Programming languages and compilers
Programming languages

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Overview

Introduction - What is a programming language?

- Many definitions
  - A programming language is a **machine-readable** artificial language designed to express **computations** that can be performed by a machine, particularly a **computer**.
  - Programming languages can be used to create programs that specify the behavior of a machine, to express algorithms **precisely**, or as a mode of human communication.
  - Wikipedia – Programming languages

Introduction - Definitions

- **Function –** a language used to write computer programs, which involve a computer performing some kind of computation or algorithm.
- **Target** - Programming languages differ from natural languages, they are build to allow humans to communicate instructions to machines.
  - Some programming languages are used by one device to control another.
- **Constructs -** Programming languages may contain constructs for defining and manipulating data structures or controlling the flow of execution.
- **Expressive power -** The theory of computation classifies languages by the computations they are capable of expressing.
  - All Turing complete languages can implement the same set of algorithms.
    - ANSI/ISO SQL and Charity are examples of languages that are not Turing complete, yet often called programming languages.
- Sometime is term "programming language" restricted to those languages that can express all possible algorithms.
  - Sometimes the term "computer language" is used for more limited artificial languages.
- Non-computational languages, such as markup languages like HTML or formal grammars like BNF, are usually not considered programming languages.

History – First Languages

Theoretical beginnings - 30s
- **Alonzo Church** - lambda calculus – theory of computations
- **Alan Turing** – show that a machine can solve a "problem".
- **John von Neumann** – defined computer's architecture (relevant even for today's computers).

Around 1946 Konrad Zuse – Plankalkul
- Used also for a chess game
- Not published until 1972, never implemented

1949 John Mauchly - Short Code
- First language actually used on an electronic device.
- Used for equations definition.
- "hand compiled" language.

1951 Grace Murray Hopper
- Enforcement of usage of high level programming languages.
- Work on a design of first compiler.

History – First Compilers

Term "compiler"
- early 50s - Grace Murray Hopper
- Program's compilation like a "compilation" of sequences of programs form a library.
- "automatic programming" – compilation in today's meaning assumed to be impossible to perform.

1954-57 FORTRAN (FORmula TRANslator)
- John Backus, IBM
- Problem's oriented, machine independent language
- Fortran shows advantages of high level compiled programming languages.
- Ad hoc structures – components and technologies were work out during development
- That day's people believes compilers are to complex, hard to understand and very expensive. (**18 humans years** –one of the greatest projects of that times)

History – FORTRAN

```
C
C     Function computing a factorial
C
      INTEGER FUNCTION FACT(N)
      IMPLICIT NONE
      INTEGER N, I, F
      F = 1
      DO 10 I = 1,N
         F = F * I
10    CONTINUE
      FACT = F
      END

      PROGRAM P1
      IMPLICIT NONE
      INTEGER N, F, FACT
      READ(*,*) N
      F = FACT(N)
      WRITE(*,*) "Fact = ", F
      END
```


History – High level programming languages(1)

1958-59 LISP 1.5 (List Processing)
- John McCarthy, M. I. T.
- First functional programming language – implementation of lambda calculus
- Also possibility of usage of a imperative style of programming

1958-60 ALGOL 60 (Algorithmic Language)
- J. Backus, P. Naur
- Blok structure, composed statements, recursion.
- Syntax formally described by a grammar (BNF) for the first time.
- Most popular language in Europe in late 60s.
- Base for other programming languages.

History – ALGOL 60

```
begin
  integer N;
  ReadInt(N);

  begin
    real array Data[1:N];
    real sum, avg;
    integer i;
    sum:=0;
    for i:=1 step 1 until N do
      begin real val;
        ReadReal(val);
        Data[i]:=if val<0 then -val else val
      end;
    for i:=1 step 1 until N do
      sum:=sum + Data[i];
    avg:=sum/N;
    PrintReal(avg)
  end
end
```


History – High level programming languages(2)

1960 COBOL (Common Business Oriented Language)

- COBOL is one of the oldest programming languages still in active use.
- Its primary domain in business, finance, and administrative systems for companies and governments.
- COBOL 2002 standard includes support for object-oriented programming and other modern language features.

1964 BASIC (Beginners All-Purpose Symbolic Instruction Code)

- John G. Kemeny, Thomas E. Kurz, Dartmouth University
- 1975 Tiny BASIC running on a computer with 2KB RAM
- 1975 Bill Gates, Paul Allen sells it to a company MITS

1963-64 PL/I (Programming Langugage I)

- Combination of languages: COBOL, FORTRAN, ALGOL 60
- Developed to contain “everything for everybody” => too complex
- Present constructions for concurrent execution and exceptions.

History – COBOL

```
IDENTIFICATION DIVISION.
PROGRAM-ID. Iter.
AUTHOR. Michael Coughlan.

DATA DIVISION.
WORKING-STORAGE SECTION.
  01  Num1 PIC 9 VALUE ZEROS.
  01  Num2 PIC 9 VALUE ZEROS.
  01  Result PIC 99 VALUE ZEROS.
  01  Operator PIC X  VALUE SPACE.

PROCEDURE DIVISION. Calculator.
    PERFORM 3 TIMES
       DISPLAY "Enter First Number      : "
       ACCEPT Num1
       DISPLAY "Enter Second Number     : "
       ACCEPT Num2
       DISPLAY "Enter operator (+ or *) : "
       ACCEPT Operator
       IF Operator = "+" THEN
          ADD Num1, Num2 GIVING Result
       END-IF
       IF Operator = "*" THEN
          MULTIPLY Num1 BY Num2 GIVING Result
       END-IF
       DISPLAY "Result is = ", Result
    END-PERFORM.
    STOP RUN.
```


History – PL/I

```
FINDSTRINGS: PROCEDURE OPTIONS(MAIN)
  /* načte STRING a poté vytiskne každý
     následující shodující se řádek */
  DECLARE PAT VARYING CHARACTER(100),
          LINEBUF VARYING CHARACTER(100),
          (LINENO, NDFILE, IX) FIXED BINARY;
  NDFILE = 0; ON ENDFILE(SYSIN) NDFILE=1;
  GET EDIT(PAT) (A);
  LINENO = 1;
  DO WHILE (NDFILE=0);
    GET EDIT(LINEBUF) (A);
    IF LENGTH(LINEBUF) > 0 THEN DO;
      IX = INDEX(LINEBUF, PAT);
      IF IX > 0 THEN DO;
        PUT SKIP EDIT (LINENO,LINEBUF)(F(2),A)
      END;
    END;
    LINENO = LINENO + 1;
  END;
END FINDSTRINGS;
```

History – High level programming languages(3)

1968 ALGOL 68

- Widely used version of ALGOL 60
- A little bit too complex to understand and to implement
- Structured data types, pointers
- Formal syntax and semantics definition
- Dynamic memory management, garbage collection, modules

1966 LOGO

- Logo is a computer programming language used for functional programming.
- Today, it is known mainly for its turtle graphics
- Development goal was to create a math land where kids could play with words and sentences.

History – Structured programming languages

1968-71 Pascal

- Niklaus Wirth, ETH Zurich
- Developed to be a small and efficient language intended to encourage good programming practices using structured programming and data structuring.

1972 C

- Dennis Ritchie
- C was designed for writing architecturally independent system software.
- It is also widely used for developing application software.

History – Pascal

```
program P3;

var
   F: Text;
   LineNo: Integer;
   Line: array [1..60] of Char;

begin
   if ParamCount < 1 then begin
      WriteLn('Pouziti: opis <inp>');
      Halt;
   end;

   Reset(F, ParamStr(1));
   LineNo := 1;
   while not Eof(F) do begin
      ReadLn(F, Line);
      WriteLn(LineNo:4, ': ', Line);
      LineNo := LineNo + 1;
   end;
end.
```


History – Modular programming

1980 Modula-2

- Support of modularity, strong type control, dynamic arrays, co programs

1980-83 Ada

- Jean Ichibah, Honeywell Bull for US DoD
- Ada was originally targeted at embedded and real-time systems.
- Ada is strongly typed and compilers are validated for reliability in mission-critical applications, such as avionics software.
- Properties: strong typing, modularity mechanisms (packages), run-time checking, parallel processing (tasks), exception handling, and generics, dynamic memory management

History – Modula-2

```
DEFINITION MODULE Storage;

VAR
  ClearOnAllocate : BOOLEAN;

PROCEDURE Allocate( VAR a: ADDRESS; size: CARDINAL );
PROCEDURE Free( VAR a: ADDRESS );
PROCEDURE Deallocate( VAR a: ADDRESS; size: CARDINAL );
PROCEDURE Reallocate( VAR a: ADDRESS; size: CARDINAL );

PROCEDURE MemorySize( a : ADDRESS ): CARDINAL;
TYPE
  TMemoryStatus = RECORD
       MemoryLoad     : LONGCARD;   (* percent of memory in use *)
       TotalPhys      : LONGCARD;   (* bytes of physical memory *)
  END;

PROCEDURE GetMemoryStatus( VAR MemoryStatus : TMemoryStatus );

END Storage.
```


History – Ada

```
with TEXT_IO; use TEXT_IO;

procedure faktorial is
   package IIO is new INTEGER_IO(Integer);
   use IIO;

   cislo: Integer;

   function f(n : Integer) return Integer is
   begin
      if n < 2 then
         return 1;
      else
         return n*f(n-1);
      end if;
   end f;

begin
   PUT("Zadejte cislo:");
   GET(cislo);
   PUT(f(cislo));
   SKIP_LINE;
end faktorial;
```


History – Object oriented languages(1)

1964-67 SIMULA 67
- Ole Dahl, Kristen Nygaard (Norsko)
- For simulation of discrete models
- Abstract data types, classes, simple inheritance – base for object oriented languages

1972 Smalltalk
- Alan Kay, Xerox
- Originally only experimental language.
- Pure object oriented language – everything is achieved with message transition.
- First language supporting GUI with windows.
- Interpreted at the beginning. Now translated into abstract machine code or Just-in-time compiled.

1982-85 C++
- Bjarne Stroustrup, AT&T Bell Labs
- Developed from C => many dangerous futures like dynamic memory management without GC, pointer arithmetic
- 1997 ISO a ANSI standard

History – Object oriented languages(2)

1984-85 Objective C
- Brad J. Cox
- C language extension, for OOP defined new constructions
- Widely considered to be better than C++, freely available compilers come to late…
- Main programming language for Apple NeXT and OS Rhapsody

1994-95 Java
- James Gosling, Sun Microsystems
- Originally developed for embedded devices, later widely used for other areas like WWW.
- Machine independent code (Java Bytecode), use just-in-time compilation

2000-02 C#
- Anders Hejlsberg, Microsoft
- One of the basics languages of .NET
- Implemented even for Linux (project Mono) a BSD Unix (project Rotor)

History – C#

```
using System;
using System.Windows.Forms;
using System.Drawing;
public class Sample : Form {
    [STAThread]
    public static int Main(string[] args) {
        Application.Run(new Sample());
        return 0;
    }
    public Sample() {
        Button btn = new Button();
        btn.Text = "  ";
        Controls.Add(btn);
    }
}
```


Language Classification- Introduction

- Many different criteria for a classification of programming languages.
  - Implemented paradigm of programming.
    - Object oriented paradigm
    - Declarative style of programming
    - Aspect oriented programming
    - …
  - Implemented type system
    - Weak vs. Strong Typing
    - Dynamic vs. Static Types
    - …
  - Generation ("level") of programming language
    - High vs. low level programming languages
    - Machine dependent programming languages
    - …

Language Classification- Paradigm of programming (1)

- A programming paradigm is a fundamental style of computer programming.
  - Compare with a methodology, which is a style of solving specific software engineering problems.
  - Paradigms differ in the concepts and abstractions used to represent the elements of a program.
    - objects, functions, variables, constraints, etc.
    - steps that compose a computation (assignation, evaluation, continuations, data flows, etc.).

