ÖGOR Summer-Workshop for PhD-candidates and Post-Docs

An introduction to Julia and JuMP for Operations Research

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Short bio


NANTES
Caen
Lisieux
Evreux
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Chartres
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Rennes
Laval
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Orléans
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Angers
Saumur
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Châtellerault
Poitiers
Châteauroux
Niort
La Roche-sur-Yon
Saint-Nazaire
Vannes
Lorient
Quimper
Brest
Morlaix
Saint-Brieuc
Dinan
Dinard
Avranches
Coutances
Senlis
Meaux
Melun
Fontainebleau
Evry
Créteil
St-Germain-en-Laye
St-Denis
Guéret

Short bio

1. Teaching areas
   - Optimization: operations research; discrete and combinatorial optimization; multi-objective optimization.
   - Artificial intelligence: metaheuristics; multi-objective metaheuristics.
   - Computer science: Introduction to computer concepts; Julia programming language.
2. Research areas
   - Optimization: operations research; multi-objective optimization.
   - Artificial intelligence: metaheuristics.
   - Scientific computing: MIP solvers.
   - Applications: railway transportation, autonomous vehicles.

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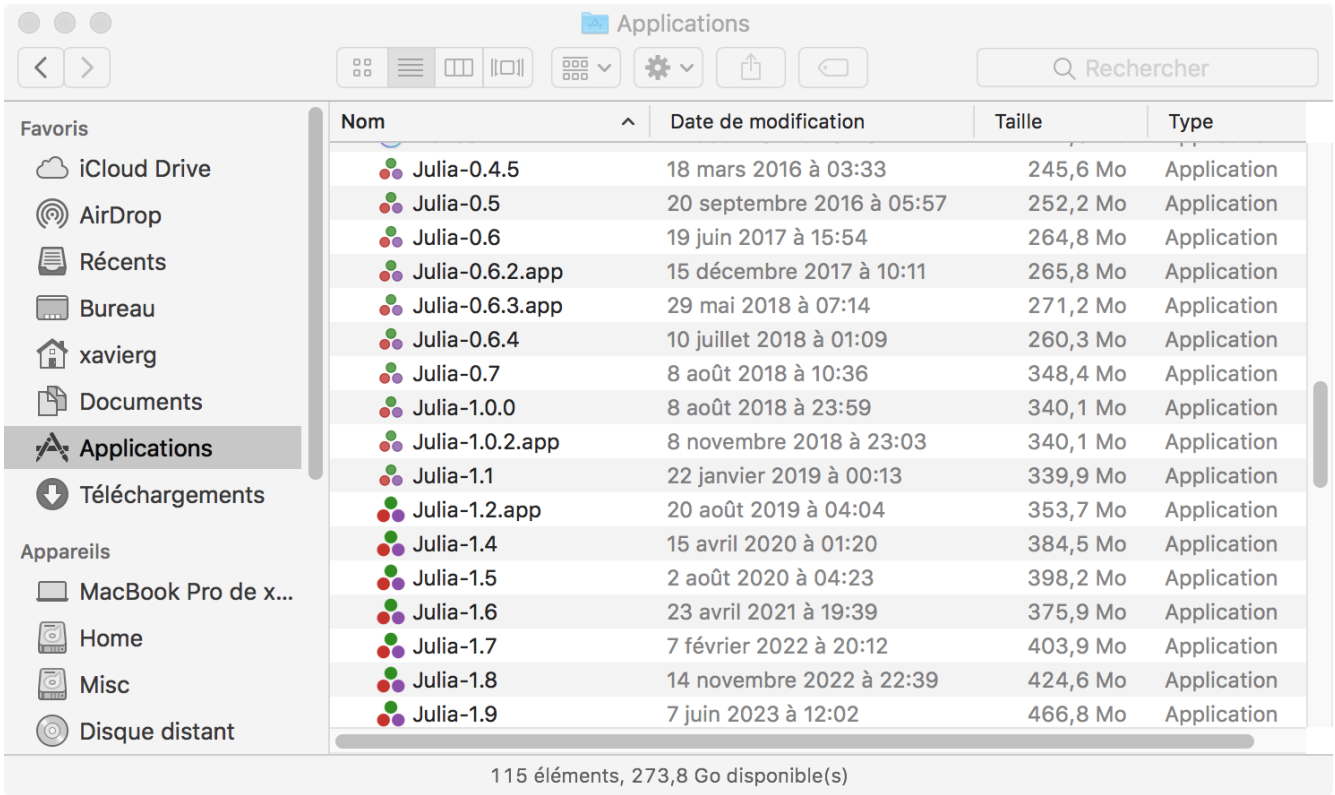
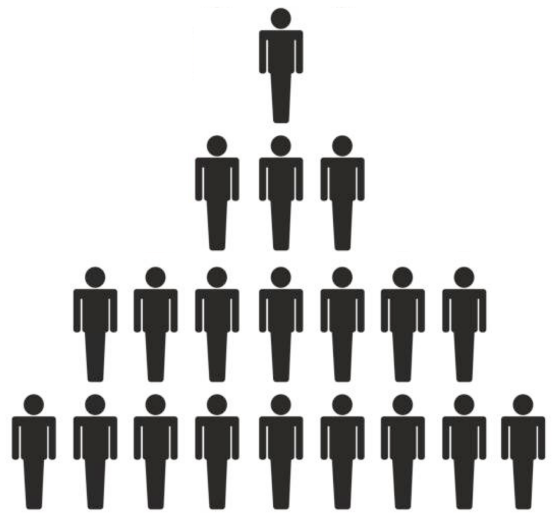
Julia

