# Programming Languages: Concepts

(Lectures on High-performance Computing for Economists IV)

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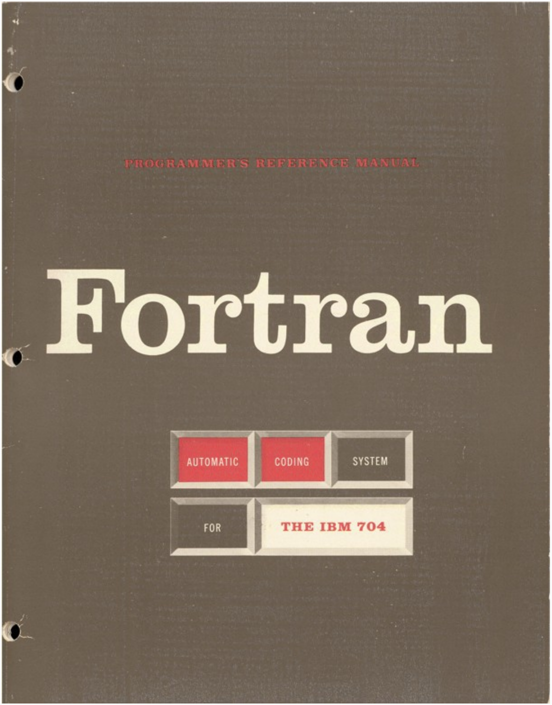
# Introduction

# Motivation

- Since the invention of `Fortran` in 1954-1957 to substitute assembly language, hundreds of programming languages have appeared.
- Some more successful than others, some more useful than others.
- Moreover, languages evolve over time (different version of `Fortran`).
- Different languages are oriented toward certain goals and have different approaches.



PROGRAMMER'S REFERENCE MANUAL

Fortran

AUTOMATIC CODING SYSTEM

FOR THE IBM 704

# Some references

- *Programming Language Pragmatics (4th Edition)*, by Michael L. Scott.
- *Essentials of Programming Languages (3rd Edition)*, by Daniel P. Friedman and Mitchell Wand.
- *Concepts of Programming Languages (11th Edition)*, by Robert W. Sebesta.
- `http://hyperpolyglot.org/`

# The basic questions

- Which programming language to learn?
- Which programming language to use in *this* project?
- Do I need to learn a *new* language?

# Which programming language? I

- Likely to be a large investment.

- Also, you will probably want to be familiar at least with a couple of them (good mental flexibility) plus LaTeX.

**Alan Perlis**

A language that doesn't affect the way you think about programming is not worth knowing.

- There is a good chance you will need to recycle yourself over your career.

# Which programming language? II

- Typical problems in economics can be:

    1. CPU-intensive.
    2. Memory-intensive.

- Imply different emphasis.

- Because of time constraints, we will not discuss memory-intensive tools such as `Hadoop` and `Spark`.

# Classification

# Classification

- There is no "best" solution.
- But there are some good tips.
- We can classify programming languages according to different criteria.
- We will pick several criteria that are relevant for economists:

    1. Level.
    2. Domain.
    3. Execution.
    4. Type.
    5. Paradigm

# Level

- Levels:

  1. `machine code`.
  2. Low level: `assembly language` like `NASM` (`http://www.nasm.us/`), `GAS`, or `HLA` (*The Art of Assembly Language (2nd Edition)*, by Randall Hyde).
  3. High level: like `C/C++`, `Julia`, ...

- You can actually mix different levels (`C`).

- Portability.

- You are unlikely to see low level programming unless you get into the absolute frontier of performance (for instance, with extremely aggressive parallelization).

# Fibonacci number

Machine code:

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

Assembler:

```
ib:  mov edx, [esp+8]  cmp edx, 0  ja @f  mov eax, 0  ret  @@:
cmp edx, 2  ja @f  mov eax, 1  ret  @@:  push ebx  mov ebx, 1
mov ecx, 1  @@:  lea eax, [ebx+ecx]  cmp edx, 3  jbe @f  mov ebx,
ecx  mov ecx, eax dec edx  jmp @b  @@:  pop ebx  ret
```

C++:

```
int fibonacci(const int x) {
       if (x==0) return(0);
       if (x==1) return(1);
       return (fibonacci(x-1))+fibonacci(x-2);}
```

# Domain

- Domain:
  1. General-purpose programming languages (GPL), such as `Fortran`, `C/C++`, `Python`, ...
  2. Domain specific language (DSL) such as `Julia`, `R`, `Matlab`, `Mathematica`, ...
- Advantages/disadvantages:
  1. GPL are more powerful, usually faster to run.
  2. DSL are easier to learn, faster to code, built-in functions and procedures.

# Execution I

- Three basic modes to run code:

    1. Interpreted: `Python`, `R`, `Matlab`, `Mathematica`.
    2. Compiled: `Fortran`, `C/C++`.
    3. JIT (Just-in-Time) compilation: `Julia`.

