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):

```
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*)

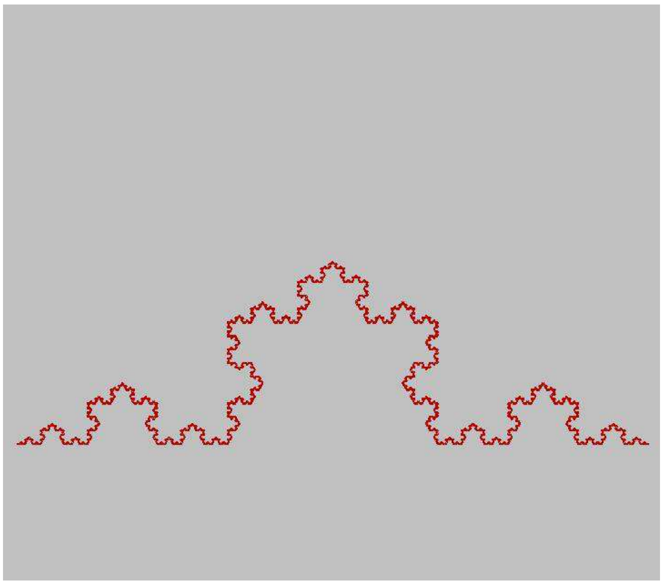
Each step of programme application consists of two substeps: Finding an applicable rule (*matching step*) and transformation of the current structure according to that rule (*rewriting step*).

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!

⇒ 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:

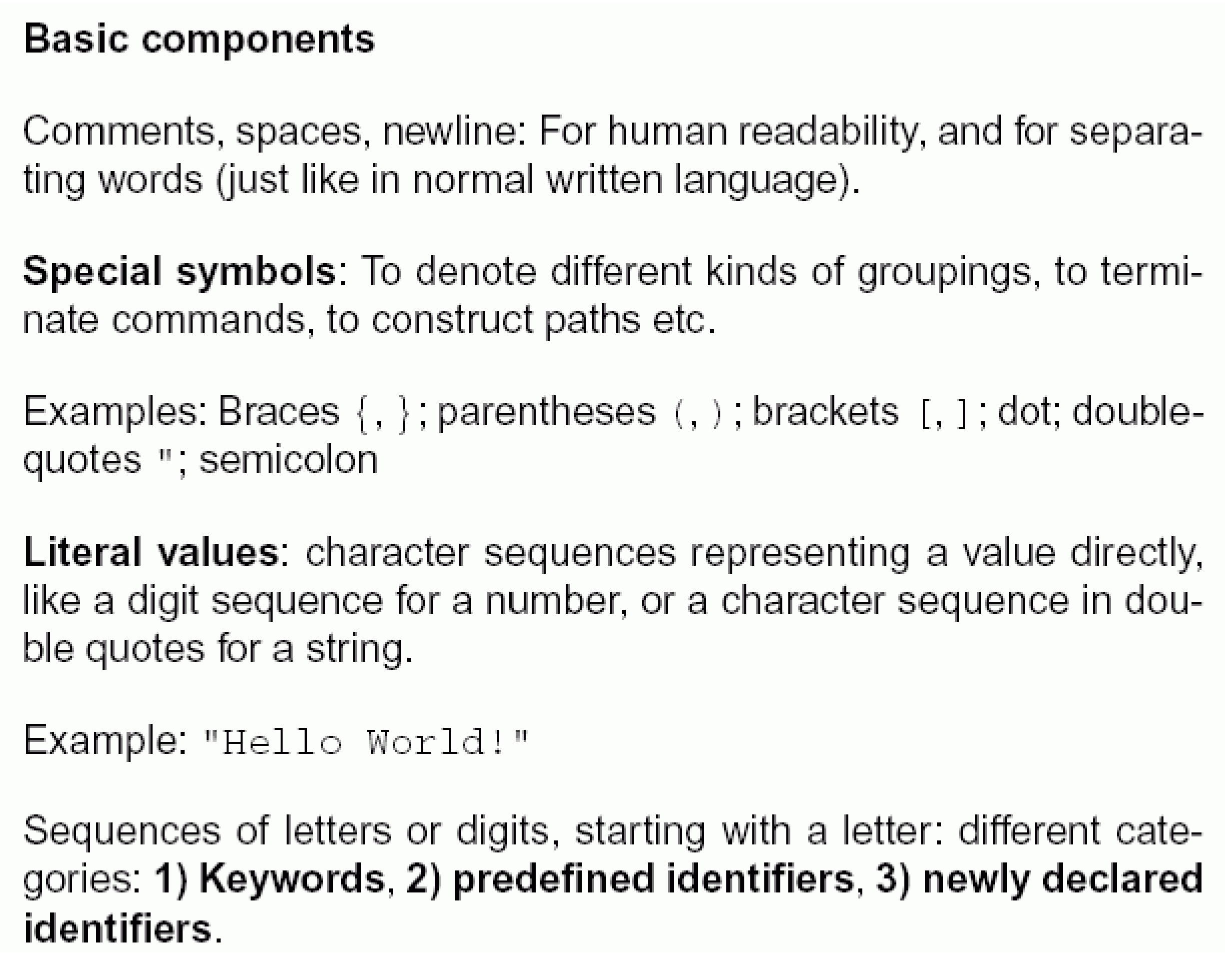
```
/* A simple Java programme for execution
with the GroIMP software. */