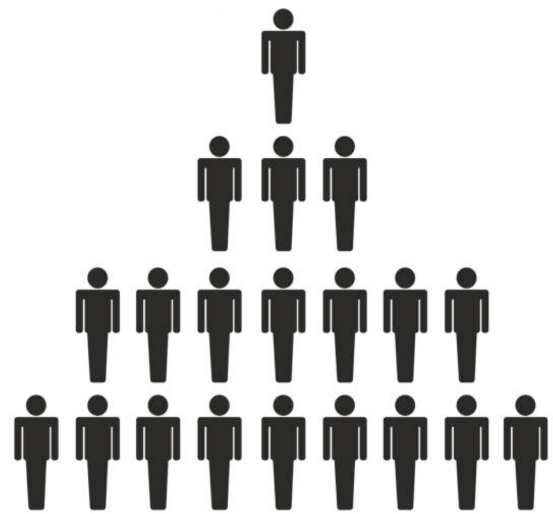
My story with Julia and JuMP: ROADEF'2016 (Feb 2016)



Julia

A programming language for optimization?





Julia

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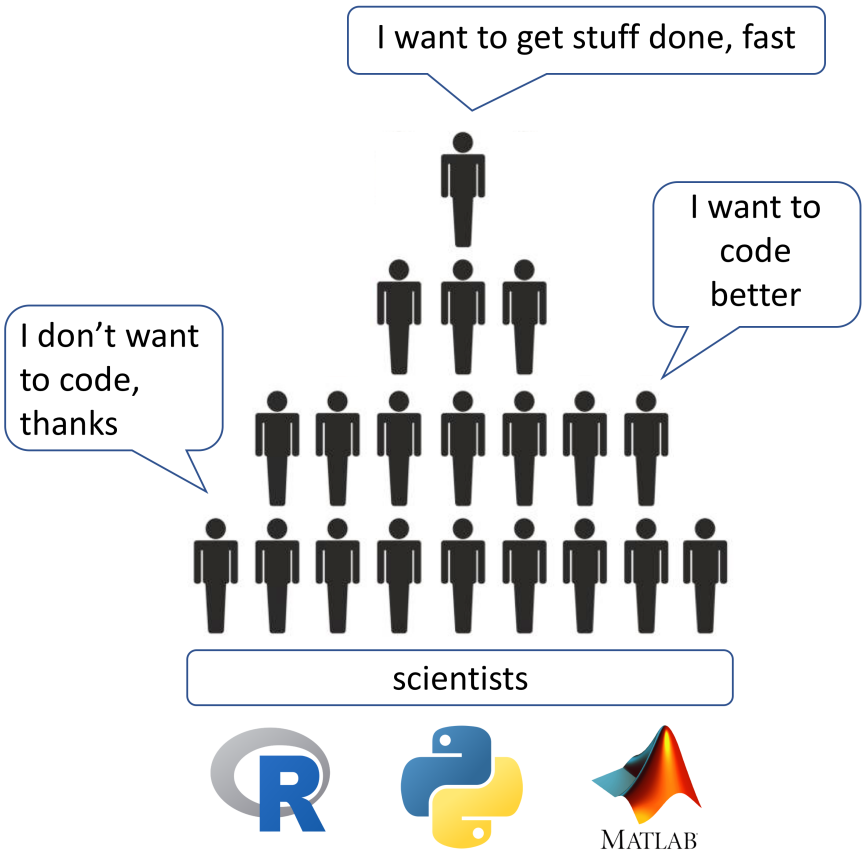

