5. Foundations of programming

Paradigms of programming:

Different viewpoints and ways of thinking about how to conceive a computer and a programme

Imperative paradigm:
Computer = machine for the manipulation of variables
Programme = sequence of commands which change values of variables, together with specifications of the *control flow* (telling which command is executed next)
Languages: Fortran, Pascal, Basic, C ...

Example (works in C or Java or XL):

```
x = 0;
while (x < 100)
    x = x + 2;
```

The variable `x` is used to produce the even numbers from 0 to 100.
Attention: The *assignment command* `x = x + 2` is not a mathematical equality!

Object-oriented paradigm:

Computer = environment for virtual objects which are created and destroyed during runtime (and can interact)

Programme = collection of general descriptions of objects (so-called *classes*), together with their hierarchical dependencies (*class hierarchy*)

Objects can contain data and functionality (*methods*)

Languages: Smalltalk, C++, Java, ...

Example (in Java):

```java
public class Car extends Vehicle
  {
  public String name;
  public int places;
  public void print_data()
    {
    System.out.println("The car is a " + name);
    System.out.println("It has " + places + "places");
    }
  }
```

Typical: class (`Car`) with data (`name`, `places`) and methods (`print_data`). The class `Car` *inherits* further data and methods from a superclass, `Vehicle`.

Rule-based paradigm:

Computer = machine which transforms a given structure according to given rules

Programme = set of transformation rules (sometimes also called a *grammar*)

Each step of programme application consists of two substeps: Finding an applicable rule (*matching step*) and transformation of the current structure according to that rule (*rewriting step*).

Languages: Prolog, AI-languages, L-system languages, particularly XL

Example (in XL):

```
public void apply()
    [
    F(x)  ==> F(x/3) RU(-60) F(x/3) RU(120)
            F(x/3) RU(-60) F(x/3);
    ]
```

produces the so-called Koch curve:
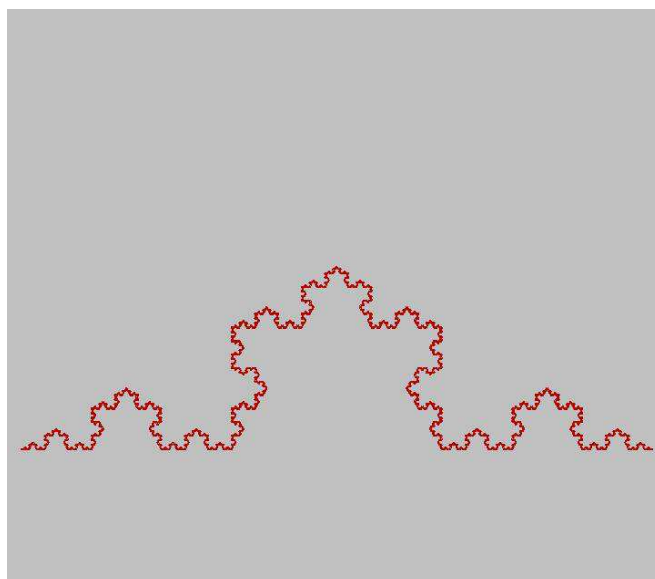
Readability of programmes by humans

programmes: have to be executed by computers, but also *to be understood by humans*

Executability can be checked automatically, understandability not!

$\Rightarrow$ Recommendations:

- make frequent use of programme comments (`/* ... */` or `// ...` in Java, C++ or XL)

- use plenty of newlines and blanks

- put braces { ... } in lines of their own, put matching braces in same horizontal position:
  ```
  {
    ....
  }
  ```

- *indentation* makes containment and nesting of programme components visible

- avoid long lines, insert line breaks for readability

- avoid very long methods

- use "speaking" variable and function names (`int iteration_counter` is better than `int x127` !)

- do not use variable names twice for different purposes, even if the language allows it

- Initialise constants, default values etc. at the beginning of a source code file, not somewhere "deep in the code" where you don't find them later on

- *adhere to conventions used by competent programmers!*

Basic parts of Java and XL

Remark: The language XL is an extension of Java. The following examples can be compiled and run with GroIMP (see **www.grogra.de**), a modelling platform which contains a development toolkit for XL and possibilities for visualization.

A first demonstration programme:

```
/* A simple Java programme for execution
with the GroIMP software. */

protected void init()
    {
    println("Hello World!");
    }
```

(= example file **prog_ex01.rgg**)

Download of GroIMP:

https://gitlab.com/grogra/groimp/-/releases

Basic components

Comments, spaces, newline: For human readability, and for separating words (just like in normal written language).

Special symbols: To denote different kinds of groupings, to terminate commands, to construct paths etc.

Examples: Braces `{`, `}`; parentheses `(`, `)`; brackets `[`, `]`; dot; double-quotes `"`; semicolon

Literal values: character sequences representing a value directly, like a digit sequence for a number, or a character sequence in double quotes for a string.

Example: `"Hello World!"`

Sequences of letters or digits, starting with a letter: different categories: **1) Keywords**, **2) predefined identifiers**, **3) newly declared identifiers**.

1) Keywords: Are fixed in the language proper, can not be given a new meaning

Examples: `public`, `class`, `static`, `void`   , `protected`

2) Predeclared identifiers: Meaning fixed by a declaration in the context, often can be "overwritten", i.e. given a new meaning. Examples:

`String`: data type for character sequences

`println`: predefined method – invoked with a string as its argument, it writes the string to the GroIMP console (a special output window) and adds a line feed.

3) newly declared identifiers: Their meaning is fixed by (explicit or implicit) declarations in the programme itself. Example: `init` is the name of the method which writes the text to the console. It expects no arguments (`init()`).

Use of simple data types and the "while" loop

```
/* A simple demonstration program,
   printing out the numbers from 0 to 10
   and their squares, each pair
   on an extra line. */

protected void init()
   {
   int i;
   i = 0;
   while (i <= 10)
      {
      println(i + ": " + (i*i));
      i = i+1;
      }
   println("Finished!");
   }
```

(example file `prog_ex02.rgg`)

While loop

`while` starts a **loop**: A sequence of commands which, under some condition, are executed repeatedly.

First, the condition given in parentheses is checked. Result must be boolean. **Our example**: Comparison of the current value of `i` (0) with `10`.

$0<10$ is true: Thus, the body of the loop is executed: Pair of values 0 and 0*0 are printed, and `i` is incremented by one.

Then, execution continues with the check of the condition, and the loop is repeated until `i` has value `11`, such that `i <= 10` becomes false.

Then, the loop body is not repeated again, and the `main` method finishes.

Assignments

In our example:
i = 0;
the variable named **i** gets the new value 0

* fundamental operation in the imperative programming paradigm

effect: content of a place in the memory is changed

Attention:
i = 0 in a Java programme does not have the same meaning as in a mathematical formula!
E.g., **i = i+1** would mathematically be a contradiction
(it would imply 0 = 1)

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– but makes sense in a programme (increment **i** by 1).
Mathematical meaning of this assignment:

$$i_{new} = i_{old} + 1.$$

In assignments, the *order is relevant*:
x1 = x2;   has another effect as **x2 = x1;**

To underline the asymmetry, other languages (e.g., Pascal) use **:=**   instead of **=** for assignments.

XL allows both notations
(but with a slightly different meaning: **:=** denotes a deferred assignment, i.e., it enables a quasi-parallel execution with other assignments.)

Comparison (checking for equality) is expressed in Java, C and XL by **==**

Java offers further assignment operators besides = :
a += b   // add content of **b** to the content of **a**
−=, *=, /=   etc. analogously.