```
#
#
#
#
#
#
#
```

nlpsol

```
from casadi import *
from numpy import *
```

In this example, we will solve a few optimization problems with increasing complexity

Scalar unconstrained problem

```

x=SX.sym('x')
nlp = {'x':x, 'f':(x-1)**2}

solver = nlpsol('solver', 'ipopt', nlp)
sol = solver(lbx=-10, ubx=10)
```

```
******************************************************************************

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 http://projects.coin-or.org/Ipopt
******************************************************************************


This is Ipopt version 3.12.3, running with linear solver ma57.

Number of nonzeros in equality constraint Jacobian...:        0
Number of nonzeros in inequality constraint Jacobian.:        0
Number of nonzeros in Lagrangian Hessian.............:        1

Total number of variables............................:        1
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        1
                     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  8.2644627e-03 0.00e+00 1.53e-02  -1.0 9.09e-01    -  9.16e-01 1.00e
     +00f  1
   2  3.3212748e-06 0.00e+00 2.08e-17  -1.0 8.91e-02    -  1.00e+00 1.00e
     +00f  1
   3  9.3171258e-10 0.00e+00 7.11e-17  -2.5 1.79e-03    -  1.00e+00 1.00e
     +00f  1
   4  2.3111166e-12 0.00e+00 2.40e-17  -3.8 2.90e-05    -  1.00e+00 1.00e
     +00f  1
   5  3.4736752e-16 0.00e+00 5.92e-17  -5.7 1.50e-06    -  1.00e+00 1.00e
     +00f  1
   6  6.4072417e-22 0.00e+00 3.96e-17  -8.6 1.86e-08    -  1.00e+00 1.00e
     +00f  1

Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:   6.4072416740416713e-22    6.4072416740416713e
    -22
Dual infeasibility......:   3.9625445352197450e-17    3.9625445352197450e
    -17
Constraint violation....:   0.0000000000000000e+00    0.0000000000000000e
    +00
Complementarity.........:   2.5059073699316697e-09    2.5059073699316697e
    -09
Overall NLP error.......:   2.5059073699316697e-09    2.5059073699316697e
    -09


Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
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             = 6
Total CPU secs in IPOPT (w/o function evaluations)   =      0.002
Total CPU secs in NLP function evaluations           =      0.000

EXIT: Optimal Solution Found.
                   proc           wall      num           mean
                                  mean
                   time           time     evals       proc time
            wall time
       nlp_f     0.000 [s]      0.000 [s]      7       0.00 [ms]
          0.03 [ms]
  nlp_grad_f     0.000 [s]      0.000 [s]      8       0.00 [ms]
       0.00 [ms]
  nlp_hess_l     0.000 [s]      0.000 [s]      6       0.00 [ms]
       0.00 [ms]
all previous     0.000 [s]      0.000 [s]
callback_prep    0.000 [s]      0.000 [s]      7       0.00 [ms]
    0.01 [ms]
      solver     0.020 [s]      0.003 [s]
    mainloop     0.020 [s]      0.003 [s]
```

The solution is obviously 1:

```
print sol['x']
```

```
1
```

```
assert(abs(sol['x']-1)<1e-9)
```