- Interpreted languages can we used with:

    1. A command line in a `REPL` (Read–eval–print loop).
    2. A script file.

- Many DSL are interpreted, but this is neither necessary nor sufficient.
- Advantages/disadvantages: similar to GPL versus DSL.
- Interpreted and JIT programs are easier to move across platforms.

# Execution II

- In reality, things are somewhat messier.

- Some languages are explicitly designed with an interpreter and a compiler (`Haksell`, `Scala`, `F#`).

- Compiled programs can be extended with third-party interpreters (`CINT` and `Cling` for C/C++).

- Often, interpreted programs can be compiled with an auxiliary tool (`Matlab`, `Mathematica`,...).

- Interpreted programs can also be compiled into byte code (`R`, languages that run on the `JVM` -by design or by a third party compiler).

- We can mix interpretation/compilation with libraries.

# Types I

- Type strength:
  1. Strong: type enforced.
  2. Weak: type is tried to be adapted.
- Type expression:
  1. Manifest: explicit type.
  2. Inferred: implicit.
- Type checking:
  1. Static: type checking is performed during compile-time.
  2. Dynamic: type checking is performed during run-time.
- Type safety:
  1. Safe: error message.
  2. Unsafe: no error.

# Types II

- Advantages of strong/manifest/static/safe type:
  1. Easier to find programming mistakes⇒`ADA`, for critical real-time applications, is strongly typed.
  2. Easier to read.
  3. Easier to optimize for compilers.
  4. Faster runtime not all values need to carry a dynamic type.
- Disadvantages:
  1. Harder to code.
  2. Harder to learn.
  3. Harder to prototype.

# Types III

- You implement strong/manifest/static/safe typing in dynamically typed languages.

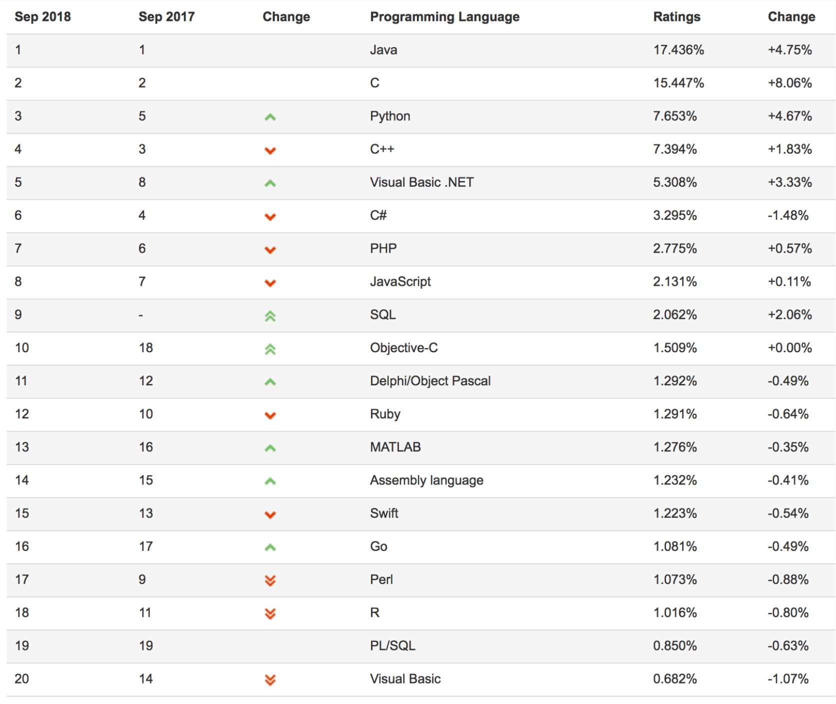
- You can define variables explicitly. For example, in Julia:

```
a::Int = 10
```

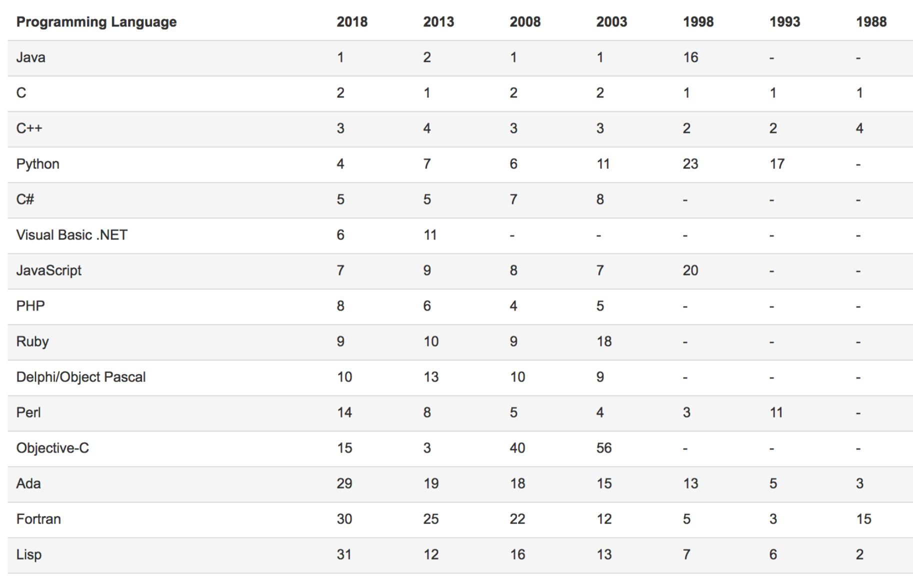
- It often improve performance speed and safety.