    - Example : In object-oriented programming, programmers can think of a program as a collection of interacting objects, while in functional programming a program can be thought of as a sequence of stateless function evaluations.

Language Classification- Paradigm of programming(2)

- A programming language can support multiple paradigms.
  - Smalltalk supports object-oriented programming.
  - Java supports imperative, generic, reflective, object-oriented (class-based) programming.

- Many programming paradigms are as well known for what techniques they forbid as for what they enable.
  - For instance, pure functional programming disallows the use of side-effects.
  - Structured programming disallows the use of the *goto* statement.

Language Classification- Examples of Programming paradigms (1)

- Annotative programming (as in Flare language)
- Aspect-oriented programming (as in AspectJ)
- Attribute-oriented programming (might be the same as annotative programming) (as in Java 5 Annotations, pre-processed by the XDoclet class; C# Attributes)
- Class-based programming, compared to Prototype-based programming (within the context of object-oriented programming]
- Concept-oriented programming is based on using concepts as the main programming construct.
- Constraint programming, compared to Logic programming
- Data-directed programming
- Dataflow programming (as in Spreadsheets)
- Flow-driven programming, compared to Event-driven programming
- Functional programming
- Imperative programming, compared to Declarative programming
- Intentional Programming
- Logic programming (as in Mathematica)

Language Classification- Examples of Programming paradigms (2)

- Message passing programming, compared to Imperative programming
- Object-Oriented Programming (as in Smalltalk)
- Pipeline Programming (as in the UNIX command line)
- Policy-based programming
- Procedural programming, compared to Functional programming
- Process oriented programming a parallel programming model.
- Recursive programming, compared to Iterative programming
- Reflective programming
- Scalar programming, compared to Array programming
- Component-oriented programming (as in OLE)
- Structured programming, compared to Unstructured programming
- Subject-oriented programming
- Tree programming
- Value-level programming, compared to Function-level programming

Language Classification- Basic programming paradigms (1)

- **Imperative**
  - Programs are sequences of statement (mostly assignments).
  - Programs flow can be changed using control statements like loops.
    - Control statement define which statement will be performed and in what order.
  - *C, Pascal, Fortran, JSI*
- **Object oriented**
  - Program are collections of interacting objects.
  - Often uses inheritance or polymorphism.
  - *Simula, Smalltalk-80, C++, Java, C#*

Language Classification – Language and computer's architecture

- Programming languages are limited by an architecture of today's computer.
  - Effective implementation must exists if we want to use them to create real life applications.
- Von Neumann's architecture
  - Model of today's mainstream computers
  - Widely used languages like Java or C/C++/C# are closely related to this architecture.
- Functional languages
  - Backus (1977, Turing Award) Can Programming Be Liberated From the von Neumann Style?
    - Criticized attempt „from architecture to language“
  - For example functional languages are considered to be superior to imperative languages.
    - We can prove some properties.
    - Easy to parallelize
    - Based on algebraic rules
  - On the other hand they are not as effective as imperative languages on Von Neumann's architecture based computers.
    - Massive optimizations needed (Ocalm - nearly as effective as C)
    - Result => Not so often used like for example Java.

Language Classification- Basic programming paradigms (2)

Declarative languages
– source code describes what to compute not how

- **Logic programming languages**
  - Programs are a collection of predicates in some concrete logic (most often predicate logic).
  - Defining feature of logic programming is that sets of formulas can be regarded as programs and proof search can be given a computational meaning.
  - *Prolog, Goedel*
- **Functional programming languages**
  - Treats computation as the evaluation of mathematical functions and avoids state and mutable data.
  - It emphasizes the application of functions, in contrast to the imperative programming style, which emphasizes changes in state.
  - *FP, LISP, Scheme, ML, Haskell*

Language Classification- Basic programming paradigms (3)

- **Concurrent programming languages**
  - Programs are designed as collections of interacting computational processes that may be executed in parallel.
  - Concurrent (parallel) programming languages are programming languages that use language constructs for concurrency.
  - Some versions of language Modula-2, Ada
    - Today's programming languages often use some sort of library for concurrent programming MPI, PVM.

Language Classification- Type system

- Type system definition
  - Strict:
    - A tractable syntactic method for proving the absence of certain program behaviors by classifying phrases according to the kinds of values they compute.
  - Loosely:
    - A type system associates one (or more) type(s) with each program value.
    - By examining the flow of these values, a type system attempts to prove that no "type errors" can occur.
- Type system's main functions
  - Assigning data types (typing) gives meaning to collections of bits.
    - Types usually have associations either with values in memory or with objects such as variable.
  - Safety - Use of types may allow a compiler to detect meaningless or probably invalid code.
  - Abstraction (or modularity) - Types allow programmers to think about programs at a higher level than the bit or byte, not bothering with low-level implementation.
  - Optimizations, documentation,…
- Type theory studies type systems.

Language Classification- Type checking

- The process of verifying and enforcing the constraints of types – *type checking* .
- Different ways to categorize the type checking.
  - The terms are not used in a strict sense!
  - Compile-time (a static check) / Run-time (a dynamic check)
  - Strongly typed / Weakly typed
  - Safely and unsafely typed systems

Language Classification- Categorizing type checking (1)

- Static typing
  - Type checking is performed during compile-time as opposed to run-time.
  - Ada, C, C++, C#, Java, Fortran, ML, Pascal, orHaskell.
  - Static typing is a limited form of program verification
    - However it allows many errors to be caught early in the development cycle.
    - Program execution may also be made more efficient (i.e. faster or taking reduced memory).
  - Static type checkers are conservative.
    - They will reject some programs that may be well-behaved at run-time, but that cannot be statically determined to be well-typed.
    - Some statically typed languages enables programmers to write pieces of code that circumvent the default verification performed by a static type checker.
      - For example, Java and most C-style languages have type conversion.

Language Classification- Categorizing type checking (2)

- Dynamic typing
  - Majority of its type checking is performed at run-time.
  - Groovy, JavaScript, Lisp, Clojure, Objective-C, Perl, PHP, Prolog, Python, Ruby, or Smalltalk.
  - Dynamic typing can be more flexible than static typing.
    - For example by allowing programs to generate types based on run-time data.
    - Run-time checks can potentially be more sophisticated, since they can use dynamic information as well as any information that was present during compilation.
      - On the other hand, runtime checks only assert that conditions hold in a particular execution of the program, and are repeated for every execution of the program.

Language Classification- Categorizing type checking (3)

- Strongly typed languages (also term memory safe is used)
  - Definition involves preventing success for an operation on arguments which have the wrong type.
  - Strongly typed languages that do not allow undefined operations to occur.
    - For example, a memory-safe language will check array bounds (resulting to compile-time and perhaps runtime errors).
- Weak typing means that a language implicitly converts (or casts) types when used.
- Example

```
var x := 5;     // (1)  (x is an integer)
var y := "37";  // (2)  (y is a string)
x + y;          // (3)  (?)
```

  - It is not clear what result one would get in a weakly typed language.
    - Visual Basic, would produce run able code producing the result 42.
    - JavaScript would produce the result "537".

Language Classification- Categorizing type checking (4)

- "Type-safe" is language if it does not allow operations or conversions which lead to erroneous conditions.
  - Let us again have a look at the pseudocode example:

```
var x := 5;     // (1)
var y := "37";  // (2)
var z := x + y; // (3)
```

    - In languages like Visual Basic variable z in the example acquires the value 42.
    - The programmer may or may not have intended this, the language defines the result specifically, and the program does not crash or assign an ill-defined value to z.
    - If the value of y was a string that could not be converted to a number (eg "hello world"), the results would be undefined.
    - Such languages are type-safe (in that they will not crash) but can easily produce undesirable results.
  - Now let us look at the same example in C:

```
int x = 5;
char y[] = "37";
char* z = x + y;
```

    - In this example z will point to a memory address five characters beyond y.
      - Might lie outside addressable memory.
    - The mere computation of such a pointer may result in undefined behavior.
    - We have a well-typed, but not memory-safe program.
      - A condition that cannot occur in a type-safe language.

Language Classification- Other Type System's Futures

- Polymorphism
  - The ability of code (in particular, methods or classes) to act on values of multiple types.
  - Or the ability of different instances of the same data-structure to contain elements of different types.
  - Type systems that allow polymorphism generally do so in order to improve the potential for code re-use.
    - In a language with polymorphism, programmers need only implement a data structure such as a list or an associative array once.

Language Classification- Level of programming language (1)

- Low-level programming languages (machine dependent programming languages).
  - language that provides little or no abstraction from a computer's instruction set architecture.
  - The first-generation programming language, or 1GL, is machine code.
    - It is the only language a microprocessor can understand directly.
    - Example: A function in 32-bit x86 machine code to calculate the nth Fibonacci number:

```
8B542408 83FA0077 06B80000 0000C383
FA027706 B8010000 00C353BB 01000000
B9010000 008D0419 83FA0376 078BD98B
C84AEBF1 5BC3
```


Language Classification- Level of programming language (2)

- The second-generation programming language, or 2GL, is assembly language.
  - It is considered a second-generation language because while it is not a microprocessor's native language, an assembly language programmer must still understand the microprocessor's unique architecture (such as its registers and instructions).
  - These simple instructions are then assembled directly into machine code.
  - Part of program computing Fibonacci numbers above, but in x86 assembly language using MASM syntax:

```
mov edx, [esp+8]
cmp edx, 0
ja @f
mov eax, 0
ret
```


Language Classification- Level of programming language (3)

- High level programming languages
  - Such languages hide the details of CPU operations such as memory access models and management of scope.
  - May use natural language elements, be easier to use, or more portable across platforms.
  - A compiler is needed when used for programming of real-life applications.
  - This greater abstraction and hiding of details is generally intended to make the language user-friendly.
    - A high level language isolates the execution semantics of a computer architecture from the specification of the program, making the process of developing a program simpler and more understandable with respect to a low-level language.
  - The amount of abstraction provided defines how 'high level' a programming language is (3GL, 4GL? 5GL??).

Language Classification- Level of programming language (4)

- A very high-level programming language (VHLL) is a programming language with a very high level of abstraction, used primarily as a professional programmer productivity tool.
  - Very high-level programming languages are usually limited to a very specific application, purpose, or type of task.
  - Due to this limitation in scope, they might use syntax that is never used in other programming languages, such as direct English syntax.
  - For this reason, very high-level programming languages are often referred to as goal-oriented programming languages.

