Tópico

Julia Language for Mathematical Programming

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Autores:
Erik Alvarez
Jefferson Chávez

Universidade Estadual de Campinas
DSEE – **D**epartamento de **S**istemas de **E**nergia **E**létrica

JuliaLang?

- ***Open-source*** & lenguaje de programación libre (MIT license).
  - Desarrollado a partir del *2012* (por: MIT researchers)
  - Creciente popularidad a nivel mundial, en investigación, data science, finanzas, etc.
  - Multi-platform: Windows, Mac OS X, GNU/Linux…
- Diseño para la ***performance:***
  - Interpretador & compilador, ***muy eficiente***
  - Fácil de ***run codes*** en paralelo (multi-core & cluster)
- Diseño para ser ***simple de aprender y usar***:
  - Easy sintax, dynamic typing (como MATLAB & Python)

Referencias

Link: [Home · The Julia Language]

Link: [Introduction · JuMP]

Link: [GLPK - GNU Project - Free Software Foundation (FSF)]

Link: [Introduction to IPOPT: A tutorial for downloading, installing, and using IPOPT]

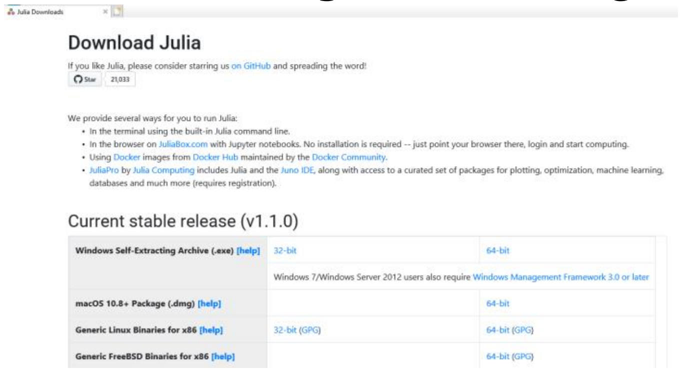
Julia vs. MATLAB: General

	Julia 🙂	**MATLAB** 🙁
Cost	Free	Hundreds of €/$ per year
License	Open-source	1 year user license
Comes from	A non-profit foundation, and the community	Mathworks Company
Editor/IDE	***Jupyter*** and ***Atom/Juno*** are recommend	Good IDE already included
Parallel computations	Very esasy, low overhead cost	Possible, high overhead
Usage	Generic, worldwide	Research in academy and industry
Fame	Young but starts to be known	Old and known

Instalación (1/3)

- Para Linux, Mac OS o Windows.
  - Se puede descargar el instalador JuliaLang en: [Julia Downloads]
  - Atom se puede descargar de: [Atom]

1. Descarga e instalar Julia con ***default settings.***



Julia Downloads

Download Julia

If you like Julia, please consider starring us on GitHub and spreading the word!

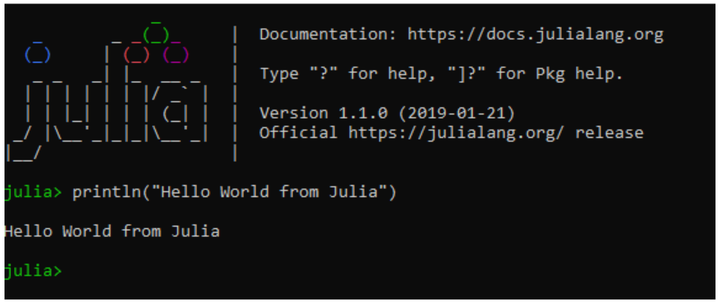
Star 21,033

We provide several ways for you to run Julia:
- In the terminal using the built-in Julia command line.
- In the browser on JuliaBox.com with Jupyter notebooks. No installation is required -- just point your browser there, login and start computing.
- Using Docker images from Docker Hub maintained by the Docker Community.
- JuliaPro by Julia Computing includes Julia and the Juno IDE, along with access to a curated set of packages for plotting, optimization, machine learning, databases and much more (requires registration).

