Julia for Machine Learning

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About me

- Associate Professor in Artificial Intelligence and Big Data at ISAE-Supaero (https://personnel.isae-supaero.fr/dennis-wilson)
- Researcher in bio-inspired AI: evolutionary computation and artificial neural networks
- Co-founder of Nautilia Computing (https://nautilia.co/), startup in ocean observation
- Julia package developer since 2013

Outline

- What is Julia
- Data representation
- Statistics
- Machine Learning

What is Julia?

Julia is interactive

Julia can be run in the REPL in a terminal, in Jupyter (https://jupyter.org/) (**ju**lia, **pyt**hon, e**R**), or in a script (`script.jl`)

In [1]:
```
println("Hello World")
```

```
Hello World
```

Julia is fast

Julia is compiled

Julia uses Just-in-time (JIT) compilaton, implemented using LLVM. This means that code is compiled the first time that it is called. Here we define a Fibonacci function, but it is not yet compiled

In [2]:
```
fib(n) = n < 2 ? n : fib(n-1) + fib(n-2)
```

Out[2]:
```
fib (generic function with 1 method)
```

The first time that we run the function, it will take longer to compile. However, after compilation, the function will be much faster

In [3]:
```
@timev fib(10)
```

```
  0.009137 seconds (2.01 k allocations: 104.129 KiB)
elapsed time (ns): 9136847
bytes allocated:   106628
pool allocs:       2011
```

Out[3]: 55

In [4]:
```
@timev fib(10)
```

```
  0.000002 seconds (4 allocations: 160 bytes)
elapsed time (ns): 2009
bytes allocated:   160
pool allocs:       4
```

Out[4]: 55

We can also evaluate the machine code which the function compiles to

In [5]:
```
@code_lowered fib(10)
```

Out[5]:
```
CodeInfo(
1 — %1 = n < 2
└──      goto #3 if not %1
2 —      return n
3 — %4 = n - 1
│   %5 = Main.fib(%4)
│   %6 = n - 2
│   %7 = Main.fib(%6)
│   %8 = %5 + %7
└──      return %8
)
```

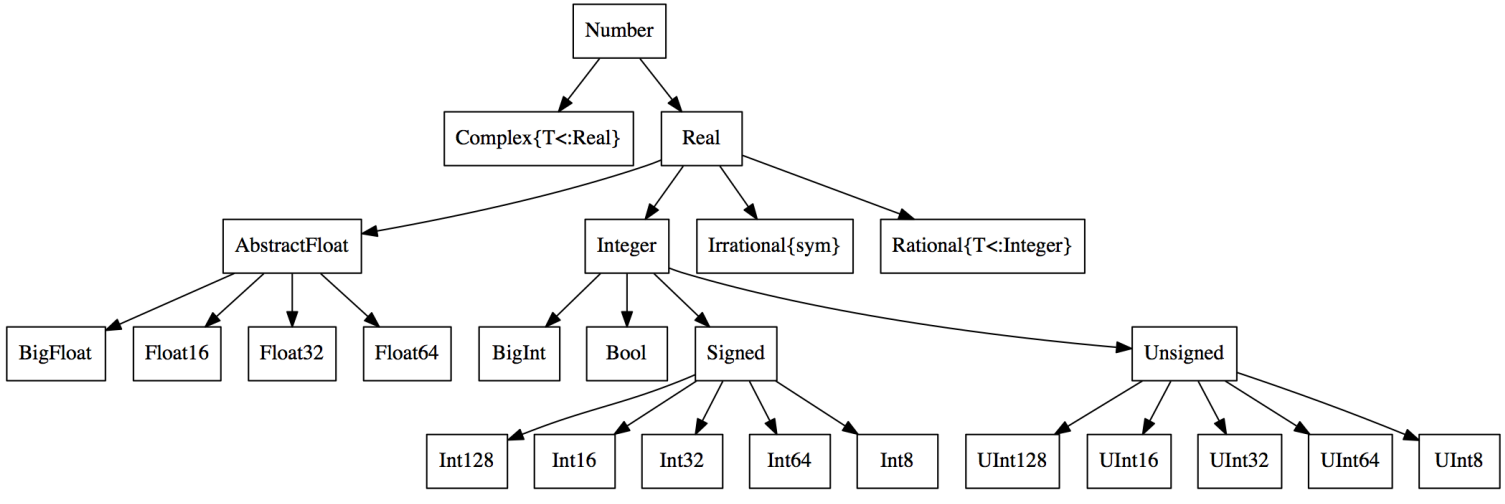
Julia is typed

Julia's type system is

- dynamic (types are checked at runtime)
- nominative (variables rely on explicity type declaration for compatibility)
- parametric (generic types can be parameterized)

Abstract types can be defined and subclassing, allowing for flexibility of not declaring a type. Every type in Julia is a subclass of the `Any` type.

