Informatik I

Course at BAUG department of ETH Zürich

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ETH Zürich

HS 2018

1. Introduction

Welcome to the Lecture Series!

Material

Course homepage

http://lec.inf.ethz.ch/baug/informatik1

The Team

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Programming and Problem Solving

In this course you learn how to program using Java

- Software development is a handicraft
- Analogy: learn to play a musical instrument
- **The problem:** nobody has become a pianist from listening to music.

Hence this course offers several possibilities, to train. Make use of it!

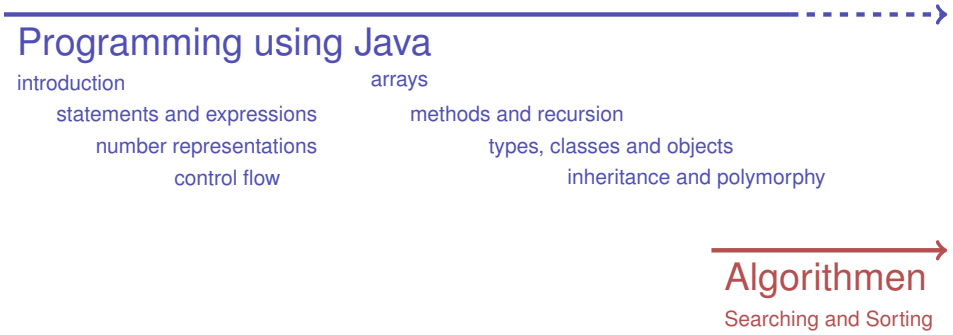
Programming and problem solving

In this course you learn to solve problems with selected algorithms and data structures

- *Fundamental knowledge* independent of the language
- Comparison: musical scale, read music, rythm skills.
- **The problem:** without musical instrument this is no fun.

Hence we combine learning problem solving with learning the programming language Java.

Course Content



Goal of *today's* Lecture

- Introduction of computer model and algorithms
- General informations to the course
- Writing a *first program*

1.1 Computer Science and Algorithms

Computer Science, Euclidean Algorithm

What is Computer Science?

- The science of **systematic processing of informations**,. . .
- . . . particularly the automatic processing using digital computers.

(Wikipedia, according to “Duden Informatik”)

Computer Science $\neq$ Computer Literacy

Computer literacy: *user knowledge*

- Handling a computer
- Working with computer programs for text processing, email, presentations . . .

Computer Science *Fundamental knowledge*

- How does a computer work?
- How do you write a computer program?

Inhalt dieser Vorlesung

- Systematic problem solving using algorithms and the programming langauge Java
- Hence:
  not only
  but also programming course.

Algorithm: Fundamental Notion of Computer Science

Algorithm:

- Instructions to solve a problem step by step
- Execution does not require any intelligence, but precision (even computers can do it)
- according to *Muhammed al-Chwarizmi*, author of an arabic computation textbook (about 825)

"Dixit algorizmi..." (Latin translation)

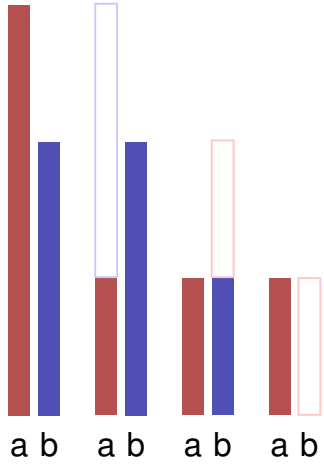
http://de.wikipedia.org/wiki/Algorithmus

Oldest Nontrivial Algorithm

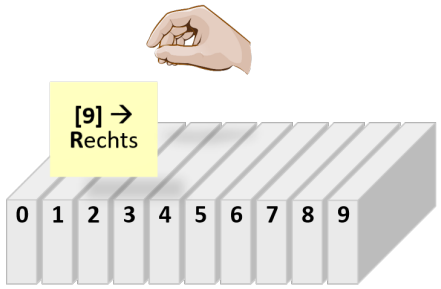
Euclidean algorithm (from the *elements* from Euklid, 3. century B.C.)

- Input: integers $a > 0, b > 0$
- Output: gcd of a und b

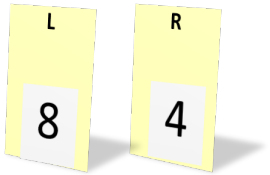
While $b \neq 0$
  If $a > b$ then
    $a \leftarrow a - b$
  else:
    $b \leftarrow b - a$
Result: a.