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

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

Download of GroIMP:

https://sourceforge.net/projects/groimp/



Basic components

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

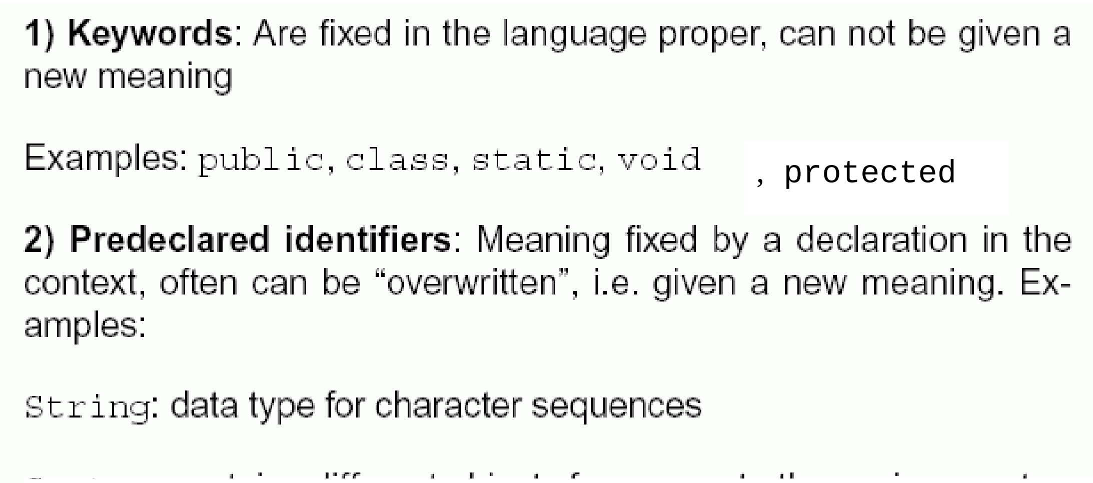
Special symbols: To denote different kinds of groupings, to terminate commands, to construct paths etc.

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.

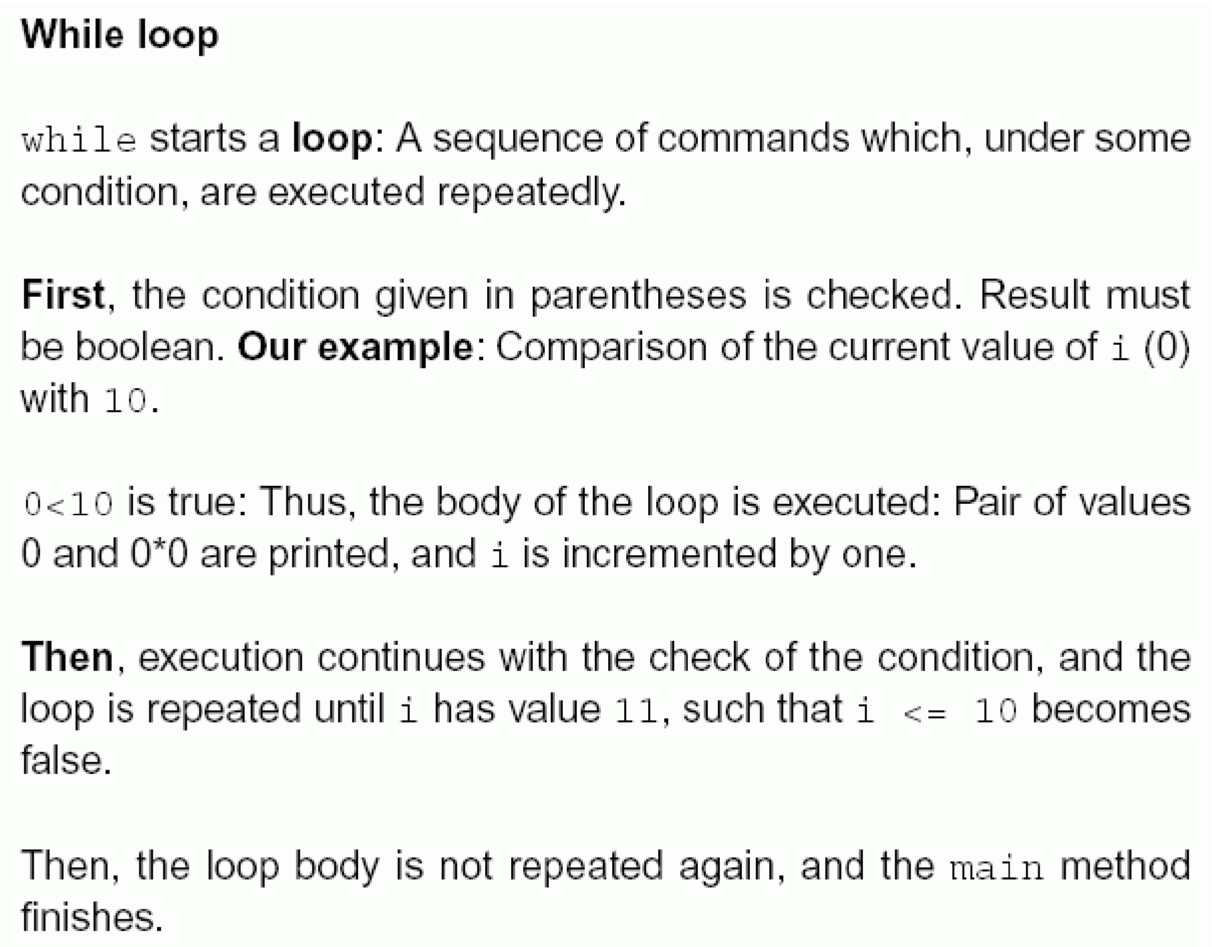
3) newly declared identifiers: Their meaning is fixed by (explicit or implicit) declarations in the programme itself. Example: **`init`** is the name of the method which writes the text to the console. It expects no arguments (**`init()`**).

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)

– 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.