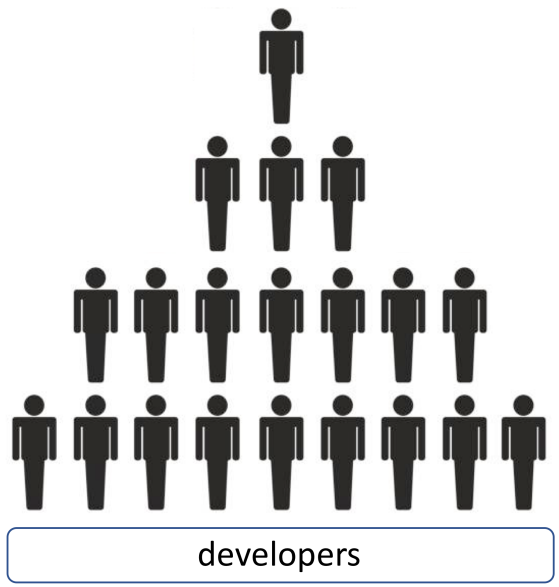

Julia

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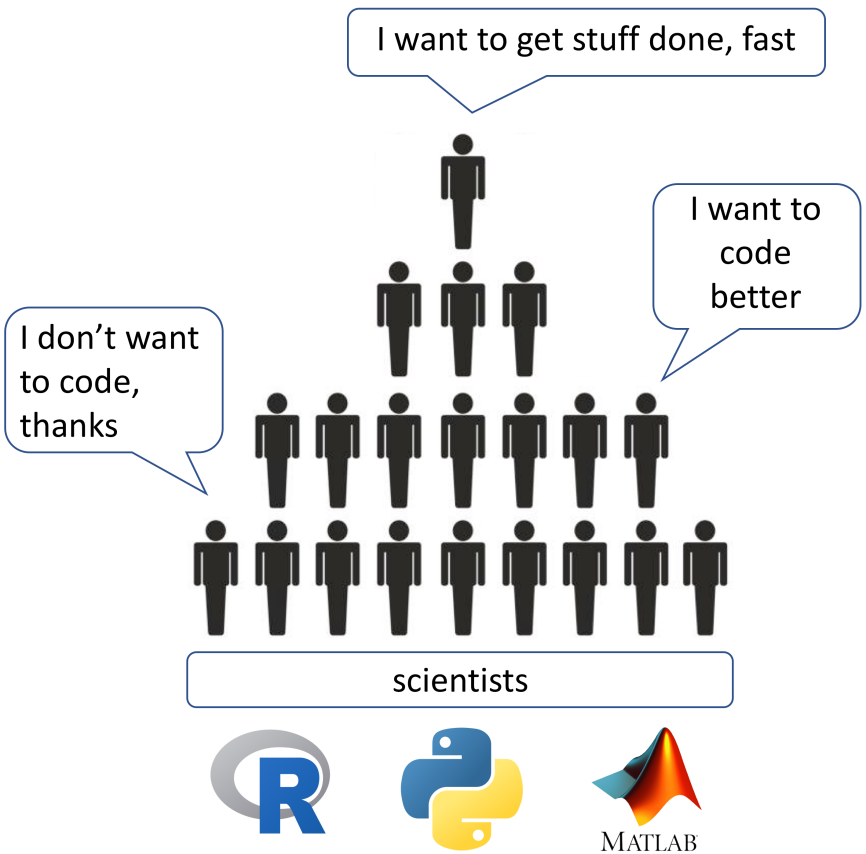