Below is the type heirarchy of the Base Types (from Julia 0.5, may not be current):



In [7]:
```
Integer <: Number
```

Out[7]:
```
true
```

In [8]:
```
Integer <: AbstractFloat
```

Out[8]:
```
false
```

We can define composite types, like a Class or object in different languages.

In [9]:
```
mutable struct Foo
    bar::Int
    baz
end
```

In Julia, functions are not part of the class definition, as they are in C++ or Python. Instead, only the values of the composite type are defined. We can define default constructors separately, or other functions:

In [10]:
```
Foo() = Foo(10, "Hello")

function Foo(x::Int)
    Foo(x, nothing)
end

function double!(x::Foo)
    x.bar *= 2
end
```

Out[10]:
```
double! (generic function with 1 method)
```

In [11]:
```
f = Foo()
g = Foo(10)
println("f: ",f)
println("g: ", g)
double!(f)
println("f: ", f)
```

```
f: Foo(10, "Hello")
g: Foo(10, nothing)
f: Foo(20, "Hello")
```

Julia is flexible

Multiple dispatch is at the base of Julia, allowing for both object oriented and functional programming methods

In [13]:
```
f + g
```

```
MethodError: no method matching +(::Foo, ::Foo)
Closest candidates are:
  +(::Any, ::Any, !Matched::Any, !Matched::Any...) at operators.jl:529

Stacktrace:
 [1] top-level scope at In[13]:1
```

In [14]:
```
import Base.+
+(a::Foo, b::Foo) = Foo(a.bar + b.bar)
```

Out[14]:
```
+ (generic function with 167 methods)
```

In [15]:
```
println("f: ", f)
println("g: ", g)
f + g
```

```
f: Foo(20, "Hello")
g: Foo(10, nothing)
```

Out[15]:
```
Foo(30, nothing)
```

Julia is compatible

Julia natively works with C and Fortran. Packages (https://github.com/JuliaInterop) exist to interface with C++, Python, MATLAB, Java, R, and more.

In [16]:
```
using PyCall
```

In [17]:
```
scipyopt = pyimport("scipy.optimize")
scipyopt.newton(x -> cos(x) - x, 1)
```

Out[17]:
```
0.7390851332151607
```

In [18]:
```
using Cxx
```

In [19]:
```
cxx""" #include<iostream> """
```

Out[19]:
```
true
```

In [20]:
```
cxx"""
    void x_times_2(int x) {
        std::cout << x * 2 << std::endl;
    }
"""
```

Out[20]:
```
true
```

In [21]:
```
jnum=10
typeof(jnum)
```

Out[21]:
```
Int64
```

In [22]:
```
@cxx x_times_2(jnum)
```

```
20
```

Julia is active

- Julia Observer (https://juliaobserver.com/) tracks popular packages
- JuliaCon (https://pretalx.com/juliacon2020/) will take place in Portugal in 2020
- JuliaComputing (https://juliacomputing.com/) offers many SaaS and PaaS Julia products, actively develops open-source packages and base language
- Active discourse (https://discourse.julialang.org/) and Slack (https://discourse.julialang.org/t/announcing-a-julia-slack/4866) discussions

Julia is growing

Cumulative Julia Growth Statistics	Total as of Jan 1, 2019	Total as of Jan 1, 2020	Growth
Number of News Articles Mentioning Julia or Julia Computing	253	468	+85%
Discourse Views (Julia Forums)	12,656,734	22,920,570	+81%
Julia Downloads (JuliaLang.org + Docker Hub + JuliaPro)	7,305,737	12,950,630	+77%
Published Citations of Julia: A Fast Dynamic Language for Technical Computing (2012) + Julia: A Fresh Approach to Numerical Computing (2017)	1,048	1,680	+60%
YouTube Julia Language Channel Views	1,013,276	1,562,223	+54%

In [ ]: