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

An introduction to Julia and JuMP for Operations Research

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Session 10

Selected topics

Random numbers

Random numbers (1/4)

Float number in [0;1]:

```
rand()
```

```
julia> rand()
```

Vector of n floats in [0;1]:

```
rand(n)
```

```
julia> rand(3)
```

Matrix of $n_1 \times n_2$ floats in [0;1]:

```
rand(n1,n2)
```

```
julia> rand(3,2)
```

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Matrix of $n_1 \times n_2$ floats in [0;1]:

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julia> rand(3,2)
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Random numbers (2/4)

Integer number in [*a*;*b*]:

```
rand(a:b)
```

```
julia> rand(1:6)
```

Vector of *n* integers in [*a*;*b*]:

```
rand(a:b,n)
```

```
julia> rand(1:6,2)
```

Matrix of $n_1 \times n_2$ integers in [*a*;*b*]:

```
rand(a:b,n1,n2)
```

```
julia> rand(1:6,3,2)
```

Random numbers (2/4)

Integer number in [a;b]:

```
rand(a:b)
```

```
julia> rand(1:6)
```

Vector of n integers in [a;b]:

```
rand(a:b,n)
```

```
julia> rand(1:6,2)
```

Matrix of $n_1 \times n_2$ integers in [a;b]:

```
rand(a:b,n1,n2)
```

```
julia> rand(1:6,3,2)
```

Random numbers (3/4)

```
julia> using Random
```

A random permutation of length *n*:

```
randperm(n)
```

```
julia> randperm(5)
```

Return a randomly permuted copy of vector *v*:

```
shuffle(v)
```

```
julia> shuffle(Vector(1:10))
```

Random numbers (3/4)

```
julia> using Random
```

A random permutation of length *n*:

```
randperm(n)
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```
julia> randperm(5)
```

Return a randomly permuted copy of vector *v*:

```
shuffle(v)
```

```
julia> shuffle(Vector(1:10))
```

Random numbers (4/4)

Reseed the random number generator:

```
Random.seed!(init)
```

```
julia> Random.seed!(1234)
julia> rand()
julia> rand()
julia> Random.seed!(1234)
julia> rand()
julia> rand()
```

→ a reproducible sequence of numbers when a seed is provided.

Selected topics

Search and Sort

Search functions on an array (1/3)

Compute the minimum (maximum) value of an array (a vector `V` or a matrix `M`) over the given dimensions

```
minimum(array, dims)
maximum(array, dims)
```

```
julia> minimum(V)
julia> minimum(M)
julia> minimum(M,dims=1)
julia> minimum(M,dims=2)
```

```
julia> maximum(V)
julia> maximum(M)
julia> maximum(M,dims=1)
julia> maximum(M,dims=2)
```

Search functions on an array (2/3)

For an array (a vector `V` or a matrix `M`), return the indices of the minimum (maximum) elements over the given dimensions

```
argmin(array, dims)
argmax(array, dims)
```

```
julia> argmin(V)
julia> argmin(M)
julia> argmin(M,dims=1)
julia> argmin(M,dims=2)
```

```
julia> argmax(V)
julia> argmax(M)
julia> argmax(M,dims=1)
julia> argmax(M,dims=2)
```

Search functions on an array (3/3)

For an array (a vector `V` or a matrix `M`), return the index or key of the first element of A for which predicate returns true. Return `nothing` if there is no such element.

```
findfirst(predicate,array)
```

```
julia> findfirst(isequal(3),M)
```

index `i,j` of the first element of `M` for which `M[i,j]=3`

```
julia> findfirst(iseven,M)
```

```
julia> findfirst("Linz", "Hello Linz")
```

See also `findlast`, `findprev`, `findnext`

Sort functions on a vector (1/2)

Returns a sorted copy of a vector `V`

```
sort(vector)
```

```
julia> sort(V)
```

Returns the vector `V` sorted

```
sort!(vector)
```

```
julia> sort!(V)
```

Option to reverse the sorting order

```
sort(vector,rev=true)
```

```
julia> sort(V,rev=true)
```

Sort functions on a vector (2/2)