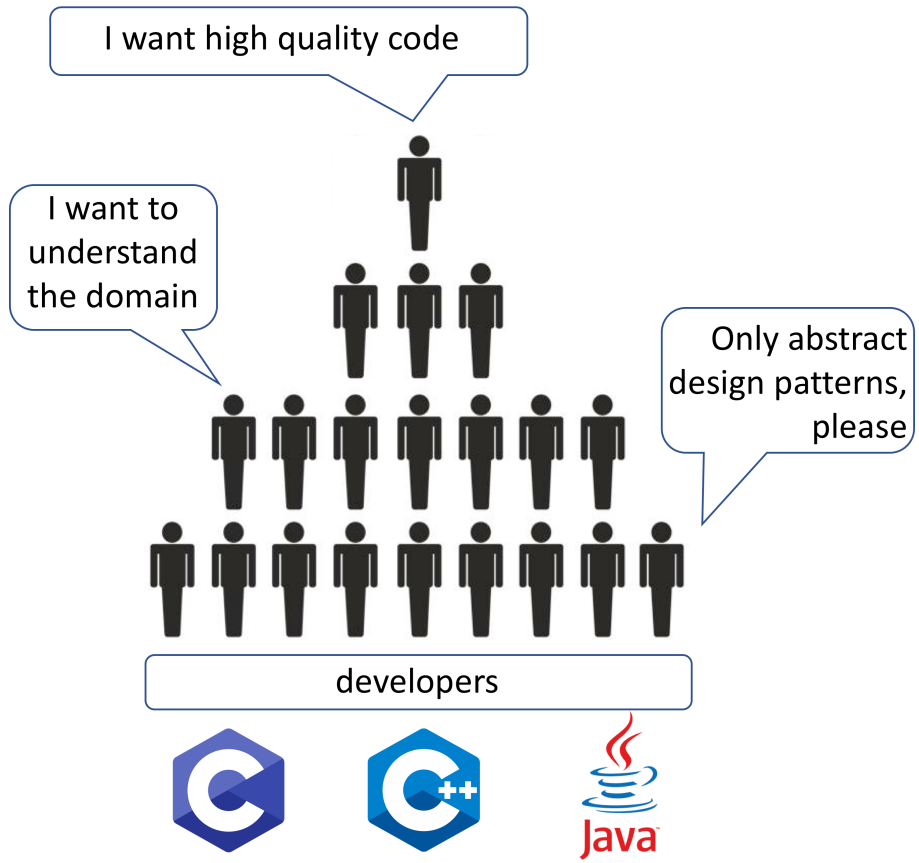

Julia

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