Current stable release (v1.1.0)

Windows Self-Extracting Archive (.exe) [help]	32-bit	64-bit
	Windows 7/Windows Server 2012 users also require Windows Management Framework 3.0 or later	
macOS 10.8+ Package (.dmg) [help]		64-bit
Generic Linux Binaries for x86 [help]	32-bit (GPG)	64-bit (GPG)
Generic FreeBSD Binaries for x86 [help]		64-bit (GPG)

2. Abrir Julia



```
               _
   _       _ _(_)_     |  Documentation: https://docs.julialang.org
  (_)     | (_) (_)    |
   _ _   _| |_  __ _   |  Type "?" for help, "]?" for Pkg help.
  | | | | | | |/ _` |  |
  | | |_| | | | (_| |  |  Version 1.1.0 (2019-01-21)
 _/ |\__'_|_|_|\__'_|  |  Official https://julialang.org/ release
|__/                   |

julia> println("Hello World from Julia")

Hello World from Julia

julia>
```

Instalación (2/3)

1. En Julia: Crtl + tecla "}" para establecer el **(v1.1) pkg>**
2. En: **(v1.1) pkg> add JuMP**
3. En: **(v1.1) pkg> add GLPK**
4. En: **(v1.1) pkg> build GLPK**
5. Apretar tecla ***"backspace"*** : **julia>**
6. En: **julia> using JuMP**
7. En: **julia> using GLPK**
8. En: **julia> using GLPK**
9. En: **(v1.1) pkg> add Ipopt**
10. En: **(v1.1) pkg> build Ipopt**
11. En: **julia> using Ipopt**
12. En: **(v1.1) pkg> status**

Instalación (3/3)

1. Descarga e instalar Julia con ***default settings.***
2. In Atom, ir a ***Settings*** (Ctrl+,, or Cmd+, on macOS) e ir al "Install" panel.

3. Escribir **uber-juno** en la sección de busqueda y apretar tecla **Enter**. Dar ***click*** en el boton ***install*** de la librería.

4. **Atom** instalará y configurará **Juno** por ti.

Descripción general de los famosos “Packages” de Julia

- ***Plotting:***
  - Winston.jl para plotear comoMATLAB
  - PyPlot.jl , interfaz al Matplotlib (Python)
- JuliaDiffEq.jl , para ecuacioanes diferenciales
- JuliaStats.jl , para estadistica
- JuliaDSP , para procesamiento de señales
- BackpropNeuralNet, para redes neuronales
- JuliaOpt/JuMP para optimización

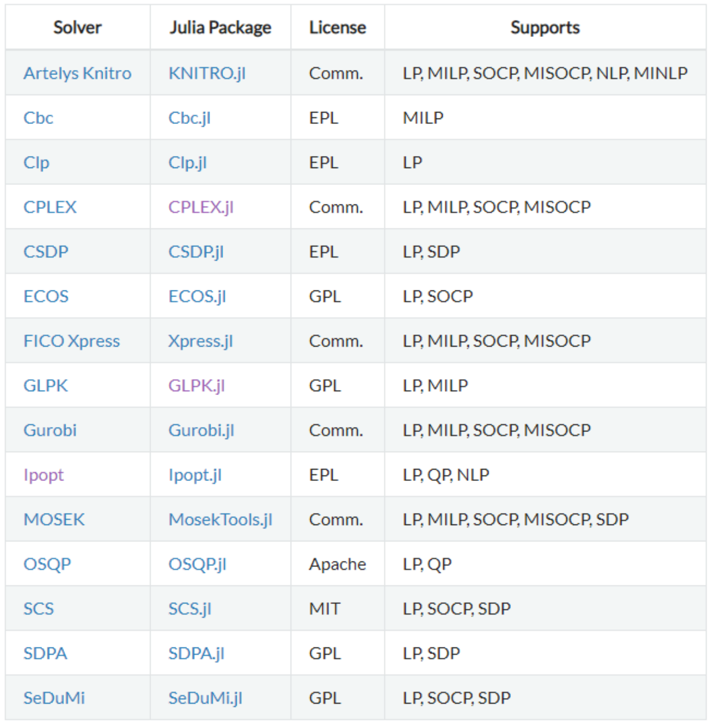
- Más “Packages” en: Julia Package Listing

Julia vs. MATLAB: Syntax

	Julia	**MATLAB**
File ext.	.jl	.m
Comment	# blabla…	% blabla…
Indexing	a[1] to a[end]	a(1) to a(end)
Slicing	a[1:100]	a(1:100)
Operations	Linear Algebra ***special library***	Linear Algebra ***by default***
Block	Use **end** to close all blocks	Use **endif**, **endfor** etc
And	a & b	a && b
Or	a | b	a || b
Array	[1 2; 3 4]	[1 2; 3 4]

JuMP

- JuMP package: lenguaje de modelamiento para optimización
- Interfaces de JuMP con solver de optimización:



Solver	Julia Package	License	Supports
Artelys Knitro	KNITRO.jl	Comm.	LP, MILP, SOCP, MISOCP, NLP, MINLP
Cbc	Cbc.jl	EPL	MILP
Clp	Clp.jl	EPL	LP
CPLEX	CPLEX.jl	Comm.	LP, MILP, SOCP, MISOCP
CSDP	CSDP.jl	EPL	LP, SDP
ECOS	ECOS.jl	GPL	LP, SOCP
FICO Xpress	Xpress.jl	Comm.	LP, MILP, SOCP, MISOCP
GLPK	GLPK.jl	GPL	LP, MILP
Gurobi	Gurobi.jl	Comm.	LP, MILP, SOCP, MISOCP
Ipopt	Ipopt.jl	EPL	LP, QP, NLP
MOSEK	MosekTools.jl	Comm.	LP, MILP, SOCP, MISOCP, SDP
OSQP	OSQP.jl	Apache	LP, QP
SCS	SCS.jl	MIT	LP, SOCP, SDP
SDPA	SDPA.jl	GPL	LP, SDP
SeDuMi	SeDuMi.jl	GPL	LP, SOCP, SDP

- Donde:
  - LP: Linear Programming
  - QP:Quadratic Programming
  - SOCP = Second-order conic programming (including problems with convex quadratic constraints and/or objective)
  - MILP = Mixed-integer linear programming
  - NLP = Nonlinear programming
  - MINLP = Mixed-integer nonlinear programming
  - SDP = Semidefinite programming
  - MISDP = Mixed-integer semidefinite programming

- Otros leguajes de modelamiento:
  - AMPL
  - GAMS
  - MATLAB: YALMIP, CVX
  - Python: Pyomo, PuLP, CVXPy

JuMP: Comparaciones “syntax” (1/2)

🟥
$$\min_{x} \sum_{(i,j)\in E} c_{i,j}\, x_{i,j}$$

s.t.

🟧
$$\sum_{(i,j)\in E} x_{i,j} = \sum_{(j,k)\in E} x_{j,k}\,, j = 2, \dots, n-1,$$

🟩
$$\sum_{(i,n)\in E} x_{i,n} = 1,$$

🟦
$$0 \le x_{i,j} \le C_{i,j}, \forall (i,j) \in E$$

JuMP: Comparaciones “syntax” (1/2)

JuMP

```
   immutable Edge
               from; to; cost; capacity
   end
   edges = [Edge(1,2,1,0.5), Edge(1,3,2,0.4), Edge(1,4,3,0.6),
            Edge(2,5,2,0.3), Edge(3,5,2,0.6), Edge(4,5,2,0.5)]
   Mcf = Model()
🟦 @variable(mcf, 0 <= flow[e in edges] <= e.capacity
🟩 @constraint(mcf, sum{flow[e], e in edges, e.to==5} == 1)
🟧 @constraint(mcf, flowcon[n=2:4], sum{flow[e], e in edges; e.to==node}
🟧                                   == sum{flow[e], e in edges; e.from==node})
🟥 @objective(mcf, Min, sum{e.cost * flow[e], e in edges})
```

AMPL

```
   set edges := {(1,2),(1,3),(1,4),(2,5),(3,5),(4,5)};
   param cost{edges}; param capacity{edges};
   data ...; # Data es alamacenada separadamente en AMPL;
🟦 var flow{(i,j) in edges} >= 0.0, <= capacity[i,j];
🟩 subject to unitflow: sum{(i,5) in edges} flow[i,5] == 1;
🟧 subject to flowconserve {n in 2..4}:
🟧   sum{(i,n) in edges} flow[i,n] == sum{(n,j) in edges} flow[n,j];
🟥 minimize flowcost:    sum{(i,j) in edges} cost[i,j] * flow[i,j];
```

JuMP: Comparaciones “syntax” (2/2)