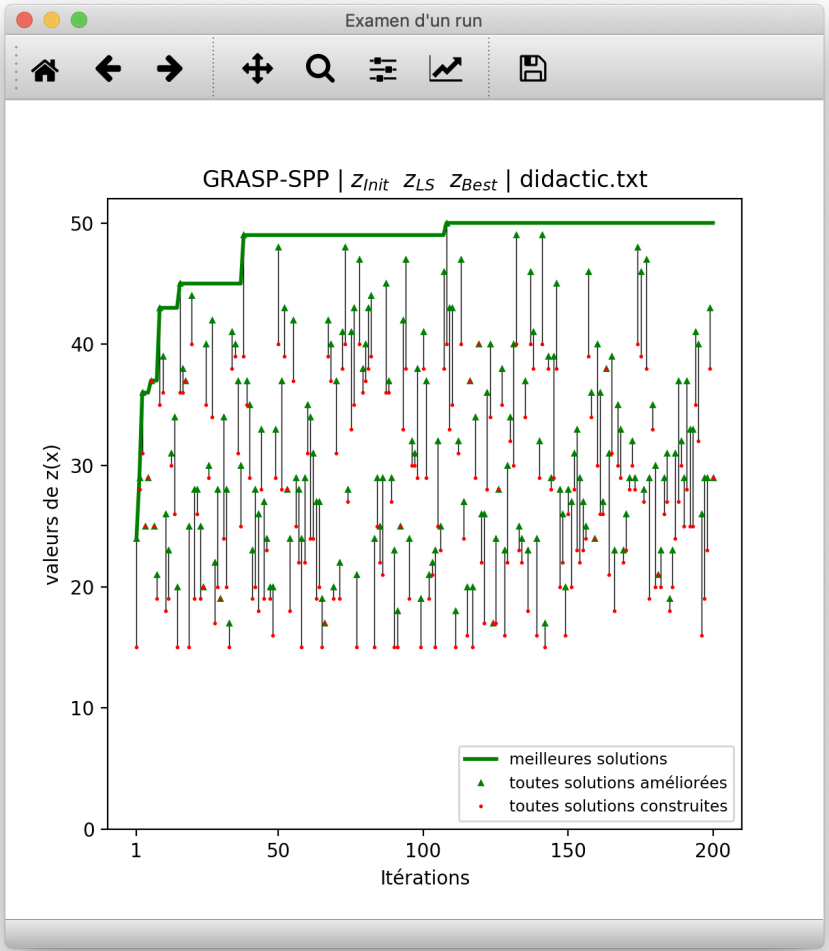
Return a permutation vector `I` that puts `V[I]` in sorted order

```
sortperm(vector)
sortperm(vector,rev=true)
```

```
julia> V=[2,7,4]
julia> p=sortperm(V)
julia> V[p]
julia> p=sortperm(V,rev=true)
julia> V[p]
```

Selected topics

Plotting



Overview

- **UnicodePlots**: a quick and easy way to draw plots in the REPL

  `https://github.com/Evizero/UnicodePlots.jl`

- **PyPlot**: a collection of command style functions that make matplotlib work like MATLAB

  `https://github.com/JuliaPy/PyPlot.jl`

  `https://matplotlib.org/tutorials/introductory/pyplot.html`

- **Plots**: a high-level plotting package that interfaces with other plotting packages

  `https://github.com/JuliaPlots/Plots.jl`

  `http://docs.juliaplots.org`

To avoid any interactions (and thus error messages) between plotting packages, use only one plotting package simultaneously.

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UnicodePlots

Install:

```
using Pkg
Pkg.add("UnicodePlots")
```

Setup:

```
using UnicodePlots
```

Example:

```
julia> f(x)=4*x+10
julia> X=[x for x=-5:5]; Y=[f(x) for x in X]
```

```
julia> lineplot(X,Y)
```

```
julia> lineplot(X,Y,title="y=f(x)",name="y=4x+10")
```

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PyPlot (1/2)

matplotlib

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Example:

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julia> f(x)=4*x+10
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julia> plot(X,Y)
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```

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PyPlot (2/2)

matplotlib

Example (Cont'd):

```
julia> title("y=f(x)"
julia> xlabel("x values"); ylabel("y values")
julia> grid()
julia> plot(X,Y,label="y=4x+10")
julia> legend(loc=4, fontsize="small")
julia> xlim(-10,10); ylim(-20,40)
```

```
julia> plot(X,Y,label="y=4x+10",
          color="red",linewidth=2.0,linestyle="--")
```

```
julia> figure("Example with PyPlot",figsize=(6,6))
```

PyPlot (2/2)

matplotlib

Example (Cont'd):

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PyPlot: example of a 2x2 subplot

```
julia> fig = figure("pyplot subplot",figsize=(5,5))
julia> suptitle("Example of a 2x2 Subplot")
julia> subplot(221)                    #---------------
julia> PyPlot.title("221 - NW"); grid("on")
julia> plot(X,Y,color="red")
julia> subplot(222)                    #---------------
julia> PyPlot.title("222 - NE")
julia> scatter(X,Y)
julia> ax = subplot(223)               #---------------
julia> PyPlot.title("223 - SW")
julia> x = randn(100); nb = 25
julia> hist(x,nb)
julia> subplot(224)                    #---------------
julia> PyPlot.title("224 - SE"); xlabel("X axis")
julia> Xc=[i for i=0:0.1:2*π]; Yc = sin.(Xc)
julia> plot(Xc,Yc)                     #---------------
julia> fig.canvas.draw()
```

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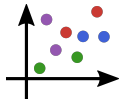
Plots (1/2)



Plots supports multiple backends:

- UnicodePlots — within the REPL
- PyPlot — the universe of Matplotlib
- GR — simple and fast
- Plotly(JS) — interactive
- etc.

Without changing syntax, we can create plots with different backends!

Install:

```
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Setup:

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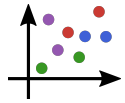
Plots (1/2)



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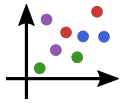
Plots (2/2)



Example with GR:

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julia> f(x)=4*x+10
julia> X=[x for x=-5:5]; Y=[f(x) for x in X]
julia> plot(X,Y, label="line")
```

```
julia> scatter!(X,Y, label="points")
```

```
julia> title!("y=f(x)")
julia> xlabel!("x values"); ylabel!("y values")
```

Example with UnicodePlots:

```
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```
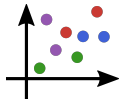

Plots (2/2)



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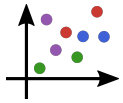
Plots (2/2)



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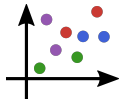

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```

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```

```
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```

Example with UnicodePlots:

```
julia> unicodeplots()
julia> plot(X,Y, label="line")
```

Review and exercises

(notebook)