Live Demo: Turing Machine



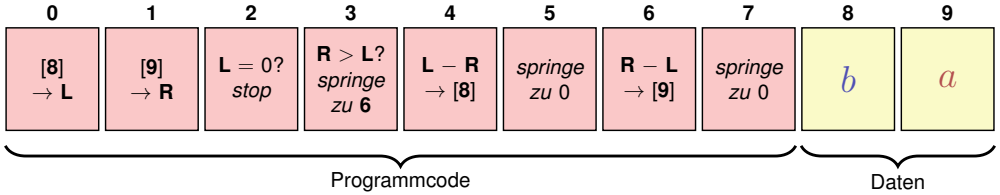
Speicher

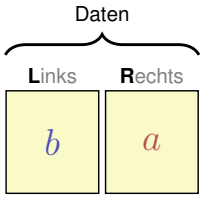


Register

Euklid in the Box

Speicher





Register

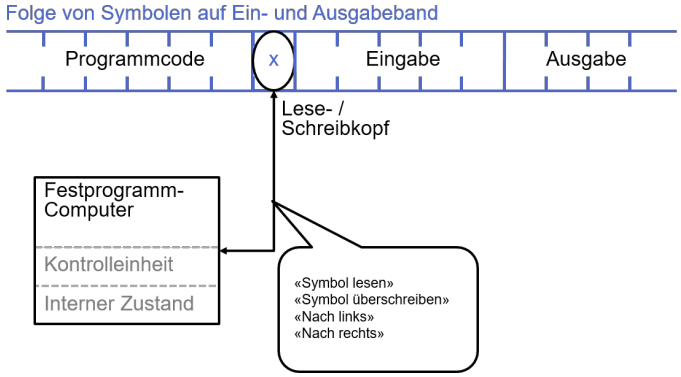
While $b \neq 0$
  If $a > b$ then
    $a \leftarrow a - b$
  else:
    $b \leftarrow b - a$
Ergebnis: a.

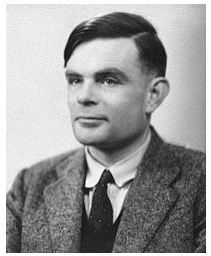
1.3 Computer Model

Turing Machine, Von Neumann Architecture

Computers – Concept

An bright idea: universal Turing machine (Alan Turing, 1936)





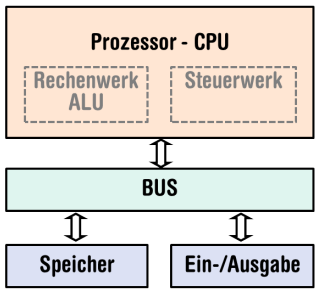
Alan Turing

http://en.wikipedia.org/wiki/Alan_Turing

Computer – Implementation

- Z1 – Konrad Zuse (1938)
- ENIAC – John Von Neumann (1945)

Von Neumann Architektur



Konrad Zuse

John von Neumann

http://www.hs.uni-hamburg.de/DE/GNT/hh/biogr/zuse.htm
http://commons.wikimedia.org/wiki/File:John_von_Neumann.jpg

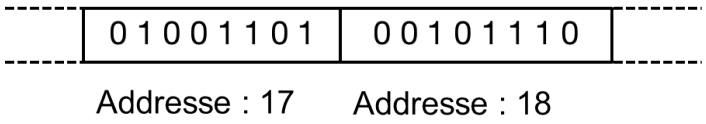
Computer

Ingredients of a *Von Neumann Architecture*

- Memory (RAM) for programs *and* data
- Processor (CPU) to process programs and data
- I/O components to communicate with the world

Memory for data *and* program

- Sequence of bits from $\{0, 1\}$.
- Program state: value of all bits.
- Aggregation of bits to memory cells (often: 8 Bits = 1 Byte)
- Every memory cell has an address.
- Random access: access time to the memory cell is (nearly) independent of its address.



Processor

The processor (CPU)

- executes instructions in machine language
- has an own "fast" memory (registers)
- can read from and write to main memory
- features a set of simplest operations = instructions (e.g. adding to register values)

Computing speed

In the time, onaverage, that the sound takes to travel from from my mouth to you ...

30 m $\widehat{=}$ more than $100.000.000$ instructions

a contemporary desktop PC can process more than 100 millions instructions [1]

[1] Uniprocessor computer at 1 GHz.

Programming

- With a *programming language* we issue commands to a computer such that it does exactly what we want.
- The sequence of instructions is the *(computer) program*

The Harvard Computers, human computers, ca.1890

http://en.wikipedia.org/wiki/Harvard_Computers

Why programming?

- Do I study computer science or what ...
- There are programs for everything ...
- I am not interested in programming ...
- because computer science is a mandatory subject here, unfortunately...
- ...

Mathematics used to be the lingua franca of the natural sciences on all universities. Today this is computer science.

Lino Guzzella, president of ETH Zurich, NZZ Online, 1.9.2017

This is why programming!

- Any understanding of modern technology requires knowledge about the fundamental operating principles of a computer.
- Programming (with the tool computer) is evolving a cultural technique like reading and writing (using the tools paper and pencil)
- Most qualified jobs require at least elementary programming skills
- Programming is fun!

This Course is for You

- You learn the *fundamental principles* – the basics of computer science and programming – from us on a nontrivial level
- You will need to *apply the principles learned in a different context – for example for other programming languages (C++ ,Python ,Matlab , R)*
- *This is not our requirement – we know this from* you *(= your department)*

Programming Languages

- The language that the computer can understand (machine language) is very primitive.
- Simple operations have to be disassembled into many single steps
- The machine language varies between computers.

Higher Programming Languages

can be represented as program text that

- can be *understood* by humans
- is *independent* of the computer model
  $\rightarrow$ Abstraction!

Java

- is based on a *virtual machine* (with von-Neumann architecture)
  - Program code is translated into intermediate code
  - Intermediate code runs in a simulated computing envrionment, the intermediate code is executed by an interpreted
  - Optimisation: Just-In-Time (JIT) compilation of frequently used code: virtual machine $\rightarrow$ physical machine
- Consequence, and manifested goal of the Java developers:

  write once – run anywhere

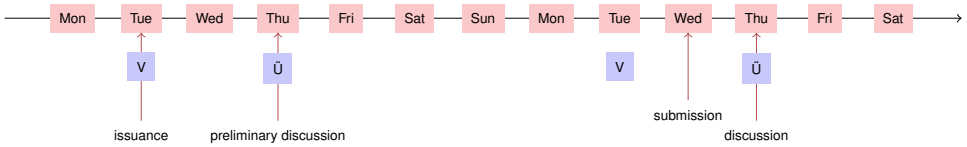
1.5 General Informations about the Course

Organisation, Tools, Exercises, Exams

Recitation Session Registry

- Registration via web page `http://echo.ethz.ch`
- Works only when enrolled for this course via myStudies.
- Available rooms depend on the course of studies.

Exercises



- Exercises availabe at lectures.
- Preliminary discussion in the following recitation session
- Solution of the exercise until the day before the next recitation session.
- Dicussion of the exercise in the next recitation session.

Exercises

- At ETH an exercise certificate is not required in order to subscribe for the exams.
- The solution of the weekly exercises is thus voluntary but *stronly* recommended.

Lacking Resources are no Excuse!

For the exercises we use an online development environment that requires only a browser, internet connection and your ETH login.

If you do not have access to a computer: there are a a lot of computers publicly accessible at ETH.

Tutorial

In the first week you work through our *Java-tutorial* on your own

- Simple introduction to Java, no foreknowledge required
- Time needed: about two hours
- In the second week recitation session there will be a *self assessment* about the tutorial

→ This time is well-invested!

Tutorial - Url

Java Tutorial

Here you find the tutorial:
`https://frontend-1.et.ethz.ch/sc/WKrEKYAuHvaeTqLzr`

Book to the Lecture

Sprechen Sie Java?

Hanspeter Mössenböck

dpunkt.verlag

- Well structured learning material
- In-depth discussion of the topics
- Exercise tasks with solutions

- *Our exam will include 1-2 questions from the book*

Exams

The exam (in examination period 2019) will cover

- Lectures content (lectures, handouts)
- Exercise content (recitation hours, exercise tasks).

Written exam - might be executed on a computer

We will test your practical skills (programming skills and theoretical knowledge (background knowledge, systematics).

Offer

- During the semester we offer weekly programming exercises that are graded. Points achieved will be taken as a bonus to the exam.
- The bonus is proportional to the score achieved in specially marked bonus tasks, where a full score equals a bonus of 0.25. The admission to specially marked bonus depends on the successful completion of other exercises. The achieved mark bonus expires as soon as the lecture is given anew.