Language Classification- Level of programming language (5)

- A third-generation language (3GL)
  - Where as a second generation language is more aimed to fix logical structure to the language, a third generation language aims to refine the usability of the language in such a way to make it more user friendly.
  - First introduced in the late 1950s, Fortran, ALGOL and COBOL are early examples of this sort of language.
  - Most "modern" languages (BASIC, C, C++, C#, Pascal, and Java) are also third-generation languages.
  - Most 3GLs support structured programming.

Language Classification- Level of programming language (6)

- A fourth-generation programming language (1970s-1990, 4GL)
  - Is a programming language or programming environment designed with a specific purpose in mind.
  - In the evolution of computing, the 4GL followed the 3GL in an upward trend toward higher abstraction and statement power.
    - 3GL development methods can be slow and error-prone.
    - Some applications could be developed more rapidly by adding a higher-level programming language and methodology which would generate the equivalent of very complicated 3GL instructions with fewer errors.
    - 4GL and 5GL projects are more oriented toward problem solving and systems engineering.
  - Fourth-generation languages have often been compared to domain-specific programming languages (maybe a sub-set of DSLs).
  - Given the persistence of assembly language even now in advanced development environments, one expects that a system ought to be a mixture of all the generations, with only very limited use of the first.
  - Examples: SQL, IDL

Language Classification- Level of programming language (7)

- A fifth-generation programming language (5GL)
  - Is a programming language based around solving problems using constraints given to the program, rather than using an algorithm written by a programmer.
  - Fifth-generation languages are used mainly in artificial intelligence research.
  - While 4GL are designed to build specific programs, 5GL are designed to make the computer solve a given problem without the programmer.
  - However, as larger programs were built, the flaws of the approach became more apparent.
    - It turns out that, starting from a set of constraints defining a particular problem, deriving an efficient algorithm to solve it is a very difficult problem in itself.
    - This crucial step cannot yet be automated and still requires the insight of a human programmer.
    - Today are mostly used in academic circles for research.
  - Example: Prolog, OPS5, and Mercury

Specification of programming languages- What we want to describe?

- **How correct program should look like?**
  - SYNTAX
  - Formal languages, grammars, automatons,...
- **What correct program should do?**
  - SEMANTICS
  - Lambda calculus, Attributed grammars,...

Specification of programming languages- Formal languages

- **Alphabet**
  - Finite set of symbols Σ
  - Example: {0,1}, {a, b, c, …, z}, {a,b,+, ∗,(,)}
- **Words over an alphabet Σ**
  - Set of symbols from Σ (Σ^*)
  - Empty set - ε
  - Examples: 1001, pjp, a∗(b+b)
- **Language over an alphabet Σ**
  - A subset of words over an alphabet Σ
  - Finite or infinite languages
  - Examples:
    {0, 00, 11, 000, 011, 101, 110, 0000, 0011, …}
    {int, double, char}
    {a, b, a+a, a+b, b+a, b+b, …, a∗(b+b), … }

Specification of programming languages- How we can describe a language?

a) **Elements list**
  - Finite languages only.

b) **Description in “spoken” language**
  - vague, can not be used for computations, complex

c) **Generative systems – grammars**
  - Instructions, how we can generate all words in a language.

d) **Detection systems – automatons**
  - Instructions, how we can check if a word belongs to a language or does not.

Specification of programming languages– Grammars (1)

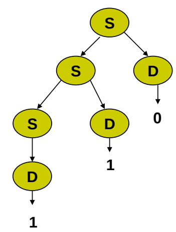
- G = (N, T, P, S)
  - N –**non-terminal symbols**
    Can be transformed to a different set of symbols.
  - T – **terminal symbols**
    Can not be transformed future.
  - P – **production rule**s
    $P \subseteq (N x T)^* N (N x T)^* \text{ x } (N x T)^*$
    $\alpha \rightarrow \beta$ α - left side, β - right side
  - S – **start symbol** $S \in N$

Specification of programming languages– **Grammars (2)**

- Binary numbers
  - N = {S, D}   T = {0, 1}
  - P: S → D | S D
    D → 0 | 1
  - S ⇒ S D ⇒ S 0 ⇒ S D 0 ⇒ D D 0 ⇒ 1 D 0 ⇒ 1 1 0
    S ⇒* 1 1 0

Specification of programming languages- **Grammar's derivation tree**

- S ⇒ S D ⇒ S 0 ⇒ S D 0 ⇒ D D 0 ⇒ 1 D 0 ⇒ 1 1 0



Specification of programming languages- **Chomsky Language Classification (1)**

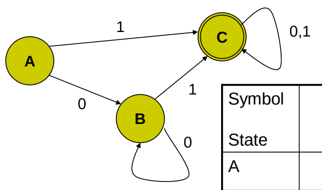
- Type 0 – Unrestricted languages
  $\alpha \rightarrow \beta$ α, β all possibilities
- Type 1 – Context languages
  $\omega_1\alpha\ \omega_2 \rightarrow \omega_1\ \beta\ \omega_2$
- Type 2 – Context free languages
  $A \rightarrow \beta$
- Type 3 – Regular languages
  $A \rightarrow$ b C
  $A \rightarrow$ b

Specification of programming languages- **Chomsky Language Classification (2)**

- **Type 0 – Unrestricted languages**
  We are unable to compute if word belongs to some language.
  Turing's machines
- **Type 1 – Context languages**
  Containing real programming languages.
  Are unable to analyze effectively
  Linearly bound Turing's machines
- **Type 2 – Context free languages**
  Can be analyzed very effectively
  Pushdown automatons
- **Type 3 – Regular languages**
  Even more effective methods to analyze them
  Finite automatons

Specification of programming languages- **Finite automatons**

States + transitions



Symbol State	0	1
A	B	C
B	B	C
C	C	C

Specification of programming languages- **Finite automatons**

A = (Q, Σ, δ, q_0, F)

- Q: a finite set of states
- Σ: input alphabet
- δ: state transition function
  $\delta_{NFA} : Q \times \Sigma \rightarrow 2^Q$ $\delta_{DFA} : Q \times \Sigma \rightarrow Q$
- q_0: initial state
- F: a set of final states

Specification of programming languages – **Syntax's description**

- Three levels of syntax's description
  - Lexical structure (identifiers, numbers, strings)
    - Regular expressions, finite automatons
  - Context free syntax
    - Context free grammars
    - Common programming languages are not context free languages.
      - If - else
  - Context restrictions

Specification of programming languages – **Syntax description's methods**

- Syntactic graph
- Backus-Naur Form (BNF)
  <decl> -> 'DEF' <ident> '=' <expr> <expr1>
  | 'TYPE' <ident> '=' <type>
  <expr1> -> ';' <expr> <expr1>
  | e
  - Example: DEF a = 1;
- Extended Backus-Naur Form (EBNF)
  - Extended with regular expression's operators
  <decl> -> 'DEF' <ident> '=' <expr> (<expr>)*
  | 'TYPE' <ident> '=' <type>

Specification of programming languages- Language's semantics specification

- Semantics reflects the meaning of programs or functions.
- Many different frameworks, none of them considered to be "standard"
- Three main approaches
  - **Axiomatic semantics**
    - Specific properties of the effect of executing the constructs as expressed as *assertions*.
      - Thus there may be aspects of the executions that are ignored.
    - {P} while R do S {Q ∧ ¬R}
  - **Operational semantics**
    - The meaning of a construct is specified by the computation it induces when it is executed on a machine.
    - In particular, it is of interest *how* the effect of a computation is produced.
  - **Denotation semantics**
    - Meanings are modeled by mathematical objects that represent the effect of executing the constructs.
      - Thus *only* the effect is of interest, not how it is obtained.
    - E : Expr → (String → Int) → Int

Functional programming – Differences between imperative and declarative programming languages

- Imperative languages
  - Imperative languages describes computation in terms of statements that change a program state.
  - Imperative programs define sequences of commands for the computer to perform
    - Explicit term sequence of commands – it express what computer should do and when
  - Statement has a side effects
  - Based on actual (Von Neumman's) computer's architecture
    - Simple and effective implementation
- Declarative languages
  - Programs are likely composed from expressions not from statements.
  - Expresses *what* needs to be done, without prescribing *how* to do it.
    - In terms of sequences of actions to be taken.
    - There is no sequence of commands given.
  - For effective implementation complex optimizations must be performed.

  - **Functional and logical programming languages** are characterized by a declarative programming style.

Functional programming – Functional programming languages(1)

- Based on lambda calculus – basic computation's model is a mathematical term function. Functions are applied on arguments and compute results.
- Programs are composed from functions without side effects.
- Functions are considered to be „first-class values".
- Functional languages have better abstraction mechanisms.
  - High order functions may be used.
  - Function's composition
  - Programs often much shorter
- Functional languages do not contain assignments, cycles, ...
  - Recursion is used instead.
  - Assignment has a mathematical meaning.
    - Variable has the same value in a given context.

Functional programming – Functional programming languages(2)

- Functional languages allow to use new algebraic approaches.
  - **Lazy evaluation** (x **eager evaluation**)
    - We could use infinite structures.
  - We could separate data from execution order – for example for parallelization.
- Functional languages allows new approaches for a application's development.
  - Proofing properties of programs.
  - Possibility to transform program based on algebraic properties.
- Easier parallelization
  - Easy to find parts which can be evaluated in parallel.
    - Functions has no side effects!
    - Often to many parallelisms.
  - We can create new parallel program simply by composing two parallel programs.

Functional programming – λ-calculus

- 1930 Alonzo Church
  - Lambda calculus is a formal system designed to investigate function definition, function application and recursion.
  - Part of an investigation into the foundations of mathematics
- Base for functional languages
- Some constructions present even in imperative languages (for example Python or C#).

Functional programming – Lambda calculus (1)

- Variables
  - x, y, z, f, g, …
- λ-abstraction
  - (λx . e)
- Application
  - $(e_1\ e_2)$
- Parentheses convention
  - $\lambda x\ .\ \lambda y\ .\ e_1\ e_2 = (\lambda x\ .\ (\lambda y\ .\ e_1\ e_2))$
  - $e_1\ e_2\ e_3 = ((e_1\ e_2)\ e_3)$

Functional programming – Lambda calculus (1)

- λ-Abstraction
  - λ *x* . *e*
    - A function with a parameter *x* and a body *e*
  - λ x y . e
    - A function with parameters *x*, *y* and a body *e*
    - Is equivalent to a notation λ *x* . (λ *y* . *e*)
  - λ e . e (λ f x (f x x)) (λ f x (f x x))
- Application
  - $(e_1\ e_2)$
    - Application of the function e_1 to the argument e_2
  - (*f x y*)
    - Application of the function (*f x*) to the argument *y*
    - Application of the function *f* to arguments *x* a *y*

Functional programming - Substitution

- $e_1\ [e_2/x]$
  - replacement of a variable X by expression e_2 every place it is free within e_1
  - Substitution must be correct.
    - We must be careful in order to avoid accidental variable capture.
- (λ x y . f x y) [g z / f] = λ x y . (g z) x y
- (λ x y . f x y) [g z / x] = λ x y . f x y
- (λ x y . f x y) [g y / f] = *error in substitution*

Functional programming – Evaluation of λ-expressions

- α-reduction
  - $\lambda x . e \leftrightarrow \lambda y . e[y / x]$
  - Renaming of a captured variable
- β-reduction
  - $(\lambda x . e_1)\ e_2 \leftrightarrow e_1 [e_2 / x]$
  - "function's call" – replacing a parameter with an argument
- η-reduction
  - $\lambda x . f\, x \leftrightarrow f$
  - Removing of an abstraction
  - Variable *x* must not be free in *f*
  - *Two functions are the same if and only if they give the same result for all arguments.*
- Substitution must be correct!