- You can introduce checks:

```
a = "This is a string"
if typeof(a) == String
    println(a)
else
    println("Error")
end
```



| Sep 2018 | Sep 2017 | Change | Programming Language | Ratings | Change |
|---|---|---|---|---|---|
| 1 | 1 | | Java | 17.436% | +4.75% |
| 2 | 2 | | C | 15.447% | +8.06% |
| 3 | 5 | ↑ | Python | 7.653% | +4.67% |
| 4 | 3 | ↓ | C++ | 7.394% | +1.83% |
| 5 | 8 | ↑ | Visual Basic .NET | 5.308% | +3.33% |
| 6 | 4 | ↓ | C# | 3.295% | -1.48% |
| 7 | 6 | ↓ | PHP | 2.775% | +0.57% |
| 8 | 7 | ↓ | JavaScript | 2.131% | +0.11% |
| 9 | - | ⇈ | SQL | 2.062% | +2.06% |
| 10 | 18 | ⇈ | Objective-C | 1.509% | +0.00% |
| 11 | 12 | ↑ | Delphi/Object Pascal | 1.292% | -0.49% |
| 12 | 10 | ↓ | Ruby | 1.291% | -0.64% |
| 13 | 16 | ↑ | MATLAB | 1.276% | -0.35% |
| 14 | 15 | ↑ | Assembly language | 1.232% | -0.41% |
| 15 | 13 | ↓ | Swift | 1.223% | -0.54% |
| 16 | 17 | ↑ | Go | 1.081% | -0.49% |
| 17 | 9 | ⇊ | Perl | 1.073% | -0.88% |
| 18 | 11 | ⇊ | R | 1.016% | -0.80% |
| 19 | 19 | | PL/SQL | 0.850% | -0.63% |
| 20 | 14 | ⇊ | Visual Basic | 0.682% | -1.07% |



| Programming Language | 2018 | 2013 | 2008 | 2003 | 1998 | 1993 | 1988 |
|---|---|---|---|---|---|---|---|
| Java | 1 | 2 | 1 | 1 | 16 | - | - |
| C | 2 | 1 | 2 | 2 | 1 | 1 | 1 |
| C++ | 3 | 4 | 3 | 3 | 2 | 2 | 4 |
| Python | 4 | 7 | 6 | 11 | 23 | 17 | - |
| C# | 5 | 5 | 7 | 8 | - | - | - |
| Visual Basic .NET | 6 | 11 | - | - | - | - | - |
| JavaScript | 7 | 9 | 8 | 7 | 20 | - | - |
| PHP | 8 | 6 | 4 | 5 | - | - | - |
| Ruby | 9 | 10 | 9 | 18 | - | - | - |
| Delphi/Object Pascal | 10 | 13 | 10 | 9 | - | - | - |
| Perl | 14 | 8 | 5 | 4 | 3 | 11 | - |
| Objective-C | 15 | 3 | 40 | 56 | - | - | - |
| Ada | 29 | 19 | 18 | 15 | 13 | 5 | 3 |
| Fortran | 30 | 25 | 22 | 12 | 5 | 3 | 15 |
| Lisp | 31 | 12 | 16 | 13 | 7 | 6 | 2 |

# Language popularity I

- C family (a subset of the ALGOL family), also known as "curly-brackets languages":

    1. C, C++, C#: 26.14%: 3 out of top 6.
    2. Java, C, C++, C#, JavaScript, PHP, Perl: 49.50%: 7 out of top 10.

- Python: position 3, 7.65%.
- Matlab: position 16, 1.28%.
- R: position 18, 1.02%.
- Fortran: position 29, 0.42%.
- Julia: position 39, 0.24%.

# Language popularity II

- High-performance and scientific computing is a small area within the programming community.

- Thus, you need to read the previous numbers carefully.

- For example:

    1. You will most likely never use `JavaScript` or `PHP` (at least while wearing with your "economist" hat) or deal with an embedded system.

    2. `C#` and `Swift` are cousins of C focused on industry applications not very relevant for you.

    3. `Java` (usually) pays a speed penalty.

    4. `Fortran` is still used in some circles in high-performance programming, but most programmers will never bump into anyone who uses `Fortran`.

# Multiprogramming

- Attractive approach in many situations.
- Best `IDEs` can easily link files from different languages.
- Easier examples:
  1. `Cpp.jl` and `PyCall` in `Julia`.
  2. `Rcpp`.
  3. `Mex` files in `Matlab`.