Academic integrity

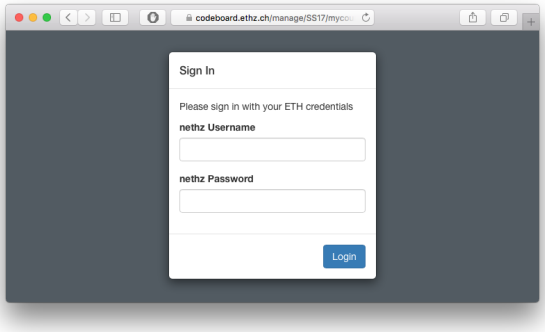
Rule: You submit solutions that you have written yourself and that you have understood.

We check this (partially automatically) and reserve our rights to invite you to interviews.

Should you be invited to an interview: don't panic. Primary we presume your innocence and want to know if you understood what you have submitted.

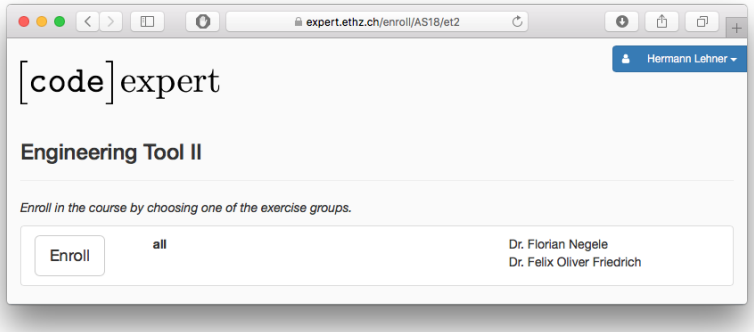
Exercise group registration I

- Visit `http://expert.ethz.ch/enroll/AS18/inf1baug`
- Log in with your nethz account.

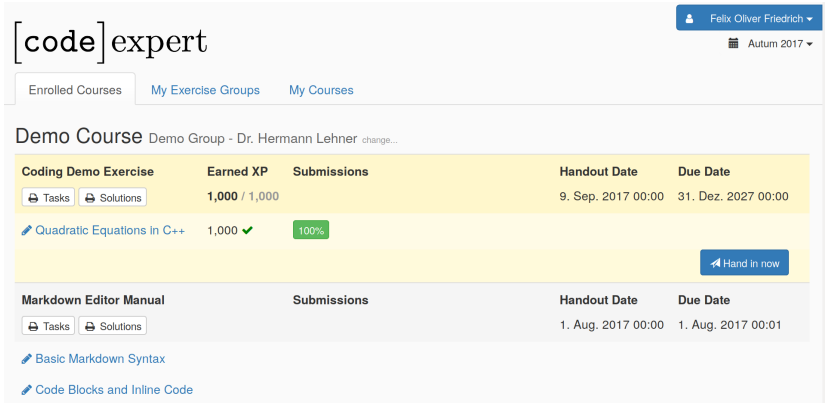


Exercise group registration II

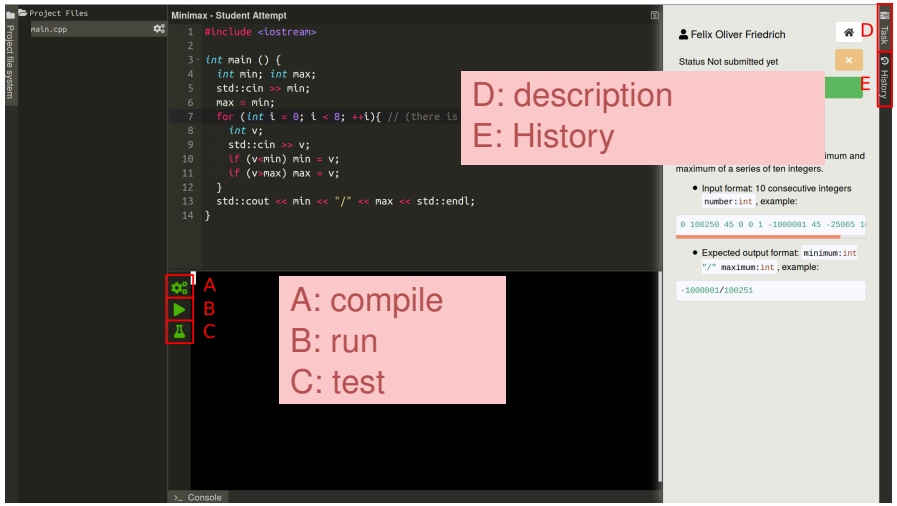
Register with the subsequent dialog for an exercise group.