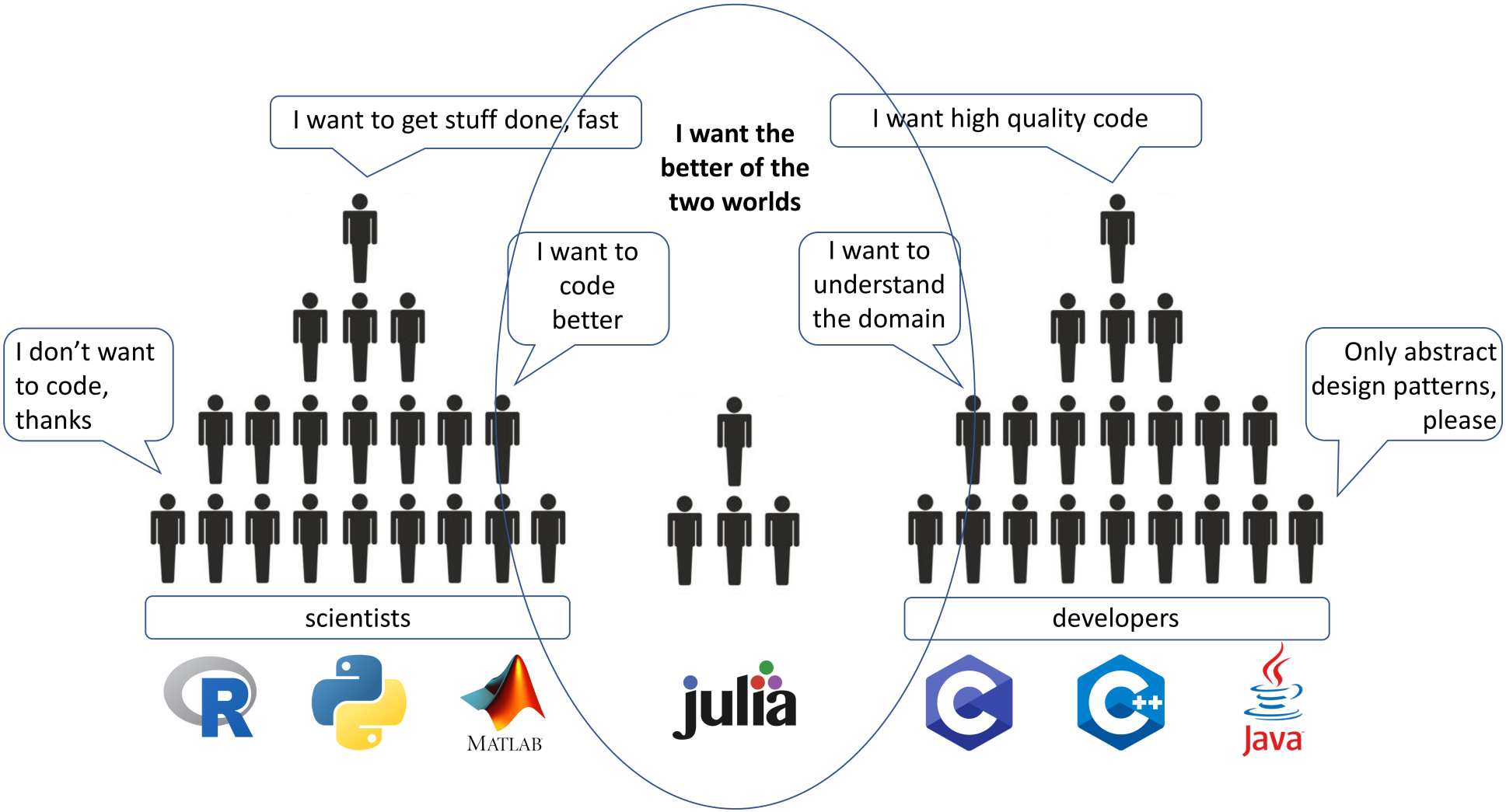
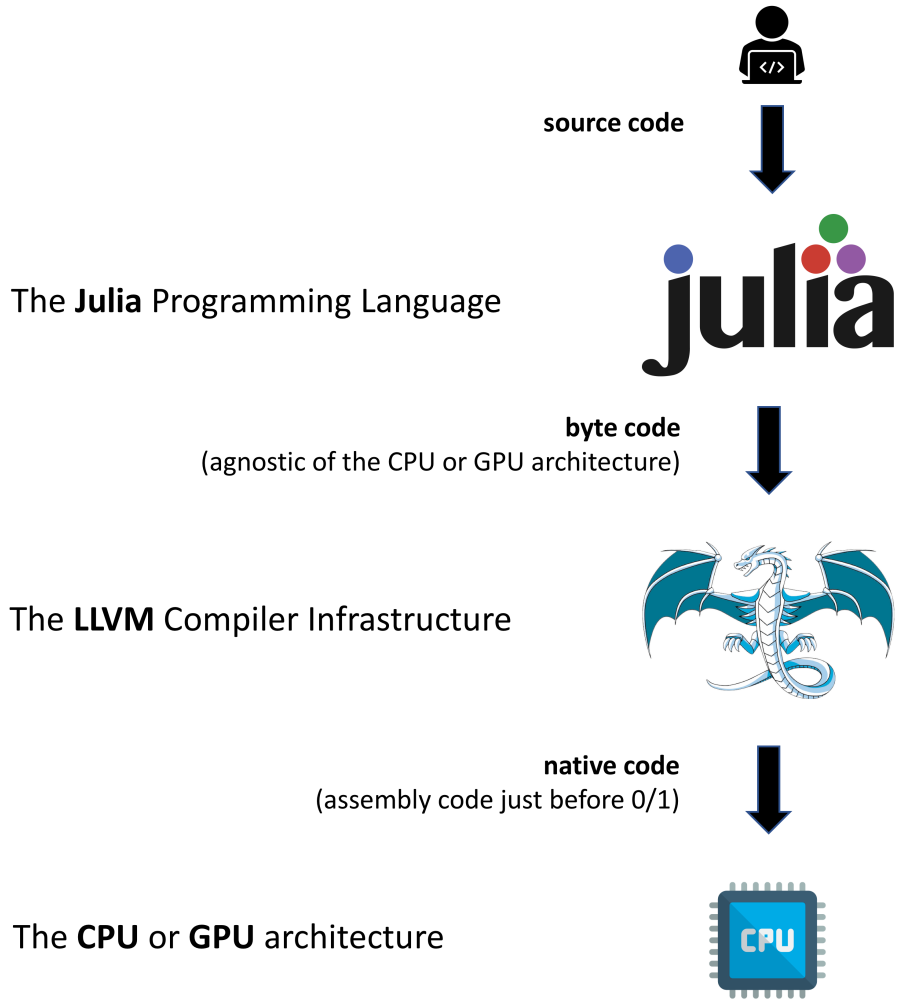


