IA010: Principles of Programming Languages

Introduction

Achim Blumensath

blumens@fi.muni.cz

Faculty of Informatics, Masaryk University, Brno

Warm-up: A Quiz

What does this program do?

```
++++++++++[>+++++++>++++++++++>+++>+<<<<-]>++.>+.+++++++
..+++.>++.<<+++++++++++++++.>.+++.------.--------.>+.>.
```

Warm-up: A Quiz

What does this program do?

```
++++++++++[>+++++++>++++++++++>+++>+<<<<-]>++.>+.+++++++
..+++.>++.<<+++++++++++++++.>.+++.------.--------.>+.>.
```

Prints “Hello World!”

Warm-up: A Quiz

What does this program do?

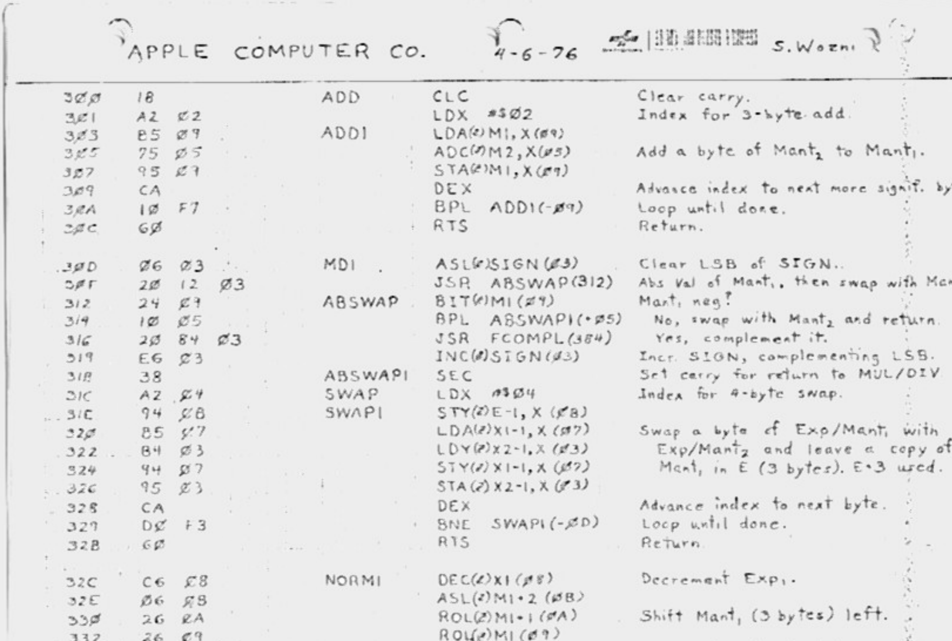
```
++++++++++[>+++++++>++++++++++>+++>+<<<<-]>++.>+.+++++++
..+++.>++.<<+++++++++++++++.>.+++.------.--------.>+.>.
```

Prints “Hello World!”

Brainfuck (1993)

- Turing-complete programming language
- tape containing numbers (inc/dec), a data pointer (l/r), input/output, conditional jump
- compiler of size 100 bytes known to exist

Before high-level programming languages …



APPLE COMPUTER CO. 4-6-76 S.Wozni

```
3ØØ   18          ADD       CLC                 Clear carry.
3Ø1   A2 Ø2                 LDX  #$Ø2           Index for 3-byte add.
3Ø3   B5 Ø9       ADD1      LDA(Ø)M1,X(Ø9)
3Ø5   75 Ø5                 ADC(Ø)M2,X(Ø5)      Add a byte of Mant2 to Mant1.
3Ø7   95 Ø9                 STA(Ø)M1,X(Ø9)
3Ø9   CA                    DEX                 Advance index to next more signif. by
3ØA   1Ø F7                 BPL  ADD1(-Ø9)      Loop until done.
3ØC   6Ø                    RTS                 Return.

3ØD   Ø6 Ø3       MD1       ASL(Ø)SIGN(Ø3)      Clear LSB of SIGN.
3ØF   2Ø 12 Ø3              JSR  ABSWAP(312)    Abs Val of Mant1, then swap with Ma
312   24 Ø9       ABSWAP    BIT(Ø)M1(Ø9)        Mant1 neg?
314   1Ø Ø5                 BPL  ABSWAP1(+Ø5)     No, swap with Mant2 and return.
316   2Ø 84 Ø3              JSR  FCOMPL(384)      Yes, complement it.
319   E6 Ø3                 INC(Ø)SIGN(Ø3)      Incr. SIGN, complementing LSB.
31B   38          ABSWAP1   SEC                 Set carry for return to MUL/DIV
31C   A2 Ø4       SWAP      LDX  #$Ø4           Index for 4-byte swap.
31E   94 Ø8       SWAP1     STY(Ø)E-1,X (Ø8)
32Ø   B5 Ø7                 LDA(Ø)X1-1,X (Ø7)   Swap a byte of Exp/Mant1 with
322   B4 Ø3                 LDY(Ø)X2-1,X (Ø3)     Exp/Mant2 and leave a copy of
324   94 Ø7                 STY(Ø)X1-1,X (Ø7)     Mant1 in E (3 bytes). E+3 used.
326   95 Ø3                 STA(Ø)X2-1,X (Ø3)
328   CA                    DEX                 Advance index to next byte.
329   DØ F3                 BNE  SWAP1(-ØD)     Loop until done.
32B   6Ø                    RTS                 Return.

32C   C6 Ø8       NORM1     DEC(Ø)X1(Ø8)        Decrement Exp1.
32E   Ø6 ØB                 ASL(Ø)M1+2 (ØB)
33Ø   26 ØA                 ROL(Ø)M1+1 (ØA)     Shift Mant1 (3 bytes) left.
332   26 Ø9                 ROL(Ø)M1 (Ø9)
```