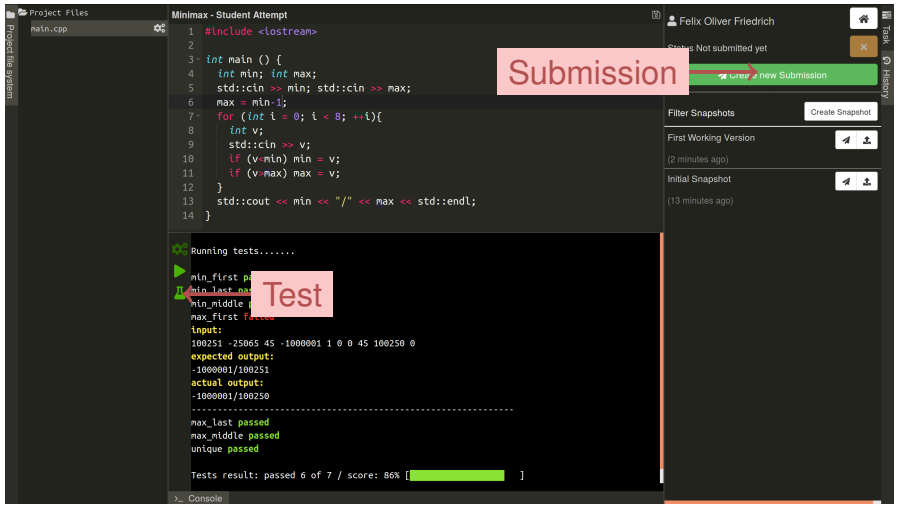
Overview



Programming Exercise



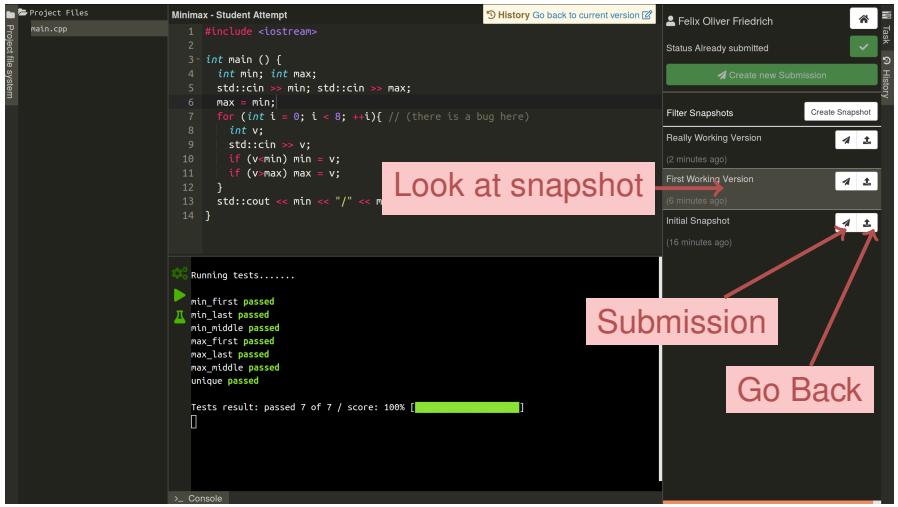
Test and Submit



Where is the Save Button?

- The file system is transaction based and is saved permanently ("autosave"). When opening a project it is found in the most recent observed state.
- The current state can be saved as (named) *snaphot*. It is always possible to return to saved snapshot.
- The current state can be submitted (as snapshot). Additionally, each saved named snapshot can be submitted.

Snapshots



2. Introduction to Java

Programming – a first Java Program

Programming Tools

- **Editor:** Program to modify, edit and store Java program texts
- **Compiler:** program to translate a program text into machine language
- **Computer:** machine to execute machine language programs
- **Operating System:** program to organize all procedures such as file handling, editor-, compiler- and program execution.