Pyomo

```
   edges = [(1,2), (1,3), (1,4), (2,5), (3,5), (4,5)]
   cost = {(1,2):1, (1,3):2, (1,4):3, (2,5):2, (3,5):2, (4,5):2}
   capacity = {(1,2):0.5, (1,3):0.4, (1,4):0.6, (2,5):0.3, (3,5):0.6, (4,5):0.5}
   mcf = ConcreteModel()
🟦 mcf.flow = Var(edges, bounds=lambda m,i,j: (0,capacity[(i,j)]))
🟩 mcf.uf = Constraint(expr=sum(mcf.flow[e] for e in edges if e[1]==5) == 1)
🟧 def con_rule(mcf,n): return sum(mcf.flow[e] for e in edges if e[1]==n) ==
🟧                                  sum(mcf.flow[e] for e in edges if e[0]==n)
🟧 mcf.flowcon = Constraint([2,3,4],rule=con_rule)
🟥 mcf.flowcost = Objective(expr=sum(cost[e]*mcf.flow[e] for e in edges))
```

GAMS

```
   SET nodes /n1*n5/; SET midnodes(nodes) /n2*n4/; SET lastnode(nodes) /n5/;
   ALIAS(nodes,nodefrom,nodeto,n);
   SET edges(nodes,nodes) / n1.n2 n1.n3 n1.n4 n2.n5 n3.n5 n4.n5 /;
   PARAMETER cost(nodes,nodes) / … /; * Data omitted
   PARAMETER capacity(nodes,nodes) / … /; * for space reasons
🟦 POSITIVE VARIABLE flow(nodefrom,nodeto); flow.UP(edges) = capacity(edges);
🟩 EQUATION unitflow;
🟩 unitflow.. sum{edges(nodefrom,lastnode), flow(nodefrom,lastnode)} =e= 1;
🟧 EQUATION flowcon(nodes);
🟧 flowcon(midnodes(n)).. sum{edges(nodefrom,n), flow(nodefrom,n)} =e=
🟧                      sum{edges(n,nodeto), flow(n,nodeto)};
🟥 FREE VARIABLE obj;
🟥 EQUATION flowcost; flowcost.. obj =e= sum{edges, cost(edges)*flow(edges)};
   MODEL mincostflow /all/; SOLVE mincostflow USING lp MINIMIZING obj;
```

JuMP: Pro & Cons (1/2)

	GAMS	AMPL	AIMMS	C++	PYOMO	JuMP
Data Input	hard	hard	✓	✓	✓	✓
Data Manipulation	✗	✗	✓	✓	✓	✓
Modeling	✓	✓	✓	hard	✓	✓
Advanced Algorithms	hard	hard	✓	✓	✓	✓
Solvers Availabilty	✓	✓	limited	✗	limited	limited
Visualization	✗	✗	✓	hard	hard	hard
License	$	$	$$	free	free	free

JuMP: Pro & Cons (2/2)

Pros

- Nuevo lenguaje de modelamiento
- Muy rápido
- Open-source
- Facil y simple de codificar
- Acceso a C/C++
- Respaldado por una amplia comunidad científica
- Amplia variedad de librerías

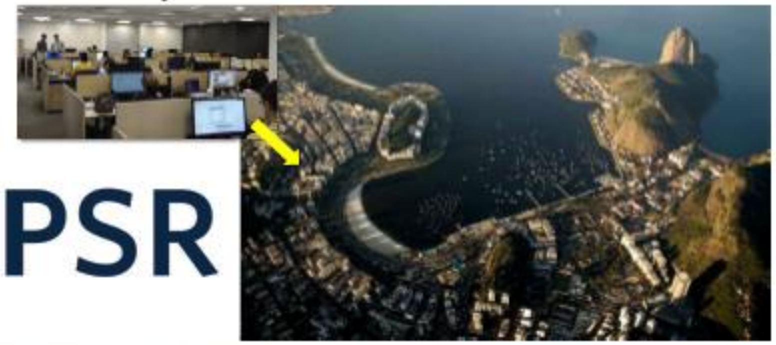
Cons

- Nuevo lenguaje de modelamiento
- Muchas librerías y plataformas aun en desarrollo
- Poco conocido

JuMP: Quiénes aplican en mercados eléctricos?

UNICAMP

PSR



Joaquim Dias Garcia

Ministerio de Energía y Minas

The Nature Conservancy

BID
Banco Interamericano de Desarrollo

Northwest Power and Conservation Council