Elements of Computer Science Programming

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based on slides by Norbert Müller

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Topic of this course:

Writing small programs

Planned content:

- Problem, Algorithm, Program
- Java as an example for a modern programming language
- Non-primitive data types in Java
- Classes and exceptions
- Exceptions
- Useful techniques: generics, collections, ...

Software: **Java Platform, Standard Edition ('SE')**

- all examples will be based on Java
- We will use Java Platform, Standard Edition 15
  `https://jdk.java.net/17/`
- We will only use Java features up to version 8
- OpenJDK Development Kit (JDK) + Java Documentation
- available on the computer science CIP pools (H523,H524)
- equivalent versions on Windows, Linux, ...
- Integrated development environment: Eclipse, IntelliJ, ...

further information on Java online:

- R. Gallardo, S. Hommel, S. Kannan, J. Gordon, S.B. Zakhour, 'The Java Tutorial',
  most recent version: Java SE Tutorial 2021-08-01,
  `http://download.oracle.com/javase/tutorial`
- 'The Java Language Specification, Java SE 17 Edition', Gosling/Joy/Steele/Bracha/Buckley/Smith
  `(docs.oracle.com/javase/specs/)`
- 'Java Look and Feel Design Guidelines', 2nd ed., Addison Wesley, 2001.
  `http://www.oracle.com/technetwork/java/jlf-135985.html`
- 'The Java Virtual Machine Specification, Java SE 17 Edition', Lindholm/Yellin/Bracha/Buckley/Smith
  `(docs.oracle.com/javase/specs/)`

Book on Java

- Quentin Charatan, Aaron Kans
  Java in Two Semesters
  Springer, 2019. `https://link.springer.com/book/10.1007/978-3-319-99420-8`

Readings on computer science in general

- Robert Sedgewick, Kevin Wayne
  Computer Science: An Interdisciplinary Approach
  Addison Wesley, 2017.

- A **problem** is identified by an initial state (‘problem exists’ or ‘problem identified’) and by the aim to reach a target state (‘problem solved’).
- An **algorithm** is a precise, finite method for solving a problem, i.e., for the transition from ‘problem identified’ to ‘problem solved’.
- A **program** is the encoding of an algorithm with a programming language for execution on a computer.

Specification of the problem:

- A precise algorithm requires a precise representation of the initial situation.
- We thus need to begin with an analysis of the problem in order to generate a specification that establishes the following:
  - information available in the initial situation.
    (input data and their allowed values, i.e., their domain)
  - desired information.
    (output data and their possible values, i.e., their range)
  - any conditions that need to be observed while deriving the desired information.
- The specification of the problem should be as detailed, as exact, and as complete as possible.

Examples for specifications of problems:

- Given: the three numbers 5, 7, and 11.
  Wanted: their arithmetic mean.
- Given: flour, water, olive oil, salt.
  Wanted: pizza dough made from these ingredients.
  Conditions: One can use at most 400g flour and 2 spoons of olive oil.
- Given: place of residence Trier, holiday destination Tahiti, possible dates for vacation, set of flight schedules.
  Wanted: proposals for trips.
  Conditions: departure on Friday or Saturday, duration 4 weeks, cost not exceeding 3000 euros

The term **algorithm** dates back to the Arabic mathematician

Mohammed ibn Musa abu Djafar al Khowarizmi

(ca. 783 - 850) and his book

‘Kitab al muhtasar fi hisab al gebr we al muqabala’

(‘The Compendious Book on Calculation
by Completion and Balancing’).

In the Latin translation each section started with ‘Dixit algorismi’ (‘thus said al Khowarizmi’), which led to the later term algorithm.

What is an ‘algorithm’?

We need to clarify the following questions:

- Which processing steps are required in an algorithm?
- How can we control the flow of the processing steps?
- How can we represent and write down algorithms?
- Which properties of algorithms are interesting?

Intuitive algorithms

Examples from everyday life:

process	algorithm	example for processing step
knit a pullover	knitting pattern	purl – plain
construct a model car	assembly instructions	glue outside mirror to left door
make a cake	recipe	beat 3 eggs until fluffy
play music piece	sheet of music	play c"'

Such daily operation procedures are often not exact and leave room for interpretations, so they are not algorithms.

Example: starting with a car from the right curb as **intuitive algorithm**

1. fasten seat belt, check rear-view mirror, if necessary pull handbrake, insert idle.
2. briefly actuate ignition.
3. If engine does not start, repeat step 2.
4. look around and wait for a traffic gap
5. pedal the clutch with left foot and brake with right foot, enable the left indicator, release the handbrake.
6. hold clutch, engage 1st gear.
7. accelerate with right foot, turn the steering wheel to the left.
8. release the clutch, accelerate, turn the steering wheel such that the car reaches the right lane.
9. ...

Observations from the examples

- The individual steps are executed by a processor.
- A single processor executes one step after the other.
- Usually a step can only be executed after the previous step was successfully completed.
- The execution of a step can depend on a condition (*if a sufficiently large gap in the traffic exists then drive off, otherwise continue waiting*).
- Some steps must be repeated multiple times (*repeatedly briefly actuate ignition*).
- Repetitions always end when a certain condition gets true (*... until the engine starts*).

- In some cases the order in which some steps are executed does not matter. Thus transposition and parallel execution are possible (*pedal the clutch with left foot and brake with right foot*)
- In principle an algorithm executes a transformation from an initial state to a final state. Or: for a given input the application of an algorithm creates a well-defined output.
- In a mathematical sense an algorithm defines a map $\boldsymbol{f : E \rightarrow A}$ from the set of input data $\boldsymbol{E}$ to the set of output data $\boldsymbol{A}$.
- Usually the algorithm cannot be applied in every initial state.