Functional programming - Example

- $(\lambda f\, x . f\, x\, x)\ (\lambda x\, y . p\, y\, x)$
  $=_\beta\ \lambda x . (\lambda x\, y . p\, y\, x)\ x\, x$
  $=_\alpha\ \lambda z . (\lambda x\, y . p\, y\, x)\ z\, z$
  $=_\beta\ \lambda z . (\lambda y . p\, y\, z)\ z$
  $=_\beta\ \lambda z . p\, z\, z$

- $(\lambda f\, x . f\, x\, x)\ (\lambda x\, y . p\, y\, x)$
  $=_\eta\ (\lambda f\, x . f\, x\, x)\ (\lambda y . p\, y)$
  $=_\eta\ (\lambda f\, x . f\, x\, x)\ p$
  $=_\beta\ \lambda x. p\, x\, x$

Functional programming – Reduction strategies

- *redex* --- **red**ucible **ex**pression
  - Expression that can be reduced further; α-redex, β-redex.
- *Expression's normal form*
  - Any expression containing no β-redex.
- Reduction strategies - The distinction between reduction strategies relates to the distinction in functional programming languages between eager evaluation and lazy evaluation.
  - Applicative order
    - The rightmost, innermost redex is always reduced first.
    - Intuitively this means a function's arguments are always reduced before the function itself.
    - **Eager evaluation –** This is essentially using applicative order, call by value reduction
  - Normal order
    - The leftmost, outermost redex is always reduced first.
  - Call by name
    - As normal order, but no reductions are performed inside abstractions.
  - Call by value
    - Only the outermost redexes are reduced: a redex is reduced only when its right hand side has reduced to a value (variable or lambda abstraction).
  - Call by need
    - As normal order, but function applications that would duplicate terms instead name the argument, which is then reduced only "when it is needed" - **lazy evaluation**.

Haskell - Haskell

- September 1991 – Gofer
  - Experimental language
  - Mark P. Jones
- February 1995 – Hugs
- Hugs98
  - Nearly full implementation of programming language Haskell 98
  - Some extension implemented
- Basic resources
  - http://haskell.org
    - Language specification and other resources
  - http://haskell.org/hugs
    - Installation packages (Win / Unix)
    - User's manual (is a part of installation)

Haskell – Hugs Interpret

- Basic evaluation: calculator
```
$ hugs
Prelude> 2*(3+5)
16
```
- Script: containing user's definitions
  - $ **hugs example.hs**
- Editing of source code
  - :*edit [file*.hs*]*
  - :e
- Loading of source code
  :*load [*file.hs*]*
  :*reload*
- Exiting work
  :*quit*
- Help
  :?

Haskell – Scritp

- example.hs
```
module Example where
-- Function computing sum of two numbers
sum x y = x + y
```
- Example.lhs
```
> module Example where

Function computing factorial
> f n = if n == 0 then 1 else n * f (n-1)
```


Haskell – Data types(1)

- Basic data types
  - 1::Int
  - 'a'::Char
  - True,False::Bool
  - 3.14::Float
- Lists `[a]`
  - Empty list `[]`
  - Non-empty list `(x:xs)`
  - `1:2:3:[] :: [Int]`
  - `[1,2,3]  :: [Int]`
- Ordered tuples `(a,b,c,...)`
  - `(1,2) :: (Int,Int)`
  - `(1,['a','b'])::(Int, [Char])`
  - `() :: ()`

Haskell – Data types(2)

- Function `a->b`
  - `factorial :: Int -> Int`
  - `sum:: Int -> Int -> Int`
  - `plus :: (Int, Int) -> Int`
- User defined data types
```
data Color  = Black
            | White

data Tree a = Leaf a
            | Node a (Tree a) (Tree a)

type String = [Char]

type Table a = [(String, a)]
```

Haskell – Type classes

- Type class – set of types with specific operations
  - Num: +, -, *, abs, negate, signum, …
  - Eq: ==, /=
  - Ord: >, >=, <, <=, min, max
- Constrains, type class specification
  - elem :: Eq a => a -> [a] -> Bool
  - minimum :: Ord a => [a] -> a
  - sum :: Num a => [a] -> a

Haskell – Function definition

- Equation and pattern unification (pattern matching):
  - `f  pat11  pat12  ...  = rhs1`
  - `f  pat21  pat22  ...  = rhs2`
  - `...`
- First corresponding equation is chosen.
- If there is none → error

Haskell – Patterns

- variable
  - `inc x = x + 1`
- constant
  - `not True = False`
  - `not False = True`
- List
  - `length []    = 0`
  - `length (x:xs) = 1 + length xs`
- tupels
  - `plus (x,y) = x+y`
- User's type constructor
  - `nl (Leaf _) = 1`
  - `nl (Node _ l r) = (nl l) + (nl r)`
- Named pattern's parts
  - `duphd p@(x:xs) = x:p`
- Another patterns - *n+k*
  - `fact 0     = 1`
  - `fact (n+1) = (n+1)*fact n`

Haskell – Example

- Factorial
  - ```
    fakt1 n     = if n == 0 then 1
                  else n * fakt1 (n-1)
    ```
  - ```
    fakt2 0     = 1
    fakt2 n     = n * fakt2 (n-1)
    ```
  - ```
    fakt3 0     = 1
    fakt3 (n+1) = (n+1) * fakt3 n
    ```
  - ```
    fakt4 n | n == 0    = 1
            | otherwise = n * fakt4 (n-1)
    ```
- Fibonacci numbers

```
fib :: Int -> Int
fib 0     = 0
fib 1     = 1
fib (n+2) = fib n + fib (n+1)
```

Haskell – Example

- List length
  - ```
    length [] = 0
    length (x:xs) = 1 + length xs
    ```
- Comment: be aware of name conflict with previously defined functions!
  - ```
    module Example where
    import Prelude hiding(length)

    length []     = 0
    length (_:xs) = 1 + length xs
    ```


Haskell – Local definition

- Construction *let ... in*
  - ```
    f x y = let p = x + y
                q = x - y
            in p * q
    ```
- Construction *where*
  - ```
    f x y = p * q
            where p = x + y
                  q = x - y
    ```


Haskell – Partial function application

- `inc x = 1 + x`
- `inc x = add 1 x`
- `inc = add 1`
- `inc = (+1)    = (1+)`
- `add = (+)`
- `Eta reduction`
- `Point free programming`
  - lcaseString s = map toLower s
  - lcaseString = map toLower

Haskell – Lambda abstraction

- **Using function like a parameter**

```
nonzero xs = filter p xs
             where p x = x /= 0

nonzero xs = filter (/= 0) xs

nonzero xs = filter (\x -> x/=0) xs
```

- \ x -> e … λx . e
  - inc = \x -> x+1
  - plus = \(x,y) -> x + y
  - dividers n = filter (\m -> n `mod` m == 0) [1..n]

Haskell – Example

- Example creating a list of squared numers

```
dm [] = []
dm (x:xs) = sq x : dm xs
            where sq x = x * x
```

- List's ordering (quicksort)

```
qs [] = []
qs (x:xs) =
   let ls = filter (< x) xs
       rs = filter (>=x) xs
   in qs ls ++ [x] ++ qs rs
```


Haskell – Functions manipulating with lists(1)

- Access to list's elements
  - `head [1,2,3]    = 1`
  - `tail [1,2,3]    = [2,3]`
  - `last [1,2,3]    = 3`
  - `init [1,2,3]    = [1,2]`
  - `[1,2,3] !! 2    = 3`
  - `null []         = True`
  - `length [1,2,3] = 3`

Haskell – Functions manipulating with list (2)

- List's union
  - `[1,2,3] ++ [4,5]  = [1,2,3,4,5]`
  - `[[1,2],[3],[4,5]] = [1,2,3,4,5]`
  - `zip [1,2] [3,4,5] = [(1,3),(2,4)]`
  - `zipWith (+) [1,2] [3,4] = [4,6]`
- List's aggregation
  - `sum [1,2,3,4]     = 10`
  - `product [1,2,3,4] = 24`
  - `minimum [1,2,3,4] = 1`
  - `maximum [1,2,3,4] = 4`

Haskell – Functions manipulating with list (3)

- Selecting list's parts
  - `take 3 [1,2,3,4,5] = [1,2,3]`
  - `drop 3 [1,2,3,4,5] = [4,5]`
  - `takeWhile (>0) [1,3,0,4] = [1,3]`
  - `dropWhile (> 0) [1,3,0,4] = [0,4]`
  - `filter (>0) [1,3,0,2,-1] = [1,3,2]`
- List's transformations
  - `reverse [1,2,3,4] = [4,3,2,1]`
  - `map (*2) [1,2,3] = [2,4,6]`

Haskell – Arithmetic rows

- [m..n]
  - [1..5] = [1,2,3,4,5]
- [m1,m2..n]
  - [1,3..10] = [1,3,5,7,9]
- [m..]
  - [1..] = [1,2,3,4,5,…]
- [m1,m2..]
  - [5,10..] = [5,10,15,20,25,…]

Haskell – Function filter

Obtaining a part of list corresponding to given rule (predicate)

```
filter :: (a -> Bool)-> [a] -> [a]
filter _ [ ] = [ ]
filter p (x:xs) | p x = x : filter p xs
                | otherwise = filter p xs

filter even  [1..10]      = [2,4,6,8]
filter (> 0) [1,3,0,2,-1] = [1,3,2]

dividers n = filter deli [1..n]
             where deli m = n `mod` m == 0
```


Haskell – Function map

- List's elements

```
map :: (a -> b) -> [a] -> [b]
map f [ ]    = [ ]
map f (x:xs) = f x : map f xs

map (+1)     [1,2,3] = [2,3,4]
map toUpper "abcd"   = "ABCD"

squares x = map (\x -> x * x) [1..]
```


Haskell – List's generators

Example: A set of even numbers from 1 to10

- { x | x ∈1..10, x is even}
- [x | x <- [1..10], even x]

```
• [ x | x <- xs ]         = xs
• [ f x | x <- xs ]       = map f xs
• [ x | x <- xs, p x ] = filter p xs

• [ (x,y) | x<-xs, y<-ys ] =
     [(x1,y1),(x1,y2),(x1,y3),…,
      (x2,y1),(x2,y2),(x2,y3),…,
       …   ]
```

Haskell – Example

- Set's operation using list's generators
  - Intersection

```
intersect xs ys = [y | y <-ys, elem y xs]
```

  - Union

```
union xs ys = xs ++ [y | y<-ys, notElem y xs]
```

  - Difference

```
diff xs ys = [x | x<-xs, notElem x ys]
```

  - Subset

```
subset xs ys = [x | x<-xs, notElem x ys] == []
subset xs ys = all (\x -> elem x ys) xs
```