Constrained problem

```

n = 5

x=SX.sym('x',n)
```

Note how we do not distinguish between equalities and inequalities here

```
nlp = {'x':x, 'f':mtimes((x-1).T,x-1), 'g':vertcat(x[1]+x[2],x[0])}

solver = nlpsol('solver', 'ipopt', nlp)
sol = solver(lbx=-10, ubx=10, lbg=[0,2], ubg=[1,2])
```

```
This is Ipopt version 3.12.3, running with linear solver ma57.

Number of nonzeros in equality constraint Jacobian...:        1
Number of nonzeros in inequality constraint Jacobian.:        2
Number of nonzeros in Lagrangian Hessian.............:        5

Total number of variables............................:        5
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        5
                     variables with only upper bounds:        0
Total number of equality constraints.................:        1
Total number of inequality constraints...............:        1
        inequality constraints with only lower bounds:        0
   inequality constraints with lower and upper bounds:        1
        inequality constraints with only upper bounds:        0

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du
    alpha_pr  ls
   0  5.0000000e+00 2.00e+00 2.00e+00  -1.0 0.00e+00    -  0.00e+00 0.00e
      +00   0
   1  2.7716739e+00 0.00e+00 1.16e+00  -1.0 2.00e+00    -  3.75e-01 1.00e
      +00f  1
   2  1.5112117e+00 0.00e+00 4.53e-01  -1.0 1.31e+00    -  9.44e-01 6.62e
      -01f  1
   3  1.5183915e+00 0.00e+00 3.20e-16  -1.7 3.46e-02    -  1.00e+00 1.00e
      +00f  1
   4  1.5009100e+00 0.00e+00 2.03e-04  -3.8 1.73e-02    -  9.88e-01 1.00e
      +00f  1
   5  1.5000028e+00 0.00e+00 2.14e-16  -5.7 9.07e-04    -  1.00e+00 1.00e
      +00f  1
   6  1.5000000e+00 0.00e+00 2.04e-16  -8.6 2.85e-06    -  1.00e+00 1.00e
      +00f  1

Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:   1.4999999925191814e+00    1.4999999925191814e
    +00
Dual infeasibility......:   2.0424918385704731e-16    2.0424918385704731e
    -16
Constraint violation....:   0.0000000000000000e+00    0.0000000000000000e
    +00
Complementarity.........:   2.5191812953934411e-09    2.5191812953934411e
    -09
Overall NLP error.......:   2.5191812953934411e-09    2.5191812953934411e
    -09


Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
Number of equality constraint evaluations            = 7
Number of inequality constraint evaluations          = 7
Number of equality constraint Jacobian evaluations   = 7
Number of inequality constraint Jacobian evaluations = 7
Number of Lagrangian Hessian evaluations             = 6
Total CPU secs in IPOPT (w/o function evaluations)   =      0.003
Total CPU secs in NLP function evaluations           =      0.001

EXIT: Optimal Solution Found.
                   proc           wall      num           mean
                                   mean
                   time           time     evals       proc time
     wall time
         nlp_f    0.000 [s]      0.000 [s]     7        0.00 [ms]
      0.01 [ms]
         nlp_g    0.010 [s]      0.000 [s]     7        1.43 [ms]
      0.01 [ms]
    nlp_grad_f    0.000 [s]      0.000 [s]     8        0.00 [ms]
     0.01 [ms]
     nlp_jac_g    0.000 [s]      0.000 [s]     8        0.00 [ms]
      0.01 [ms]
    nlp_hess_l    0.000 [s]      0.000 [s]     6        0.00 [ms]
     0.01 [ms]
  all previous    0.010 [s]      0.000 [s]
 callback_prep    0.000 [s]      0.000 [s]     7        0.00 [ms]
    0.01 [ms]
        solver    0.000 [s]      0.004 [s]
      mainloop    0.010 [s]      0.004 [s]
```

The solution is obviously [2,0.5,0.5,1,1]:

```
print sol['x']
```

```
[2, 0.5, 0.5, 1, 1]
```

```
for (i,e) in zip(range(n),[2,0.5,0.5,1,1]):
  assert(abs(sol['x'][i]-e)<1e-7)
```

Problem with parameters

```

x=SX.sym('x')
```

```
52 a=SX.sym('a')
53 a_ = 2
54 nlp={'x':x, 'p':a, 'f':(x-a)**2}
55
56 solver = nlpsol('solver', 'ipopt', nlp)
57 sol = solver(lbx=-10, ubx=10, p=a_)
```

```
This is Ipopt version 3.12.3, running with linear solver ma57.

Number of nonzeros in equality constraint Jacobian...:        0
Number of nonzeros in inequality constraint Jacobian.:        0
Number of nonzeros in Lagrangian Hessian.....:        1

Total number of variables.....:        1
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        1
                     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  4.0000000e+00 0.00e+00 4.00e+00  -1.0 0.00e+00    -  0.00e+00 0.00e
       +00   0
   1  3.3057851e-02 0.00e+00 5.64e-02  -1.0 1.82e+00    -  8.45e-01 1.00e
       +00f  1
   2  2.8894889e-05 0.00e+00 1.53e-16  -1.0 1.76e-01    -  1.00e+00 1.00e
       +00f  1
   3  4.4774726e-09 0.00e+00 1.08e-16  -2.5 5.31e-03    -  1.00e+00 1.00e
       +00f  1
   4  9.8332283e-12 0.00e+00 2.02e-16  -3.8 6.38e-05    -  1.00e+00 1.00e
       +00f  1
   5  1.4777036e-15 0.00e+00 3.79e-18  -5.7 3.10e-06    -  1.00e+00 1.00e
       +00f  1
   6  2.7255842e-21 0.00e+00 1.26e-17  -8.6 3.84e-08    -  1.00e+00 1.00e
       +00f  1

Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:   2.7255841628426173e-21    2.7255841628426173e
    -21
Dual infeasibility......:   1.2569571890559792e-17    1.2569571890559792e
    -17
Constraint violation....:   0.0000000000000000e+00    0.0000000000000000e
    +00
Complementarity.........:   2.5059124009153784e-09    2.5059124009153784e
    -09
Overall NLP error.......:   2.5059124009153784e-09    2.5059124009153784e
    -09


Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
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             = 6
Total CPU secs in IPOPT (w/o function evaluations)   =      0.003
Total CPU secs in NLP function evaluations           =      0.000

EXIT: Optimal Solution Found.
                  proc           wall      num           mean
                                  mean
                  time           time    evals       proc time
                      wall time
       nlp_f     0.000 [s]      0.000 [s]     7       0.00 [ms]
          0.01 [ms]
  nlp_grad_f     0.000 [s]      0.000 [s]     8       0.00 [ms]
       0.01 [ms]
  nlp_hess_l     0.000 [s]      0.000 [s]     6       0.00 [ms]
       0.01 [ms]
 all previous     0.000 [s]      0.000 [s]
callback_prep     0.000 [s]      0.000 [s]     7       0.00 [ms]
    0.01 [ms]
      solver     0.010 [s]      0.003 [s]
    mainloop     0.010 [s]      0.003 [s]
```

The solution is obviously a:

```
59 print sol['x']
```

```
2
```

```
60 assert(abs(sol['x']-a_)<1e-9)
```

The parameter can change inbetween two solve calls:

```
63 sol = solver(lbx=-10, ubx=10, p=2*a_)
```

```
This is Ipopt version 3.12.3, running with linear solver ma57.

Number of nonzeros in equality constraint Jacobian...:        0
Number of nonzeros in inequality constraint Jacobian.:        0
Number of nonzeros in Lagrangian Hessian.....:        1

Total number of variables.....:        1
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        1
                     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  1.6000000e+01 0.00e+00 8.00e+00  -1.0 0.00e+00    -  0.00e+00 0.00e
       +00   0
   1  1.3223140e-01 0.00e+00 1.95e-01  -1.0 3.64e+00    -  7.31e-01 1.00e
```

```
      +00f  1
   2  3.6066256e-04 0.00e+00 1.04e-16  -1.0 3.45e-01    -  1.00e+00 1.00e
      +00f  1
   3  1.0362906e-06 0.00e+00 3.71e-16  -1.7 1.80e-02    -  1.00e+00 1.00e
      +00f  1
   4  5.6293833e-11 0.00e+00 8.15e-17  -3.8 1.01e-03    -  1.00e+00 1.00e
      +00f  1
   5  7.7214018e-15 0.00e+00 3.56e-16  -5.7 7.42e-06    -  1.00e+00 1.00e
      +00f  1
   6  1.4239938e-20 0.00e+00 3.69e-16  -8.6 8.78e-08    -  1.00e+00 1.00e
      +00f  1

Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:   1.4239938056866796e-20    1.4239938056866796e
    -20
Dual infeasibility......:   3.6930385037381279e-16    3.6930385037381279e
    -16
Constraint violation....:   0.0000000000000000e+00    0.0000000000000000e
    +00
Complementarity.........:   2.5059305083202185e-09    2.5059305083202185e
    -09
Overall NLP error.......:   2.5059305083202185e-09    2.5059305083202185e
    -09


Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
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             = 6
Total CPU secs in IPOPT (w/o function evaluations)   =      0.002
Total CPU secs in NLP function evaluations           =      0.000

EXIT: Optimal Solution Found.
                 proc           wall      num           mean
                                 mean
                 time           time     evals       proc time
                     wall time
        nlp_f     0.000 [s]      0.000 [s]     7       0.00 [ms]
            0.01 [ms]
   nlp_grad_f     0.000 [s]      0.000 [s]     8       0.00 [ms]
        0.00 [ms]
   nlp_hess_l     0.000 [s]      0.000 [s]     6       0.00 [ms]
        0.00 [ms]
 all previous     0.000 [s]      0.000 [s]
callback_prep     0.000 [s]      0.000 [s]     7       0.00 [ms]
    0.01 [ms]
      solver     0.000 [s]      0.003 [s]
    mainloop     0.000 [s]      0.003 [s]
```

The solution is obviously 2*a:

```
66 print sol['x']
```

```
   4
67 assert(abs(sol['x']-2*a_)<1e-9)
```