In [ ]:
```
## Rapport Laboratoire 1
# Adam Osmani, 2026348
print("Hello World!")
using Pkg;

Pkg.add("JuMP")
using JuMP

Pkg.add("Ipopt")
using Ipopt

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

```
Hello World!
   Resolving package versions...
  No Changes to `C:\Users\adamo\.julia\environments\v1.10\Project.toml`
  No Changes to `C:\Users\adamo\.julia\environments\v1.10\Manifest.toml`
   Resolving package versions...
  No Changes to `C:\Users\adamo\.julia\environments\v1.10\Project.toml`
  No Changes to `C:\Users\adamo\.julia\environments\v1.10\Manifest.toml`
   Resolving package versions...
  No Changes to `C:\Users\adamo\.julia\environments\v1.10\Project.toml`
  No Changes to `C:\Users\adamo\.julia\environments\v1.10\Manifest.toml`
```

Le bloc de code suivant permet de calculer les solutions à l'équation ax^2+bx+c=0 tel que démontré:

In [ ]:
```
function quadslv(a,b,c)
    Δ = b^2-4*a*c
    if(Δ < 0)
        sln1 = (-b+sqrt(-Δ)*im)/2*a
        sln2 = (-b-sqrt(-Δ)*im)/2*a
        return [sln1, sln2]
    end
    sln1 = (-b+sqrt(Δ))/2*a
    sln2 = (-b-sqrt(Δ))/2*a
    return [sln1, sln2]
end

println("Les solutions sont : ",quadslv(1,3,4))
println("Les solutions sont : ",quadslv(1,5,4))
```

```
Les solutions sont : ComplexF64[-1.5 + 1.3228756555322954im, -1.5 - 1.3228756555322
954im]
Les solutions sont : [-1.0, -4.0]
```

Le code suivant permet de d'optimiser la fonction 100(x2-x1^2)^2+(1-x1)^2 de façon linéaire :

In [ ]:
```
model2D = Model(Ipopt.Optimizer)
@variable(model2D,x1)
@variable(model2D,x2)

@objective(model2D, Min, 100(x2-x1^2)^2+(1-x1)^2)

optimize!(model2D)
println("x1 = ",value(x1))
println("x2 = ",value(x2))
```

```
******************************************************************************
This program contains Ipopt, a library for large-scale nonlinear optimization.
 Ipopt is released as open source code under the Eclipse Public License (EPL).
         For more information visit https://github.com/coin-or/Ipopt
******************************************************************************

This is Ipopt version 3.14.13, running with linear solver MUMPS 5.6.2.

Number of nonzeros in equality constraint Jacobian...:        0
Number of nonzeros in inequality constraint Jacobian.:        0
Number of nonzeros in Lagrangian Hessian.............:        3

Total number of variables............................:        2
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        0
                     variables with only upper bounds:        0
Total number of equality constraints.................:        0
Total number of inequality constraints...............:        0
        inequality constraints with only lower bounds:        0
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        0

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
   0  1.0000000e+00 0.00e+00 2.00e+00  -1.0 0.00e+00    -  0.00e+00 0.00e+00   0
   1  9.5312500e-01 0.00e+00 1.25e+01  -1.0 1.00e+00    -  1.00e+00 2.50e-01f  3
   2  4.8320569e-01 0.00e+00 1.01e+00  -1.0 9.03e-02    -  1.00e+00 1.00e+00f  1
   3  4.5708829e-01 0.00e+00 9.53e+00  -1.0 4.29e-01    -  1.00e+00 5.00e-01f  2
   4  1.8894205e-01 0.00e+00 4.15e-01  -1.0 9.51e-02    -  1.00e+00 1.00e+00f  1
   5  1.3918726e-01 0.00e+00 6.51e+00  -1.7 3.49e-01    -  1.00e+00 5.00e-01f  2
   6  5.4940990e-02 0.00e+00 4.51e-01  -1.7 9.29e-02    -  1.00e+00 1.00e+00f  1
   7  2.9144630e-02 0.00e+00 2.27e+00  -1.7 2.49e-01    -  1.00e+00 5.00e-01f  2
   8  9.8586451e-03 0.00e+00 1.15e+00  -1.7 1.10e-01    -  1.00e+00 1.00e+00f  1
   9  2.3237475e-03 0.00e+00 1.00e+00  -1.7 1.00e-01    -  1.00e+00 1.00e+00f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
  10  2.3797236e-04 0.00e+00 2.19e-01  -1.7 5.09e-02    -  1.00e+00 1.00e+00f  1
  11  4.9267371e-06 0.00e+00 5.95e-02  -1.7 2.53e-02    -  1.00e+00 1.00e+00f  1
  12  2.8189506e-09 0.00e+00 8.31e-04  -2.5 3.20e-03    -  1.00e+00 1.00e+00f  1
  13  9.6379884e-16 0.00e+00 8.68e-07  -5.7 9.78e-05    -  1.00e+00 1.00e+00f  1
  14  1.9721523e-29 0.00e+00 1.57e-13  -8.6 4.65e-08    -  1.00e+00 1.00e+00f  1

Number of Iterations....: 14

                                   (scaled)                 (unscaled)
Objective...............:   1.9721522630525295e-29    1.9721522630525295e-29
Dual infeasibility......:   1.5720758028692217e-13    1.5720758028692217e-13
Constraint violation....:   0.0000000000000000e+00    0.0000000000000000e+00
Variable bound violation:   0.0000000000000000e+00    0.0000000000000000e+00
Complementarity.........:   0.0000000000000000e+00    0.0000000000000000e+00
Overall NLP error.......:   1.5720758028692217e-13    1.5720758028692217e-13


Number of objective function evaluations             = 36
Number of objective gradient evaluations             = 15
Number of equality constraint evaluations            = 0
Number of inequality constraint evaluations          = 0
Number of equality constraint Jacobian evaluations   = 0
Number of inequality constraint Jacobian evaluations = 0
Number of Lagrangian Hessian evaluations             = 14
Total seconds in IPOPT                               = 0.035
```

```
EXIT: Optimal Solution Found.
x1 = 0.9999999999999899
x2 = 0.9999999999999793
```

Le code suivant permet de d'optimiser la fonction 100(x2-x1^2)^2+(1-x1)^2 de façon non linéaire :

In [ ]:
```
model = Model(Ipopt.Optimizer)
x0 = [-1.2; 1.0]
@variable(model, x[i=1:2], start=x0[i])
@NLobjective(model, Min, (x[1] - 1)^2 + 100 * (x[2] - x[1]^2)^2)
optimize!(model)

println("x1 = ",value(x[1]))
println("x2 = ",value(x[2]))
```

```
This is Ipopt version 3.14.13, running with linear solver MUMPS 5.6.2.

Number of nonzeros in equality constraint Jacobian...:        0
Number of nonzeros in inequality constraint Jacobian.:        0
Number of nonzeros in Lagrangian Hessian.............:        3

Total number of variables............................:        2
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        0
                     variables with only upper bounds:        0
Total number of equality constraints.................:        0
Total number of inequality constraints...............:        0
        inequality constraints with only lower bounds:        0
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        0

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
   0  2.4200000e+01 0.00e+00 1.00e+02  -1.0 0.00e+00    -  0.00e+00 0.00e+00   0
   1  4.7318843e+00 0.00e+00 2.15e+00  -1.0 3.81e-01    -  1.00e+00 1.00e+00f  1
   2  4.0873987e+00 0.00e+00 1.20e+01  -1.0 4.56e+00    -  1.00e+00 1.25e-01f  4
   3  3.2286726e+00 0.00e+00 4.94e+00  -1.0 2.21e-01    -  1.00e+00 1.00e+00f  1
   4  3.2138981e+00 0.00e+00 1.02e+01  -1.0 4.82e-01    -  1.00e+00 1.00e+00f  1
   5  1.9425854e+00 0.00e+00 1.62e+00  -1.0 6.70e-02    -  1.00e+00 1.00e+00f  1
   6  1.6001937e+00 0.00e+00 3.44e+00  -1.0 7.35e-01    -  1.00e+00 2.50e-01f  3
   7  1.1783896e+00 0.00e+00 1.92e+00  -1.0 1.44e-01    -  1.00e+00 1.00e+00f  1
   8  9.2241158e-01 0.00e+00 4.00e+00  -1.0 2.08e-01    -  1.00e+00 1.00e+00f  1
   9  5.9748862e-01 0.00e+00 7.36e-01  -1.0 8.91e-02    -  1.00e+00 1.00e+00f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
  10  4.5262510e-01 0.00e+00 2.42e+00  -1.7 2.97e-01    -  1.00e+00 5.00e-01f  2
  11  2.8076244e-01 0.00e+00 9.25e-01  -1.7 1.02e-01    -  1.00e+00 1.00e+00f  1
  12  2.1139340e-01 0.00e+00 3.34e+00  -1.7 1.77e-01    -  1.00e+00 1.00e+00f  1
  13  8.9019501e-02 0.00e+00 2.25e-01  -1.7 9.45e-02    -  1.00e+00 1.00e+00f  1
  14  5.1535405e-02 0.00e+00 1.49e+00  -1.7 2.84e-01    -  1.00e+00 5.00e-01f  2
  15  1.9992778e-02 0.00e+00 4.64e-01  -1.7 1.09e-01    -  1.00e+00 1.00e+00f  1
  16  7.1692436e-03 0.00e+00 1.03e+00  -1.7 1.39e-01    -  1.00e+00 1.00e+00f  1
  17  1.0696137e-03 0.00e+00 9.09e-02  -1.7 5.50e-02    -  1.00e+00 1.00e+00f  1
  18  7.7768464e-05 0.00e+00 1.44e-01  -2.5 5.53e-02    -  1.00e+00 1.00e+00f  1
  19  2.8246695e-07 0.00e+00 1.50e-03  -2.5 7.31e-03    -  1.00e+00 1.00e+00f  1
iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
  20  8.5170750e-12 0.00e+00 4.90e-05  -5.7 1.05e-03    -  1.00e+00 1.00e+00f  1
  21  3.7439756e-21 0.00e+00 1.73e-10  -5.7 2.49e-06    -  1.00e+00 1.00e+00f  1

Number of Iterations....: 21

                                   (scaled)                 (unscaled)
Objective...............:   1.7365378678754519e-21    3.7439756431394737e-21
Dual infeasibility......:   1.7312156654298279e-10    3.7325009746667082e-10
Constraint violation....:   0.0000000000000000e+00    0.0000000000000000e+00
Variable bound violation:   0.0000000000000000e+00    0.0000000000000000e+00
Complementarity.........:   0.0000000000000000e+00    0.0000000000000000e+00
Overall NLP error.......:   1.7312156654298279e-10    3.7325009746667082e-10


Number of objective function evaluations             = 45
Number of objective gradient evaluations             = 22
Number of equality constraint evaluations            = 0
Number of inequality constraint evaluations          = 0
Number of equality constraint Jacobian evaluations   = 0
Number of inequality constraint Jacobian evaluations = 0
```

```
Number of Lagrangian Hessian evaluations             = 21
Total seconds in IPOPT                               = 0.028

EXIT: Optimal Solution Found.
x1 = 0.9999999999400667
x2 = 0.9999999998789006
```