German vs. Programming Language

Deutsch

Es ist nicht genug zu wissen,
man muss auch anwenden.
(Johann Wolfgang von Goethe)

Java / C / C++

```
// computation
int b = a * a; // b = a^2
b = b * b;     // b = a^4
```

Syntax and Semantics

- Like our langauge, programs have to be formed according to certain rules.
  - Syntax: Connection rules for elementary symbols (characters)
  - Semantics: interpretation rules for connected symbols.
- Corresponding rules for a computer program are simpler but also more strict because computers are relatively stupid.

Syntax and Semantics of Java

Syntax

- What *is* a Java program?
- Is it *grammatically* correct?

Semantics

- What does a program *mean*?
- What kind of algorithm does a program implement?

First Java Program

```
// Program to raise a number to the eighth power
public class Main {
  public static void main(String[] args) {
    // input
    Out.print("Compute a^8 for a= ?");
    int a;
    a = In.readInt();
    // computation
    int b = a * a; // b = a^2
    b = b * b; // b = a^4
    // output b*b, i.e. a^8
    Out.println(a + "^8 = " + b*b);
  }
}
```

Class: a program

Method: named sequence of statements.

Java Classes

A Java program comprises at least one class with main-method. The sequence of statements in this method is executed when the program starts.

```
public class Test{
  // Potentiell weiterer Code und Daten

  public static void main(String[] args) {
    // Hier beginnt die Ausfuehrung
    ...
  }
}
```

Behavior of a Program

At compile time:

- program accepted by the compiler (syntactically correct)
- Compiler error

During runtime:

- correct result
- incorrect result
- program crashes
- program does not terminate (endless loop)

Comments

```
// Program to raise a number to the eighth power
public class Main {

  public static void main(String[] args) {
    // input
    Out.print("Compute a^8 for a= ?");
    int a;
    a = In.readInt();
    // computation
    int b = a * a;  // b = a^2
    b = b * b;  // b = a^4
    // output b*b, i.e. a^8
    Out.println(a + "^8 = " + b*b);
  }
}
```

Kommentare

Comments and Layout

Comments

- are contained in every good program.
- document, *what* and *how* a program does something and how it should be used,
- are ignored by the compiler
- Syntax: “double slash” `// until the line end.`

The compiler *ignores* additionally

- Empty lines, spaces,
- Indendations that should reflect the program logic

Comments and Layout

The compiler does not care...

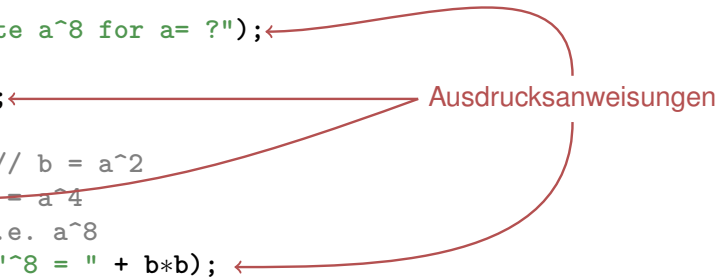
```
public class Main{public static void main(String[] args){Out.print
("Compute a^8 for a= ?");int a;a = In.readInt();int b = a*a;b =
b * b;Out.println(a + "^8 = " + b*b);}}
```

... but we do!

Statements

```
// Program to raise a number to the eighth power
public class Main {

  public static void main(String[] args) {
    // input
    Out.print("Compute a^8 for a= ?");
    int a;
    a = In.readInt();
    // computation
    int b = a * a;  // b = a^2
    b = b * b; // b = a^4
    // output b*b, i.e. a^8
    Out.println(a + "^8 = " + b*b);
  }
}
```



Statements

- building blocks of a Java program
- are *executed* (sequentially)
- end with a semicolon
- Any statement provide an *effect* (potentially)

Expression Statements

- have the following form:

  expr;

  where *expr* is an expression
- Effect is the effect of *expr*, the value of *expr* is ignored.