Haskell – Definition of user's types

- data Color = Red | Green | Blue
  - Color –type's constructor
  - Red / Green / Blue – data constructor
- data Point = Point Float Float
  - `dist (Point x1 y1) (Point x2 y2) = sqrt ((x2-x1)**2 + (y2-y1)**2)`
  - *dist (Point 1.0 2.0) (Point 4.0 5.0) = 5.0*
- data Point a = Point a a
  - Polymorphism
  - Constructor `Point :: a -> a -> Point a`

Haskell – Recursive data types

Tree

```
data Tree1 a = Leaf a
             | Branch (Tree1 a) (Tree1 a)
data Tree2 a = Leaf a
             | Branch a (Tree2 a) (Tree2 a)
data Tree3 a = Null
             | Branch a (Tree3 a) (Tree3 a)

t2l (Leaf x) = [x]
t2l (Branch lt rt) = (t2l lt) ++ (t2l rt)
```


Haskell – Type's Synonyms

- `type String = [Char]`

```
type Name = String
data Address = None | Addr String
type Person = (Name, Address)

type Table a = [(String, a)]
```

  - They are equivalent to original types
  - They represent only a shortcuts

Haskell – Basic type classes

Eq a	(==), (/=)
Eq a => Ord a	(<), (<=), (>), (>=), min, max
Enum a	succ, pred
Read a	readsPrec
Show a	showsPres, show
(Eq a, Show a) => Num a	(+), (-), (*), negate, abs
(Num a) => Fractional a	(/), recip
(Fractional a) => Floating a	pi, exp, log, sqrt, (**), …

Haskell – Type class *Show*

- Values that can be converted to a string
  - ```
    type  ShowS  = String -> String
    class Show a where
      showsPrec   :: Int -> a -> ShowS
      show        :: a -> String
      showList    :: [a] -> ShowS
    ```
  - ```
    showPoint :: Point -> String
    showPoint (Point x y) =
      "(" ++ show x ++ ";" ++ show y ++ ")"
    ```
  - ```
    instance Show Point where
       show p = showPoint p
    ```


Haskell – Type class *Read*

- Values readable form a string
  - ```
    type ReadS a = String -> [(a,String)]
    class Read a where
        readsPrec :: Int -> ReadS a
        readList  :: ReadS [a]
    ```
  - ```
    readsPoint :: ReadS Point
    readsPoint ('(':s) =
       [ (Pt x y, s'') |
            (x, ';':s') <- reads s,
            (y, ')':s;;) <- reads s']
    ```
  - ```
    instance Read Point where
       readsPrec _ = readsPoint
    ```


Haskell – Programming with Actions

- Imperative languages
  - Program is a sequence of statements
    - Straight forward and clear sequence of actions
    - Side effects
  - We can for example easily use global variables, read and write file,…
- Haskell (simplified)
  - Actions are divided from pure functional code.
  - *Monadic operators*
  - Actions is a function which's result is of type: **(IO a).**

Haskell – Programming with Actions Example

- Char's read and write
  - ```
    getChar :: IO Char
    putChar :: Char -> IO ()
    ```
- Transformation of a function to a action
  - ```
    return :: a -> IO a
    ```
- Test: y/n check – sequence of actions
  - ```
    ready :: IO Bool
    ready = do c <- getChar
               return (c == 'y')
    ```


Haskell – Function *main*

- Represents main program
- Action returning nothing:
  - ```
    main :: IO ()
    main = do c <- getChar
              putChar c
    ```

1. Reads character and marks it c.
2. Write character c.
3. Returns the result of last action – IO().

Haskell – Line reader example

1. Program reads first character.
2. If program reads end of line character then program returns readied string.
3. Otherwise program adds readied character to a result.

```
getLine :: IO String
getLine = do x <- getChar
             if x=='\n' then return ""
             else do xs <- getLine
                     return (x:xs)
```


Haskell – Writing of a *string*

- We can use function putChar on every character. For example:
  - map putChar xs
  - The result is a list of actions.
    - ```
      map :: (a -> b) -> [a] -> [b]
      putChar :: Char -> IO ()
      map putChar s :: [IO ()]
      ```
- Can be transformed to a single action.
  - ```
    sequence :: [IO()] -> IO ()
    putStr :: String -> IO ()
    putStr s = sequence (map putChar s)
    ```

Haskell – Proving using mathematical induction

- The simplest and most common form of mathematical induction proves that a statement involving a natural number *n* holds for all values of *n*.
  - The proof consists of two steps:
    - The **basis (base case)**: showing that the statement holds when *n* = 0.
    - The **inductive step**: showing that ***if*** the statement holds for some *n*, ***then*** the statement also holds when *n* + 1 is substituted for *n*.
- Structural induction for lists.
  a) We prove a statement for empty list - []
  b) If a statement holds for xs, then we show that it also holds for (x:xs).

Haskell – Example – Associativity of ++ (1)

(xs ++ ys) ++ zs = xs ++ (ys ++ zs)

```
[] ++ ys      = ys                (++.1)
(x:xs) ++ ys = x: (xs ++ ys)      (++.2)
```

a) [ ] => xs

```
([] ++ ys) ++ zs
   = ys ++ zs                     (++.1)
   = [] ++ (ys ++ zs)             (++.1)
```


Haskell – Example – Associativity of ++ (2)

(xs ++ ys) ++ zs = xs ++ (ys ++ zs)

```
[] ++ ys      = ys                (++.1)
(x:xs) ++ ys = x: (xs ++ ys)      (++.2)
```

b) (x:xs) => xs

```
((x:xs)++ys)++zs
   = x:(xs++ys)++zs               (++.2)
   = x:((xs++ys)++zs)             (++.2)
   = x:(xs++(ys++zs))             (assumption)
   = (x:xs)++(ys++zs)             (++.2)
```


Haskell – Example – length (xs++ys) (1)

length (xs++ys) = length xs + length ys

```
length []       = 0               (len.1)
length (_:xs) = 1 + length xs     (len.2)
```

a) [] => xs

```
length ([] ++ ys)
   = length ys                    (++.1)
   = 0 + length ys                (base case +)
   = length [] + length ys        (len.1)
```

Haskell – Example – length (xs++ys) (2)

length (xs++ys) = length xs + length ys

```
length []      = 0                  (len.1)
length (_:xs) = 1 + length xs       (len.2)
```

b) (x:xs) => xs

```
length ((x:xs) ++ ys)
   = length (x:(xs++ys))            (++.2)
   = 1 + length (xs++ys)            (len.2)
   = 1 + (length xs + length ys)    (Assumption)
   = (1 + length xs) + length ys    (+ Associativity)
   = length (x:xs) + length ys      (len.2)
```


Logické jazyky - Introduction

- Hlavní myšlenka:
  Využití počítače k vyvozování důsledků na základě deklarativního popisu
- Postup**:**
  - reálný svět →
  - zamýšlená interpretace →
  - logický model →
  - program
- Výpočet - určení splnitelnosti či nesplnitelnosti **cíle**, případně včetně vhodných **substitucí**.
- Pro Example použit jazyk Prolog

Logické jazyky - Logický program

- **Fakta**
```
vek(petr, 30).
vek(jana, 24).
```
- **Pravidla**
```
starsi(X, Y) :-
    vek(X, V1), vek(Y, V2), V1 > V2.
```
- **Dotazy**
```
?- starsi(petr, jana).
Yes
```


Logické jazyky - Co je to dotaz?

- Odpověď na dotaz vzhledem k programu = určení, zda je dotaz logickým důsledkem programu.
- Logické důsledky se odvozují aplikací dedukčních pravidel, např**.**
  P ├ P (identita)
  - Je-li nalezen fakt identický dotazu, dostaneme Yes.
  - Odpověď No znamená pouze to, že z programu nelze platnost dotazu vyvodit.

Logické jazyky - Předpoklad uzavřeného světa

```
zvire(pes).
zvire(kocka).
?- zvire(pes).
Yes
?- zvire(zirafa).
No
```

=> Předpokládáme platnost pouze toho, co je uveděno v programu.

Logické jazyky - Logická proměnná

- Představuje nespecifikovaný objekt
- Jméno začíná velkým písmenem

```
?- vek(jana, X).
X = 24.
?- vek(pavla, X).
No
```

- Existuje X takové, že vek(jana, X) lze odvodit z programu? Pokud ano, jaká je hodnota X?

Logické jazyky - Kvantifikátory

- likes(X, beer).
  Pro všechna X platí likes(X, beer).
- ?- likes(X, beer).
  Existuje X takové, že likes(X, beer)?

Logické jazyky - Term

- Datová struktura definovaná rekurzivně:
  - Konstanty a proměnné jsou termy
  - Struktury jsou termy: *funktor(arg1, arg2, …)*
    - *funktor:* jméno začínající malým písmenem
    - *argument*: term
- Funktor je určen **jménem** a **aritou**
  - f(t1, t2, …, tn) …. f/*n*
- Příklad:
  - z/0 s/1 … z, s(z), s(s(z)), s(s(s(z)))

Logické jazyky - Substituce

- **Základní term** (ground term)
  - neobsahuje proměnné s(s(z))
- **Substituce**
  - Konečná množina dvojic ve tvaru $X_i=t_i$
  - Aplikace substituce θ na term A … $A\theta$
    f(X, a) {X=g(z), Y=b} = f(g(z), a)
- **Instance termu**
  - A je instancí B, existuje-li substituce θ taková, že
    $A = B\theta$
    f(g(z), a) je instancí termu f(X, a)

Logické jazyky - Konjunktivní dotazy

- ?- zvire(pes), zvire(kocka).
  Yes

Sdílení proměnných:

- ?- vek(X, V), vek(Y, V).
  Existují X a Y se stejným věkem?

Logické jazyky - Pravidla

- A :- $B_1, B_2, \ldots, B_n$.
  A = **hlava** pravidla
  $B_1, B_2, \ldots, B_n$ = **tělo** pravidla

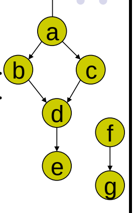
```
syn(X, Y)  :- otec(Y, X), muz(X).
deda(X, Y) :- otec(X, Z), otec(Z, Y).
```

- Proměnné jsou univerzálně kvantifikované.
- Platnost proměnných je celé pravidlo.

Logické jazyky - Rekurzivní pravidla

- **Definice grafu**