Julia

LLVM: middleman between source code and compiled native code




```
julia> 1+2
3
```

```
julia> @code_llvm 1+2
;  @ int.jl:87 within `+`
define i64 @"julia_+_115"(i64 signext %0, i64 signext %1) #0 {
top:
  %2 = add i64 %1, %0
  ret i64 %2
}
```

```
julia> @code_native 1+2
        .section        __TEXT,__text,regular,pure_instructions
        .build_version macos, 13, 0
        .globl  "_julia_+_150"                  ; -- Begin function julia_+_150
        .p2align        2
"_julia_+_150":                         ; @"julia_+_150"
; ┌ @ int.jl:87 within `+`
        .cfi_startproc
; %bb.0:                                ; %top
        add     x0, x1, x0
        ret
        .cfi_endproc
; └
                                        ; -- End function
.subsections_via_symbols
```

```
01101100
01101111
01110110
01100101
```

Julia

Example: how to get the column sums of a matrix . . .

$$A = \begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$$

$$V = \begin{pmatrix} 4 & 6 \end{pmatrix}$$

. . . in C/C++ ?

Julia

Example: how to get the column sums of a matrix?

Assembler

C/C++

```c
#include <stdio.h>
#define nLin 2
#define nCol 2

int main(void)
{
    int A[nLin][nCol] = {{1,2} ,
                         {3,4}};
    int V[nCol];
    int i, j;

    for (j = 0; j < nCol; j++)
    {
        V[j] = 0;
        for (i = 0; i < nLin; i++)
            V[j] += A[i][j];
        printf("%3d ", V[j]);
    }
    printf("\n");
    return 0;
}

```

Julia

Julia

Example: how to get the column sums of a matrix?