Example: `b = b*b;`

Statements – Values and Effects

```
// Program to raise a number to the eighth power
public class Main {

  public static void main(String[] args) {
    // input
    Out.print("Compute a^8 for a= ?");
    int a;
    a = In.readInt();
    // computation
    int b = a * a; // b = a^2
    b = b * b; // b = a^4
    // output b*b, i.e. a^8
    Out.println(a + "^8 = " + b*b);
  }
}
```

Effekt: Ausgabe des Strings `Compute ...`

Effekt: Eingabe einer Zahl und Speichern in a

Effekt: Speichern des berechneten *Wertes* von a*a in b

Effekt: Speichern des berechneten *Wertes* von b*b in b

Effekt: Ausgabe des *Wertes* von a und des berechneten *Wertes* von b*b

Values and Effects

- determine what a program does,
- are purely semantical concepts:
  - Symbol `0` means Value $0 \in \mathbb{Z}$
  - `a = In.readInt();` means effect "read in a number"
- depend on the program state (memory content, inputs)

Variable Definitions

```
// Program to raise a number to the eighth power
public class Main {

  public static void main(String[] args) {
    // input
    Out.print("Compute a^8 for a= ?");
    int a;
    a = In.readInt();
    // computation
    int b = a * a;// b = a^2
    b = b * b;  // b = a^4
    // output b*b, i.e. a^8
    Out.println(a + "^8 = " + b*b);
  }
}
```

Typ-namen

Deklarationsanweisungen

Declaration Statements

- introduce new names in the program,
- consist of declaration and semicolon

  Example: `int a;`
- can initialize variables

  Example: `int b = a * a;`

Types and Functionality

`int`:

- Java integer type
- corresponds to $(\mathbb{Z}, +, \times)$ in math

In Java each type has a name and

- a domain (e.g. integers)
- functionality (e.g. addition/multiplication)

Fundamental Types

Java comprises fundamental types for

- integers (`int`)
- real numbers (`float`, `double`)
- boolean values (`boolean`)
- ...

Literals

- represent constant values
- have a fixed *type* and *value*
- are "syntactical values".

Examples:

- `0` has type `int`, value 0.
- `1.2e5` has type `double`, transWertvalue $1.2 \cdot 10^5$.

Variables

- represent (varying) values,
- have
  - *name*
  - *type*
  - *value*
  - *address*
- are "visible" in the program context.

Beispiel

`int a;` defines a variable with

- name: `a`
- type: `int`
- value: (initially) undefined
- Address: determined by compiler

Objects

- represent values in main memory
- have *type*, *address* and *value* (memory content at the address)
- can be named (variable) ...
- ... but also anonymous.

Remarks

A program has a *fixed* number of variables. In order to be able to deal with a variable number of value, it requires "anonymous" addresses that can be address via temporary names.

Identifiers and Names

(Variable-)names are identifiers

- allowed: A,...,Z; a,...,z; 0,...,9;_
- First symbol needs to be a character.

There are more names:

- `Out.println` (Qualified identifier)

Expressions

- represent *Computations*
- are either primary (`b`)
- or composed (`b*b`)...
- ...from different expressions by operators

Analogy: building blocks

Expressions

```
// input
Out.print("Compute a^8 for a= ?");
int a;
a = In.readInt();

// computation
int b = a * a; // b = a^2
b = b * b;    // b = a^4

// output b*b, i.e. a^8
Out.println(a + "^8 = " + b * b| ); ||
```


Expressions

- represent *computations*
- are *primary* or *composite* (by other expressions and operations)

`a * a`
composed of
variable name, operator symbol,variable name
variable name: primary expression

- can be put into parantheses

`a * a` is equivalent to `(a * a)`

Expressions

have *type*, *value* und *effect* (potentially).

Example

`a * a`

- type: `int` (type of the operands)
- Value: product of `a` and `a`
- Effect: none.

Example

`b = b * b`

- type: `int` (Typ der Operanden)
- Value: product of `b` and `b`
- effect: assignment of the product value to `b`

The type of an expression is fixed but the value and effect are only determined by the *evaluation* of the expression

Operators and Operands

```
// input
Out.print("Compute a^8 for a= ?");
int a;
a = In.readInt();
// computation
int b = a * a; // b = a^2
b = b * b;     // b = a^4
// output
Out.println(a + "^8 = " + b * b );
```

left operand (variable)

right operand (expression)

assignment operator

multiplication operator

Operators

Operators

- make expressions (*operands*) into new composed expressions
- specify the required and resulting types for the operands and the result
- have an arity

Multiplication Operator *

- expects to R-values of the same type as operands (arity 2)
- "returns the product as value of the same type", that means formally:
  - The composite expression is value of the product of the value of the two operands

Examples: `a * a` and `b * b`

Assignment Operator =

- Assigns to the left operand the value of the right operand and returns the left operand

Examples: `b = b * b` and `a = b`

Attention, Trap!

The operator = corresponds to the assignment operator of mathematics ($:=$), not to the comparison operator ($=$).