```
edge(a, b). edge(a, c). edge(b, d).
edge(c, d). edge(d, e). edge(f, g).
```




```
connected(N, N).
connected(N1, N2) :-
   edge(N1, L), connected(L, N2).
```

Skriptovací jazyky - **Obsah**

- Co jsou to skriptovací jazyky
- Výhody a nevýhody skriptovacích jazyků
- Hlavní oblasti použití
- Example jazyků: Perl, Python, Java Script
- Jazyk PHP - Introduction

Skriptovací jazyky - **Skriptovací jazyky (1)**

- Jazyky určené k rozšíření nebo propojení existujících aplikací a komponent
  - Uživatelem definované Function (např. editory)
  - Grafické uživatelské rozhraní (Tcl, VB)
  - Webový server (PHP) nebo klient (Java Script)
- Nepoužívají se obvykle ke složitým výpočtům nebo k práci se složitými datovými strukturami

Skriptovací jazyky - **Skriptovací jazyky (2)**

- Obvykle netypované (nebo slabě typované)
  - Automatická konverze typů
  - Proměnné mohou obsahovat cokoliv
- Obvykle interpretované
  - Nevyžadují samostatný překlad
  - Možnost měnit části programu za běhu
- Vestavěné složitější typy a operátory
  - Seznamy, vyhledávací tabulky

Skriptovací jazyky - **Výhody skriptovacích jazyků**

- **Rychlý vývoj aplikací**
- **Jednoduchá instalace aplikací**
  - často stačí pouze zkopírovat zdrojové soubory
- **Integrace s existujícími technologie**
  - např. komponentní technologie
- **Jednoduchost určení a použití**
- **Dynamické vlastnosti**
  - např. typování, rozsahy polí, konverze

Skriptovací jazyky - **Example**

- select | grep scripting | wc *(sh)*
- button .b –text Hello! –font {Times 16}
  –command {puts hello} *(Tcl)*
  - Java: 7 řádků
  - C++ (MFC): 25 řádků

Skriptovací jazyky - **Nevýhody skriptovacích jazyků**

- **Neúplnost**
  - předpokládá se spolupráce s „normálními" jazyky
- **Nesoulad s pravidly „dobrého" návrhu**
  - strukturování programu
  - objektově orientované programování
- **Zaměření na konkrétní oblast**
  - **např. PHP pro dynamické WWW stránky**

Skriptovací jazyky - **Použití skriptovacích jazyků**

- Správa systému
  - Řízení startu a ukončení činnosti systému
  - Základní systémové operace – např. archivace
  - Provádění dávkových operací
  - Shell – JCL, COMMAND/CMD, bash
- Automatizace tvorby programů
  - Často se opakující činnosti (překlad, instalace)
  - Ant – uživatelem definované činnosti

Skriptovací jazyky - **Použití skriptovacích jazyků**

- Přizpůsobení aplikací
  - Windows Scripting Host (WSH) – integrováno do operačního systému (VBScript, JScript)
  - Makra v textových editorech – VBA (MS Office), Office Basic (Sun StarOffice), eLISP (emacs)
- Přizpůsobení zařízení
  - Měřící přístroje s vestavěnými Tcl

Skriptovací jazyky - **Hlavní oblasti použití**

- GUI – grafické uživatelské rozhraní
  - Visual Basic, Tcl/Tk
- Internet
  - Perl, JavaScript, PHP
- Komponentní technologie
  - Visual Basic

Skriptovací jazyky – **Perl (1)**

- Practical Extraction and Report Language
- http://www.perl.com/
- Populární mezi administrátory Unixu
- Obtížně čitelná syntaxe, mnoho implicitních vlastností

Skriptovací jazyky - **Python**

- http://www.python.org/
- Původně vyvinutá jako komponenta operačního systému Amoeba
- Jednodušší syntaxe
- Jython – běží pod JVM

Skriptovací jazyky – **Javascript**

- Netscape Corp. – pro prohlížeč
- „Java…" je zavádějící – mnoho odlišností
  - Java: jazyk založený na třídách a dědičnosti
  - JS: jazyk založený na prototypech
- JScript (MS), ECMAscript (European Computer Manufacturer's Association)
- Sun StarOffice, Macromedia Flash

Skriptovací jazyky – Porovnávání jazyků

Perl

```
for $i (0 .. 6000-1) {
   %x=();
   for $j (0 .. 1000-1) {
        x{$j}=$i;
        $x{$j}
   }
}
```

Python

```
for i in range (6000) :
   x={}
   for j in range (1000):
        x[j]=I
        x[j]
```

Java

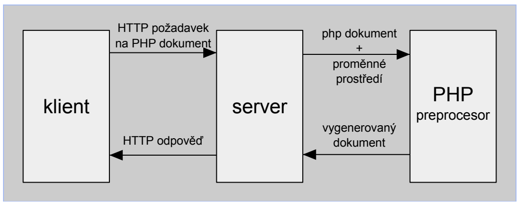
```
import java.util.*;
public class Test {

  public static void main(
   String[] args) {
     for(int i=0; i<6000;i++) {
       Map x=new HashMap();
       for (int j=0; j<1000; j++){
         Integer I=new Integer(i);
         Integer J=new Integer(j);
         x.put(I, J); x.get(I);
       }
     }
   }
}
```


Skriptovací jazyky – Internet

- Protokol HTTP
  - protokol pro přenos dat mezi klientem a webovým serverem
  - typy požadavků
    - GET, POST, HEAD
- Statický stránky
  - Protokol HTML (XHTML)
  - Soubor s příponou .html, .htm

Skriptovací jazyky – Webové aplikace



Skriptovací jazyky – HTTP požadavek GET

```
GET /index.html HTTP/1.0
User-Agent: Mozilla/5.0
Accept: text/plain, text/xml, text/html, ...
Accept-Language: en
```

```
HTTP/1.0 200 OK
Date: Sun, 02 October 2005 20:19:32 GMT
Content-Type: text/plain
Content-Length: 32

Toto je obsah souboru index.html
```

Skriptovací jazyky – PHP

- http://www.php.net/
- Původně pro návrh WWW stránek (Personal Home Page)
- K dispozici zdarma pro všechny OS
- Syntaxe podobná C/C++
- Hlavní oblasti
  - Skripty na straně serveru
  - Skripty spouštěné z příkazového řádku

Skriptovací jazyky – PHP

- Verze PHP5: kompletní objektový model
- Spolupráce s mnoha databázemi
  - MySQL, PostgreSQL, ODBC, Oracle, DB2, …
- Přístup k dalším službám
  - LDAP, IMAP, SNMP, NNTP, POP3, HTTP, …
- Napojení na jiné technologie
  - Java, COM
- Silná podpora zpracování textu, regulární výrazy, XML, komprese dat, …

Skriptovací jazyky – PHP a Internet

- Zdrojový text je HTML obsahující úseky programu v PHP:

```
<p><?php echo "ahoj";?></p>
<p><? echo date('Y-m-d') ?></p>
```

- Skripty jsou umístěny někde v adresáři ~/public_html/ s příponou .php (linux456)
- Je třeba zajistit, aby měl webový server právo číst soubory .php (příkaz chmod)

Skriptovací jazyky – PHP - Proměnné

- Uživatelské proměnné
  - Nedeklarují se
  - Jejich jméno začíná znakem $
  - ```
    $x = 10;
    if ( $x > 0 ) echo "$x je kladné";
    ```
- Systémové proměnné
  - $GLOBALS
  - $_REQUEST, $_SERVER, $?_SESSION, …
    ```

Skriptovací jazyky – PHP – Pole (1)

- Indexovaná pole
  - $a = array();
  - $a[0] = 10; $a[1] = 5;
  - $a =array (0=>10, 1=>5);
- Asociativní pole
  - $a = array();
  - $a[“Po”] = “Pondělí“;
  - $a = array (“Po”=>”Pondělí“, “Ut”=>”Úterý”, …)

Skriptovací jazyky – PHP – Pole (2)

- Průchod polem
  - for ($i = 0; $i < count($a); $i++)
    echo “a[$i] = {$a[$i]}\n”;
  - foreach ($a as $i => $v) echo “a[$i] = $v\n”;
  - foreach ($a as $v) echo “$v”;

Skriptovací jazyky – PHP - Příklad – generování tabulky

```
<table border="1">
<?
  for($i = 0; $i < 10; $i++) {
     echo "<tr>\n";
     echo "   <td>$i</td>\n";
     echo "   <td>", $i * $i, "</td>\n";
     echo "</tr>\n";
  }
?>
</table>
```


Skriptovací jazyky – PHP - Další řídící konstrukce

- if (*podmínka*) *příkaz*
- if (*podmínka*) *příkaz* else *příkaz*
- while (*podmínka*) *příkaz*;
- do *příkaz* while (*podmínka*);
- break;
- continue;
- switch (*výraz*) *příkaz*
- include “soubor”; require “soubor”;

Skriptovací jazyky – PHP - Příklad

```
<? if ( $pocet > 0 ) { ?>
<p> Počet = <? echo $pocet ?> </p>
<? } ?>

<? Switch ( $den ) {
  case "So": case "Ne":
      $vikend = true;
      break;
  default:
      $vikend = false;
      break;
}?>
```


Skriptovací jazyky – PHP - Function

```
function soucet ( $x, $y = 1 ) {
  return $x +$y;
}
```

- Všechny proměnné jsou lokální, globální proměnné se musí deklarovat:

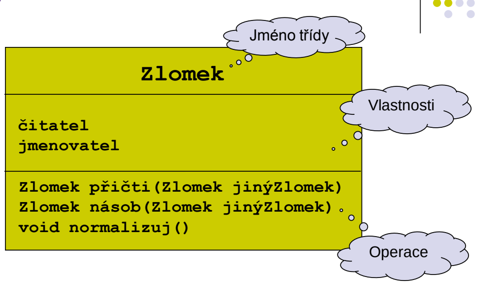
```
global $g;
```


Skriptovací jazyky – PHP - Příklad

```
function table_row ( $row ) {
  echo "<tr>\n";
  foreach ( $row as $v ) {
     echo " <td>$v</td>\n";
  }
  echo "</tr>\n";
}

echo "<table border=`1`>\n";
  table_row(array(1,2,3,4,5));
echo "</table>\n";
```


Skriptovací jazyky – PHP - Třídy



Skriptovací jazyky – PHP - Třídy v jazyce Java

```
class Zlomek {
// instanční proměnné
   int       cit;
   int       jm;
   public Zlomek(int jm, int cit) {
        this.jm=jm;
        this.cit=cit;
   }
// metody
   Zlomek soucin(Zlomek jiny)
   {
        citatel    *= jiny.citatel;
        jmenovatel *= jiny.jmenovatel;
   }
}
```


Skriptovací jazyky – PHP - Třídy a objekty

```
//PHP4

class Zlomek {
   var $cit, &jm;

   function Zlomek($c, $j) {
        $this->cit = $c;
        $this->jm = $j;
   }

   function  soucin($z) {
        $this->cit *= $z->cit;
        $this->jm *= $z->jm;
   }

}
```

```
//PHP5

Class Zlomek {
   public $cit, $jm;

   function __constructor($c,
   $j)
   {
        $this->cit = $c;
        $this->jm = $j;
   }

   …
}
```


Skriptovací jazyky – PHP - Třídy a objekty

- Vytvoření instance třídy

```
$z = new Zlomek(3, 5);
```

- Přístup k atributům a metodám objektu

```
$z->soucin( new Zlomek(2, 3));
echo "$z->cit / $z->jm";
```


Skriptovací jazyky – PHP - Dědičnost

```
class LepsiZlomek extends Zlomek
{
   function LepsiZlomek($c=1, $j=1)
   {
        //konstruktor předka se nevolá automaticky!
        Zlomek::Zlomek($c, $j);
   }
   …
}
```