Assembler

```
26          str     x8, [sp]
27          ldr     x8, [x0]
28          str     x8, [sp, #8]
29          mov     x8, sp
30          str     x8, [x0]
31
32          ldr     x1, [x20]
33          mov     x0, x19
34          mov     x2, #0
35          bl      _j_reducedim_initarray
36          mov     x20, x0
37          str     x0, [sp, #16]
38          mov     x8, #16720
39          movk    x8, #6111, lsl #16
40          movk    x8, #1, lsl #32
41          mov     x9, #38080
42          movk    x9, #6109, lsl #16
43          movk    x9, #1, lsl #32
44
45          stp     x8, x9, [sp, #32]
46          stp     x0, x19, [sp, #48]
47          add     x1, sp, #32
48          mov     x0, #13456
49          movk    x0, #6286, lsl #16
50          movk    x0, #1, lsl #32
51          mov     w2, #4
52          bl      "_j1__mapreducedim!_1977"
53          ldr     x8, [sp, #8]
54          str     x8, [x21]
55
56          mov     x0, x20
57          ldp     x29, x30, [sp, #96]
58          ldp     x20, x19, [sp, #80]
59          ldp     x22, x21, [sp, #64]
60          add     sp, sp, #112
61          ret
```

C/C++

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#define nLin 2
#define nCol 2

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    for (j = 0; j < nCol; j++)
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            V[j] += A[i][j];
        printf("%3d ", V[j]);
    }
    printf("\n");
    return 0;
}

```

Julia

```julia
A = [1 2; 3 4]
V = sum(A, dims=1)
println(V)

```

version 1.9.x and later

Why Julia?

1. Runs like C, walks like Python, talks like Lisp
   - Same speed as C or FORTRAN code
   - Development dynamic like writing python code
   - Less object-oriented more function-oriented (like Lisp)

   ⇒ High-level and high-performance!

   ⇒ Extremely good ratio between coding time and running time.

   ⇒ Familiar for the users of Matlab, Fortran, Python, C/C++, etc.

2. Additional value
   - Open source: MIT license, source code available on GitHub
   - Multi-platform (x86, ARM, Apple Silicon, etc.)
   - Cross-language support: C, FORTRAN, python, R ... from Julia
   - Rich set of packages: Optimisation, Plotting, Visualisation, Statistics, Data science, GPU, etc.

   ⇒ Ideal for the development of efficient open-source app

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A high-level, high-performance programming language for scientific computing

https://julialang.org/

- Timeline:
  2009...2012 @ MIT, USA
  version 1.0.0 in 2018; version 1.9.1 (June 7, 2023)
- Communities:
  Over 9,100 Julia packages https://julialang.org/packages/
  Optimization https://jump.dev/
- JuliaCon...ferences:
  every year since 2014 https://juliacon.org/
  2023: Cambridge, USA. July 25th - 29th, 2023
- Structures:
  JuliaComputing http://juliacomputing.com
  JuliaLab http://julia.mit.edu

Jeff Bezanson, Alan Edelman, Stefan Karpinski and Viral B. Shah: Julia: A Fresh Approach to Numerical Computing. *SIAM Review*, 59: 65–98. 2017.

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Key concepts

- Julia has an LLVM-based Just-in-time compilation (JIT)
- Compilation down to native code (running on CPU and GPU, ...)
- Julia is dynamically typed, provides multiple dispatch
- Julia has many built-in mathematical functions
- A built-in package manager
- Designed for parallelism and distributed computation

Resources

Some URL to know:

- Official website
  `https://julialang.org/`
- Official documentation (online and pdf)
  `https://docs.julialang.org/`
- Julia channel on *youtube*
  `https://www.youtube.com/channel/UC9IuUwwE2xdjQUT_LMLONoA/featured`
- Questions and discussion on *discourse*
  `https://discourse.julialang.org/`
- Book online « Think Julia: How to Think Like a Computer Scientist »
  `https://benlauwens.github.io/ThinkJulia.jl/latest/book.html`

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- Book online « Think Julia: How to Think Like a Computer Scientist »
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Planning, organisation

Planning, organisation

Planning:

- 2 days, notions and practices
- AM: 09h00 → 12h00
- PM: 13h30 → 16h30

Content of the course:

- Day 1: Julia
  Crash course in Julia, optimization algorithms with Julia
- Day 2: JuMP
  Optimization models and algorithms with JuMP

Profile of the public for this course

Level of fluency with

- a programming language..... ★★★☆☆
- data structures..... ★★☆☆☆
- LP/IP/MIP optimisation..... ★★★★☆
- an algebraic modeling language... ★★★★☆