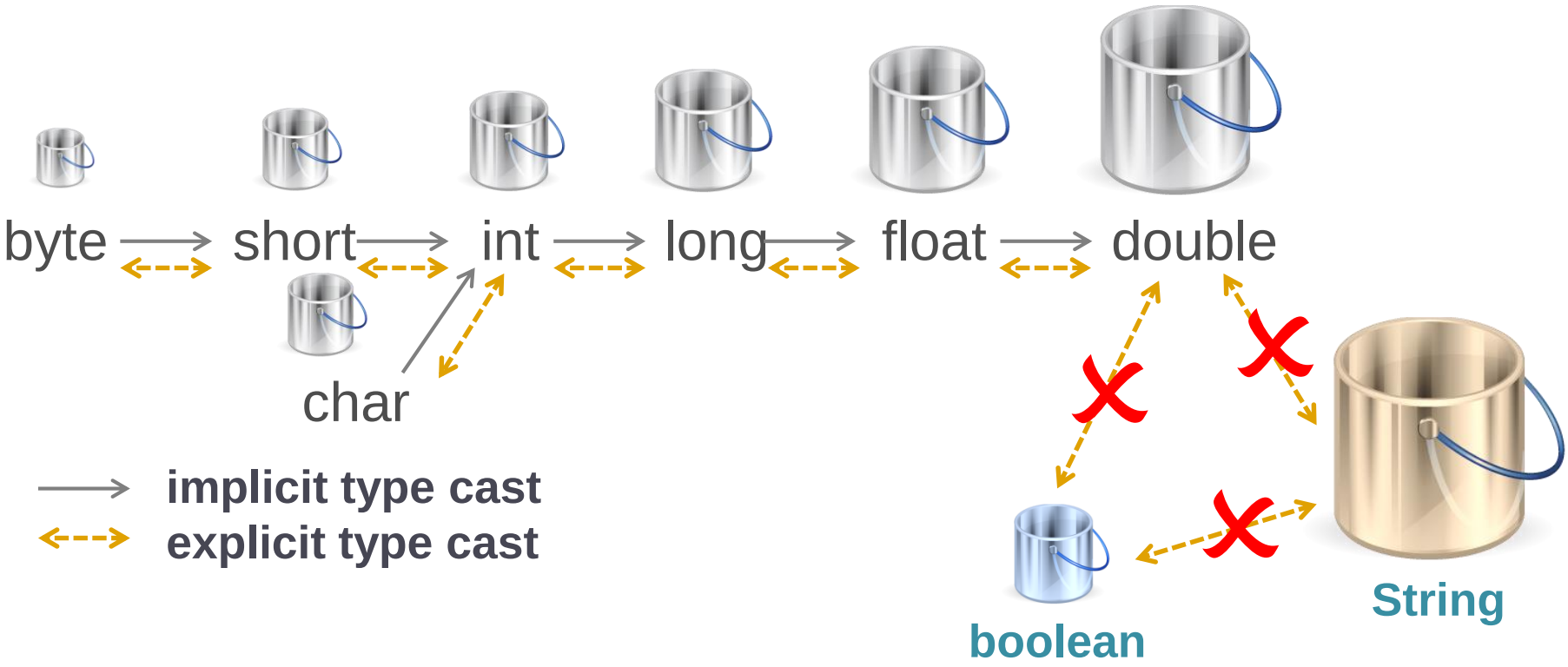
Examples

- ```
  int i = 70;
  double radius = i; // radius contains 70.0
  ```
- ```
  double d = 70.3456;
  int num = (int)d; // num contains 70
  ```

Implicit type cast only one way



Type cast overview



Output

- How does Java output information on the screen?
- Without linefeed: System.out.print (<output>)
- With linefeed: System.out.println (<output>)

Examples

- ```
  System.out.print("Hello, World");
  System.out.print ("!"); // Output: Hello, World!
  ```
- ```
  System.out.println ("Hello, World");
  ```

Thank you very much!

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