Skriptovací jazyky – PHP - Novinky v PHP5

- Konstruktory a destruktory
  - `__construct()` `__destruct()`
- Viditelnost atributů a metod
  - `public, protected, private`
- Statické atributy a metody
  - `public static $x = "abcd";`
  - `… Třída::$x`
- Abstraktní třídy a metody, rozhraní
- Reflexe

Skriptovací jazyky – PHP - Reference na objekt (1)

- PHP4
  - operátor = vytváří kopii objektu
  - operátor =& vytváří referenci na objekt
- PHP5
  - operátor = vytváří kopii reference na objekt (jako v Javě)
  - operátor =& pořád vytváří referenci na objekt

Skriptovací jazyky – PHP - Reference na objekt (2)

```
$zlomek1 = new Zlomek(1, 2);
$zlomek2 = $zlomek1;
$zlomek1->soucin(new Zlomek(1, 2));
$echo "$zlomek2->cit/$zlomek2->jm";
//výsledek bude 1/2 v PHP4
//výsledek bude 1/4 v PHP5

//úprava 2. řádku pro stejný výsledek v
  PHP4 i PHP5
$zlomek2 =& $zlomek1
```


Skriptovací jazyky – PHP - Reference na objekt (3)

```
$zlomek1 = new Zlomek(1, 2);
$zlomek2 =& $zlomek1;
$zlomek2 = new Zlomek(1, 3);

//$zlomek1 bude uvolněn!
```

Skriptovací jazyky – PHP - Výjimky (PHP5)

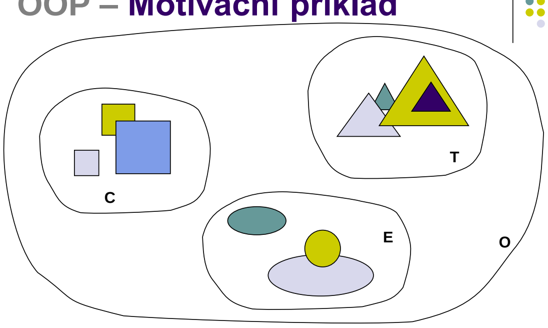
```
try {
  $error = 'Always throw this error';
  throw new Exception($error);

  echo 'Never executed';
} catch (Exception e) {
  echo 'Caught exception: ',
     $e->getMessage(), "\n";
}
```


Skriptovací jazyky – PHP - Parametry z požadavků

- /app/predmet.php?kod=456-513/1&arg=1
  - $_REQUEST["kod"] = '456-513/1'
  - $_REQUEST["arg"] = '1'
  - Odstranit
- Speciální proměnné
  - $_REQUEST, $_GET, $_POST, $_FILES
  - $_COOKIE
  - $_SESSION
  - $_SERVER, $_ENV

OOP – Motivační příklad



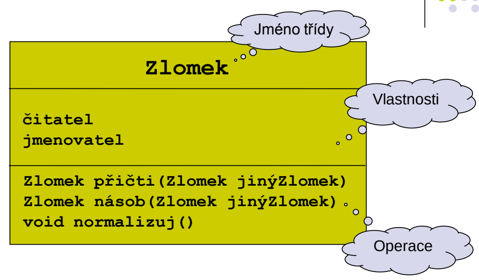
OOP – Motivační příklad (2)

- **Vlastnosti (stav)**
  - souřadnice středu x, y
  - barva
  - obsah, obvod
- **Operace (chování)**
  - přesunutí na jinou pozici
  - n-násobné zvětšení a zmenšení
  - vykreslení na obrazovku
- **Vztahy**
  - sousedí, překrývají se, ...

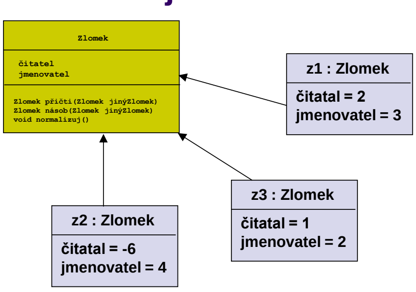
OOP – Motivační příklad (3)

- **Druh obrazce**
  - čtverec, trojúhelník, elipsa
- **Specifické vlastnosti**
  - délka strany čtverce
  - velikosti poloos elipsy
- **Hodnoty vlastností**
  - konkrétní souřadnice, barva, ...
- **Způsob provedení operací**
  - vykreslení na obrazovku

OOP – Grafická reprezentace třídy



OOP – Objekt = instance třídy



OOP – Třídy v jazyce Java

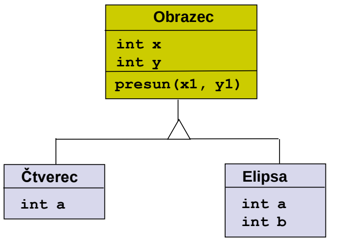
```
class Zlomek {
// instanční proměnné
  int     citatel;
  int     jmenovatel;

// metody
  Zlomek nasob(Zlomek jiny)
  {
     citatel    *= jiny.citatel;
     jmenovatel *= jiny.jmenovatel;
  }
}
```

OOP – Vytvoření instance třídy

```
public static void main(String[] args)
{
                    reference
  Zlomek z = new Zlomek;
  // nastavení instančních proměnných
  z.citatel = 2;
  z.jmenovatel = 3;
  // volání metody
  z.nasob(z);                 // z *= z
}
```


OOP – Dědičnost



OOP – Dědičnost

```
class Obrazec {
  int x, y;
  void presun(int x, int y) {
     this.x = x; this.y = y;
  }
}

class Ctverec extends Obrazec {
  int a;
}
```


OOP – Další vlastnosti OOP

- Zapouzdření prvků třídy
  - Soukromé proměnné/metody – private
  - Chráněné proměnné/metody – protected
  - Veřejné proměnné/metody – public
- Polymorfismus

OOP – Smalltalk - **Introduction do jazyka Smalltalk**

- Existují i jiné objektově orientované jazyky než Java…
- "When I invented the term 'object-oriented' I did not have C++ in mind." -- Alan Kay
- Jedním z „jiných“ objektově orientovaných jazyků je jazyk Smalltalk
  - Ve skutečnosti neexistuje jazyk Smalltalk. Existuje celá řada „variant“ jazyků obsahujících Smalltalk v jejich názvu.
  - Obvykle je pod pojemem Smalltalk rozuměn jazyk Smalltalk-80.

OOP – Smalltalk - **History jazyka Smalltalk (1)**

- 1968: SIMULA – první „objektově orientovaný“ jazyk
- 1973: Xerox Alto computer
  - Používal Smalltalk (implementovaný v jazyce BASIC)
  - implementoval „želví“ grafiku (LOGO)
  - Třídy (žádná hierarchie),instance, `self`
- 1974:
  - Zlepšení výkonnosti
  - První meta-objekty
- 1976
  - Vše je objekt
  - Hierarchie tříd, `super`
  - Implementováno procházení a ladění zdrojových kódů (code browser, inspector, debugger)

OOP – Smalltalk - **History jazyka Smalltalk (2)**

- Smalltalk-80 :
  - Jazykový standard
  - Masivně používá MVC
  - Celá řada variant. Volně dostupné jsou:
    - Squeak (open source) - http://www.squeak.org/
    - Smalltalk/X – volně dostupný pro nekomerční použití: http://www.exept.de/
    - Cincom Smalltalk: volně dostupný pro nekomerční použití: http://www.parcplace.com/
    - Strongtalk (typovaný Smalltalk) http://www.cs.ucsb.edu/projects/strongtalk/pages/index.html
- Celá řada jazyků vychází s jazyka Smalltalk
  - S# - určený pro tvorbu skiptů
  - Python, Ruby - jazyky postavené na stejných ideách jako Smalltalk, syntaxe jazyka se více blíží Javě a C.

OOP – Smalltalk - **Základní koncepty jazyka Smalltalk (1)**

- Smalltalk je *čistě* objektově orientovaný jazyk.
  - Koncepce tříd a objektů
  - Základní myšlenkou je, že vše je objekt a objekty spolu komunikují prostřednictvím zpráv
  - Výjimkou jsou proměnné (jejich obsah proměnnou je).
  - Nejsou v něm „hodnotové“ datové typy.
- Objekty mohou v jazyce Smalltalk provádět právě tři činnosti
  - Udržovat stav (reference na další objekty)
  - Přijímat zprávy od sebe a nebo od jiných objektů
  - V rámci reakce na zprávu posílat zprávy jiným objektům.
- Objekty mohou o jiných objektech zjišťovat informace (nebo měnit stav jiných objektů) posíláním zpráv.

OOP – Smalltalk - **Základní koncepty jazyka Smalltalk (2)**

- Vše v jazyce Smalltalk je objekt.
- Každý objekt je instancí nějaké třídy. Třídy jsou také objekty.
- Každá třída je instancí nějaké *metatřídy*.
- Metatřídy jsou všechny instancí třídy `Metaclass`.
- Blok zdrojového kódu je taky objekt
  - Například tělo metody – zprávy
- Výhody tohoto přístupu jsou například:
  - Dynamický typový systém
  - Striktní hierarchie tříd
  - Silný mechanismus reflexe

OOP – Smalltalk - **Mechanismus reflexe (1)**

- Smaltalk-80 plně implementuje mechanismus reflexe.
- Strukturální reflexe – *Třídy a metody, které definují systém jsou také objekty a jsou součástí systému, který pomáhají definovat.*
  - Systém se chová „živý“. Nové třídy jsou zkompilovány a přidány do systému (třída *CompiledMethod*).
  - Můžeme se ptát na „otázky“ jako:
    - Jaké metody implementuje třída XY?
    - Jaké třídy jsou definované v systému?

OOP – Smalltalk - **Mechanismus reflexe (2)**

- Výpočetní reflexe – schopnost pozorovat aktuální stav systému, průběh výpočtu programu.
  - Můžeme získat odpovědi na otázky jako: Kdo poslal objektu X zprávu Y?

OOP – Smalltalk - **Prostředí jazyka Smalltalk (1)**

- Liší se dle specifické implementace konkrétní varianty jazyka Smalltalk
- Obvykle realizuje „image-based persistence“
  - Prostředí pro jazyky jako Java oddělují zdrojový kód od stavu programu.
    - Zdrojový kód je nahrán při startu aplikace.
    - Po ukončení jsou ztraceny všechny data kromě těch, které byly explicitně uloženy.
  - V jazyce Smalltalk je vše objektem, tedy například i třídy, a vše je uloženo jako jeden „image“.
  - Ten může být snadno „obnoven“.