Now …

C
C++
Java
C#
Ada

Python
PHP
JavaScript
VisualBasic
Perl

Haskell
OCaml
F#
Scheme
…

Scala
Rust
Go
Swift

Now …

C
C++
Java
C#
Ada

Python
PHP
JavaScript
VisualBasic
Perl

Haskell
OCaml
F#
Scheme
…

Scala
Rust
Go
Swift

A zoo of programming languages

Now …

C
C++
Java
C#
Ada
Python
PHP
JavaScript
VisualBasic
Perl
Haskell
OCaml
F#
Scheme
…
Scala
Rust
Go
Swift

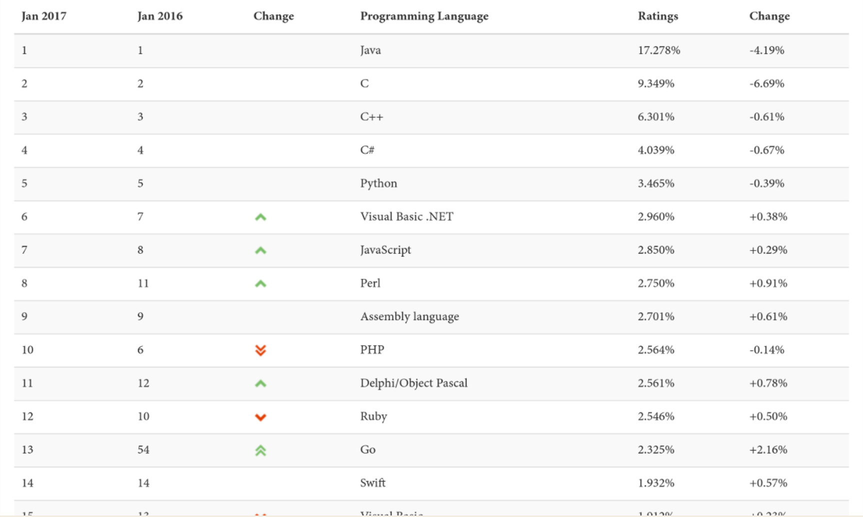
A zoo of programming languages

Can we somehow categorise them?

How do we choose one?

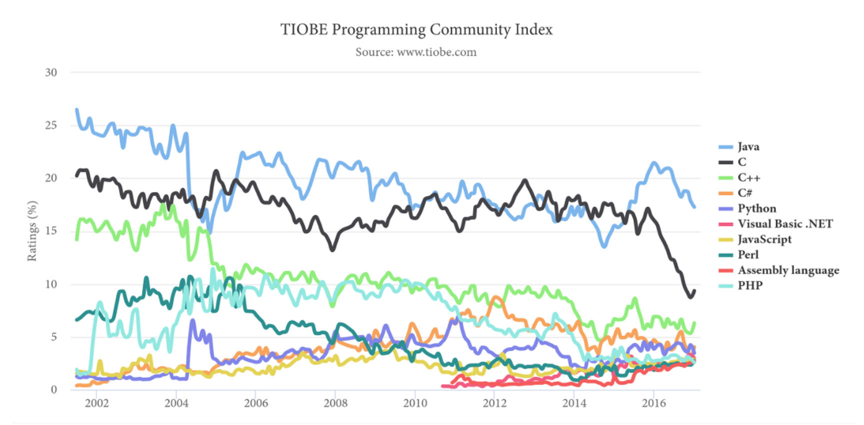
Language popularity

TIOBE index, January 2017, www.tiobe.com



Jan 2017	Jan 2016	Change	Programming Language	Ratings	Change
1	1		Java	17.278%	-4.19%
2	2		C	9.349%	-6.69%
3	3		C++	6.301%	-0.61%
4	4		C#	4.039%	-0.67%
5	5		Python	3.465%	-0.39%
6	7	▲	Visual Basic .NET	2.960%	+0.38%
7	8	▲	JavaScript	2.850%	+0.29%
8	11	▲	Perl	2.750%	+0.91%
9	9		Assembly language	2.701%	+0.61%
10	6	▼▼	PHP	2.564%	-0.14%
11	12	▲	Delphi/Object Pascal	2.561%	+0.78%
12	10	▼	Ruby	2.546%	+0.50%
13	54	▲▲	Go	2.325%	+2.16%
14	14		Swift	1.932%	+0.57%
15	13	▼▼	Visual Basic	1.912%	+0.23%