OOP – Smalltalk - **Prostředí jazyka Smalltalk (2)**

- Pro spuštění aplikace je obvykle použit virtuální stroj.
  - Obvykle využívá JIT
  - Instalace aplikace je pak dodání „image“ spolu se spustitelnou (binární) verzí virtuálního stroje.
- Vývojové prostředí je obvykle součástí prostředí. Není využíván žádný „externi“ nástroj.
- Výhody
  - Velmi dobré prostředky pro ladění aplikace.
  - Možnost měnit chod aplikace za jejího běhu.
    - Můžeme měnit hierarchii tříd
    - Můžeme měnit vlastní IDE
    - Můžeme měnit činnost garbage collectoru
    - `true become: false` ☺

OOP – Smalltalk – **Syntaxe jazyka**

- Čistě objektové jazyky jsou ze své podstaty velmi jednoduché.
- Jazyk Smalltalk má velmi jednoduchou syntaxi.
  - Obsahuje pět klíčových slov:
    - **true**, **false**, **nil**, **self** a **super**
  - Podporuje tvorbu a zasílání zpráv.
  - Obsahuje tři operátory := (přiřazení), = (rovnost), == (identita)
  - Umožňuje realizaci několika typů „literálů“.
  - Poznámky jsou v úvozovkách…

OOP – Smalltalk – **Definice literálů (1)**

- Čísla
  - 42
  - -42
  - 123.45
  - 1.2345e2
  - 2r10010010
  - 16rA000
- Znaky
  - Začínají znakem $ - $A
- Řetezce
  - Jsou v jednoduchých úvozovkách - 'Hello, world!'

OOP – Smalltalk – **Definice literálů (2)**

- Symboly
  - Dva stejné řetězce mohou být uloženy na dvou místech v paměti – může jít o různé objekty
  - Smalltalk obsahuje jiný „typ“ řetezce. Symbol je sekvence znaků a je garantováno, že bude unikátní, právě jedna v systému.
  - Symbol je definován za znakem # - #foo
- Pole
  - # (1 2 3 4)

OOP – Smalltalk – **Proměnné**

- Implementace proměnných se liší podle konkrétní verze jazyka.
- Obvyklé dělení je na instanční proměnné a dočasné proměnné.
  - Dočasné proměnné jsou v rámci bloku kódu – deklarují se v bloku ohraničeném | |
  - Instanční proměnné (Squeak)
    - Třídní proměnné
    - Globální proměnné
    - Pool variables (Sdílené?)

OOP – Smalltalk – **Zprávy (1)**

- Smalltalk „nemá“ žádna klíčová slova

Java / C++ verze:

```
Transformation t;
float a;
Vector v;
t->rotate(a,v); // for C++
t.rotate(a,v); // for Java
```

Smalltalk:

```
| t a v |
“lepší!“
| aTransformation angle aVector |
```

```
t rotateBy: a around: v
```

Jde o SmallTalk!

OOP – Smalltalk – **Zprávy (2)**

- Definice „těla“ metody `rotateBy`

```
rotateBy: angle around: aVector
| result |
result := do some computations.
^result
```

```
makeWindow
| window |
window := Window new.
window label: 'Hello'.
window open.
```

- Alternativy:
  - `rotateAround: aVector by: angle`
  - `rotate: angle and: aVector` („špatně“)
  - „klíčová“ slova udávají pořadí parametrů

OOP – Smalltalk – **Zprávy (3)**

- Obecná struktura zprávy

```
keyword1: param1 keyword2: param2 ...
| local variables |
expressions
```

- Jednotlivé výrazy končí tečkou (kromě poslední).
- Hodnota může být ihned vrácena použitím:
  - operátoru ^ - ^value
- Která zpráva bude vybrána je rozhodnuto na základě selektoru: **keyword1:keyword2:... – keyword messages**

OOP – Smalltalk – Zprávy (4)

- Sémantika posílání zpráv
  - Zprávy jsou posílány objektům
  - První element ve výraze je vždy objekt
  - Výsledek činnosti je také objekt
  - Pořadí vyhodnocování je zleva do prava
  - Pořadí vyhodnocování může být změněno použitím závorek.
  - Smalltalk nemá implicitní volání na sebe sama.

Java:
myMethod();
this.myMethod();

Smalltalk:
self myMethod

OOP – Smalltalk – Výrazy (1)

- Aritmetické výrazy
  - Smalltalk neobsahuje unární operátory
  - Speciální binární operátry jako +, -,…

  - Výsledkem výrazu `4 sqrt` bude 2.0
  - Výsledkem výrazu `1 + 2 * 3` bude 9 (zprávy jsou vyhodnocovány zleva do prava)
  - Výsledkem výrazu `1 + (2 * 3)` bude in 7

OOP – Smalltalk – Výrazy (2)

- Priorita vyhodnocení zasílaných zpráv ve výraze je následující:
  - Nejvyšší prioritu mají unární zprávy
  - Následují binární operátory
  - Potom *keywords messages*
  - Pořadí vyhodnocování je zleva do prava
- Výraz:
  `3 factorial + 4 factorial between: 10 and: 100`
- Bude vyhodnocen:
  3 receives the message "factorial" and answers 6
  4 receives the message "factorial" and answers 24
  6 receives the message "+" with 24 as the argument and answers 30
  30 receives the message "between:and:" with 10 and 100 as arguments and answers true

OOP – Smalltalk – Výrazy (3)

- Sekvence zpráv určená jednomu objektu může být zapsána jako „kaskáda“ (cascade)
- Místo:

```
| p |
p := Client new.
p name: 'Jack'.
p age: 32.
p address: 'Earth,
```

- Můžeme použít:

```
| p |
p := Client new name: 'Jack'; age: '32';
  address: 'Earth'
```

OOP – Smalltalk – Bloky

- Blok kódu (anonymní Function) může také býr chápán jako literál.
- Syntaxe: `[ :params | <message-expressions> ]`
- Příklad bloku: `[:x | x + 1]`
- Můžeme chápat jako:
  - f(x) = x + 1
  - λx.(x+1)
- Blok je také objekt.
  - Můžeme ho „nechat“ vypočítat svou hodnotu voláním zprávy `:value`.
  - Může být přadán jako parametr:

```
positiveAmounts := allAmounts select: [:amt | amt
  isPositive]
```

- Bloky se používají pro realizaci řady uživatelsky definovaných řídících struktur.

OOP – Smalltalk – Řídicí struktury (1)

- Řídicí struktury nemají speciální syntaxi v jazyce Smalltalk.
- *Jsou realizovány prostřednictvím zpráv!*

- Například „podmínka“ je realizována voláním zprávy `isTrue` na objekt typu `Boolean.` Argument (blok kódu) se provede jen tehdy, pokud je jeho hodnota `true`.

```
result := a > b
         ifTrue:[ 'greater' ]
         ifFalse:[ 'less' ]
```


OOP – Smalltalk – Řídicí struktury (2)

- Cykly typu „`while`“

```
| a |
a := 100 atRandom.
[ a = 42 ] whileFalse: [ a := 100 atRandom ]
```

- Cyklus typu „`for`“

```
100 timesRepeat: [ Transcript show: 'Hello
  world.'; cr ]
1 to: 100 do: [ :i | Transcript show: i; cr ]
1 to: 100 by: 10 do: [ :i | Transcript show:
  i; cr ]
100 to: 1 by: -1 do: [ ... ] 0.5 to: 7.3 by:
  1.1 do: [ ... ]
```


OOP – Smalltalk – Definice tříd

- Obecné schéma:

```
Object subclass: #MessagePublisher
    instanceVariableNames: ''
    classVariableNames: ''
    poolDictionaries: ''
    category: 'Smalltalk Examples'
```

- Obecná nadtřída je třída `Object`
- Vytvoření nové třídy je vlastně posílání zprávy `subclass`
- Vytvoření nového objektu posíláním zprávy `new`

- Na závěr Hello world program (omlouvám se, že nebyl někde na začátku☺):

```
Transcript show: 'Hello, world!'.
```

OOP – Self – Jazyky založené na prototypech (1)

- Dalším „stupněm“ vývoje objektově orientovaných jazyků jsou jazyky založené na prototypech.
- Jako příklad těchto jazyků může být Self, Io nebo JavaScript.
- Tradiční objektově orientované jazyky obsahují:
  - Třídy – zobecňují vlastnosti a chování množiny objektů
  - Objekty – konkrétní skutečné případy, které třídy zobecňují
- Vývoj jazyků založených na prototypech byl motivován:
  - Je těžké definovat hierarchii tříd, pokud neznáme přesné vlastnosti všech objektů (někdy i pokud je známe).
  - Můžeme použít refaktorizaci, ale v principu by se nám hodil nějaký lepší mechanismus, jak měnit strukturu tříd.
  - Jazyky založené na prototypech tento problém eliminují eliminací duality mezi instancemi objektů a třídami.

OOP – Self – Jazyky založené na prototypech (2)

- V jazycích založených na prototypech nejsou objekty instancemi tříd
- Nové objekty vznikají klonováním objektů stávajících
  - Prototypy – objekty, které slouží zejména jako vzor pro klonování nových objektů.
  - Pokud chceme vytvořit unikátní typ objektu s právě jednou instancí, nemusíme vytvořit dvě entity – třídu a objekt.
- Tato technika přináší výrazné zjednodušení

OOP – Self – Popis jazyka Self

- Jazyk Self vychází z jazyka Smalltalk
- Základní vlastnosti:
  - Self obsahuje pouze objekty.
  - Objekty v jazyce self jsou kolekcí „slotů“.
    - Self nerozlišuje instanční proměnné a metody.
  - Do každého slotu můžeme umístit nějaký objekt a tento objekt jsem schopni pak také získat.
    `myPerson name` – vrací hodnotu uloženou v objektu `myPerson` ve slotu pojmenovaném `name`.
    `myPerson name:'Marek'` – vloží do slotu novou hodnotu.
  - Self používá bloky kódu (jako Smalltalk).
  - Metody jsou objekty, které kromě slotů obsahují navíc i kód.
    - Ve slotech metody jsou uloženy parametry a dočasné proměnné.
  - Posílání zpráv je základem syntaxe jazyka Self. V principu je řada zpráv posílána implicitně na `self` (jako v Javě `this`).

OOP – Self – Popis syntaxe

- Obdobně jako ve Smalltalku existují tři typy zpráv:
  - unary - *receiver* slot_name
  - binary - *receiver* + *argument*
  - Keyword - *receiver* keyword: *arg1* With: *arg2*
    - Klíčové slovo (selektor) začíná malým pismenem, argumenty velkým!
- Příklad použití:
  - `valid: base bottom between: ligature bottom + height And: base top / scale factor.`
  - `valid: ((base bottom) between: ((ligature bottom) + height) And: ((base top) / (scale factor))).`
- Příklad Hello world programu:

```
'Hello, World!' print.
```

OOP – Self – **Vytváření nových objektů (1)**

- Nové objekty v jazyce Self vznikají kopírováním
  `labelWidget copy label: 'Hello, World!'.`
  - Objekt je samostatná entita. Neexistují žádné třídy či meta-třídy.
  - Vytvořený objekt udržuje vazbu na „rodičovský" objekt.
  - Jeden slot (parent) obsahuje odkaz na rodičovský objekt a může být použit k delegování zpráv na tento objekt.
    - Tímto způsobem je „realizována dědičnost".
    - Stejný princip lze využít k realizaci jmenných prostorů.
  - Pokud potřebujeme změnit chování objektu, můžeme přidávat či jinak modifikovat sloty.

OOP – Self – **Prostředí**

- Prostředí pro realizaci a spuštění programu v jazyce Self je podobné jazyku Smalltalk
  - Programy nejsou „samostatné" entity.
  - Je použit virtuální stroj.
  - Program je přenášen jako obraz paměti (snapshot).
  - Umožňuje jednoduše modifikovat program za běhu.
  - Snadné ladění aplikace.