Language popularity



Desirable language features

Desirable language features

- simplicity
- orthogonality
- clear (and defined) semantics
- ease of use
- easy to learn
- clean and readable syntax
- expressive power
- support for many paradigms and coding styles
- strong safety guarantees
- produces fast code
- compilation speed
- reduced memory usage
- good library and tool chain support
- standardisation and documentation
- interoperability with other languages
- hardware and system independence
- support for hardware and system programming
- usability by non-programmers
- …

Kinds of software

Kinds of software

- business applications
- office software, graphics software
- server software
- video games
- number crunching
- phone apps
- control software for embedded devices
- scripts, utilities

Programming paradigms

Programming paradigms

- **procedural:** program is structured as a collection of procedures/functions
- **imperative:** list of commands
- **functional:** expressions that compute a value
- **declarative:** describe what you want to compute, not how
- **object-oriented:** objects communicating via messages
- **data-oriented:** layout of your data in memory
- **reactive:** network of components that react to events

Which language/paradigm/coding style is the best?

Which language/paradigm/coding style is the best?

Choose the right tools for the job!

Which language/paradigm/coding style is the best?

Choose the right tools for the job!

⇒ the more tools available, the better

Which language/paradigm/coding style is the best?

Choose the right tools for the job!

⇒ the more tools available, the better

⇒ need to be familiar with many styles and paradigms

Which language/paradigm/coding style is the best?

Choose the right tools for the job!

⇒ the more tools available, the better

⇒ need to be familiar with many styles and paradigms

Multi-paradigm languages

The more paradigms your language support, the more tools you have in your toolbox.

State of the art

- functional programming, dependent types: Idris
- linear types, borrow checker: Rust
- imperative programming, error handling: Zig
- imperative programming, design by contract: Dafny, Whiley
- module system: SML, Ocaml
- declarative programming: Mercury
- object-oriented programming: Scala
- concurrency: Go, Pony

(list somewhat biased and certainly incomplete)

Why study programming languages and paradigms?

The study of **language features** and **programming styles** helps you to

- choose a language **most appropriate** for a given task
- think about problems in **new ways**
- learn new ways to **express** your ideas and **structure** your code (⇒ more tools in your toolbox)
- read **other peoples code**
- **learn** new languages faster (you only need to learn a new syntax)
- understand the design/implementation decisions and limitations of a given language, so you can **use it better:**
  - You can choose between **alternative ways** of expressing things.
  - You understand more **obscure features**.
  - You can **simulate features** not available in this particular language.

Aspects of programming languages

Syntax: the **structure** of programs.

Describes how the various constructs (statements, expressions, …) can be combined into well-formed programs.

Semantics: the **meaning** of programs.

Tells us what behaviour we can expect from a program.

Pragmatics: the **use** of programming languages.

In which way is the language intended to be used in practice?
What are the various language constructions good for?

Aspects of programming languages

Syntax: the **structure** of programs.

Describes how the various constructs (statements, expressions, …) can be combined into well-formed programs.

PA008 Compiler Construction, PA037 Compiler Project,

IB005/IA006 Formal Languages

Semantics: the **meaning** of programs.

Tells us what behaviour we can expect from a program.

IA011 Programming Language Semantics, IA014 Advanced Functional Programming

Pragmatics: the **use** of programming languages.

In which way is the language intended to be used in practice?
What are the various language constructions good for?

this course

Course organisation

Lectures

- **Monday, 12:00, A318**
- language: English
- slides, lecture notes, and source code can be found in IS
- video recordings will also be made available there

Examination

- final written exam, in English
- **k** and **z** completion possible

Prerequisites

- no **formal** requirements
- knowledge of at least one programming language
- some basic knowledge of Haskell helpful
- the more languages you know the better

Study materials

Books (only somewhat relevant)

- P. V. Roy, S. Haridi, **Concepts, Techniques, and Models of Computer Programming,** 1st ed., MIT Press, 2004.
- R. W. Sebesta, **Concepts of Programming Languages,** 10th ed., Addison-Wesley, 2012.
- **Programming language pragmatics,** (Ed. M. L. Scott) 3rd ed. Oxford, Elsevier Science, 2009.

Additional resources

- Crafting Interpreters, `www.craftinginterpreters.com`

Topics covered

- a brief history of programming languages
- expressions and functions
- types, type checking, type inference
- state and side-effects
- modules
- control-flow
- declarative programming
- object-oriented programming
- concurrency