OML Lab Assiginment 2

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```
import imp
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from pulp import *
import cvxopt as cp
import cvxpy as cvx
```

Question 1

```
""" We need to write a python code to solve the following LP

min max{5x1 + 2x2 , 3x1 + 7x2}
s.t. x1 + 2x2 ≤ 3
4x1 + 3x2 ≥ 6
3x1 + x2 = 3
x1, x2 ≥ 0

"""

c = np.array([[0.0],[0.0],[1.0]])
A = np.array([[5,2,-1],[3,7,-1],[1,2,0],[-4,-3,0],[3,1,0],
              [-3,-1,0],[-1,0,0],[0,-1,0]])
b = np.array([[0],[0],[3],[-6],[3],[-3],[0],[0]])
sol = cp.solvers.lp(cp.matrix(c,tc='d'), cp.matrix(A,tc='d'),cp.matrix(b,tc='d'))
print(sol['x'],sol['primal objective'])
```

```
     pcost       dcost       gap    pres   dres   k/t
 0:  6.3199e+00  1.0259e+01  2e+01  5e-01  1e+01  1e+00
 1:  7.1245e+00  9.5250e+00  7e+00  2e-01  4e+00  1e+00
 2:  9.5893e+00  1.0482e+01  3e+00  6e-02  1e+00  6e-01
 3:  1.0185e+01  1.0198e+01  7e-02  1e-03  3e-02  6e-03
 4:  1.0200e+01  1.0200e+01  7e-04  1e-05  3e-04  6e-05
 5:  1.0200e+01  1.0200e+01  7e-06  1e-07  3e-06  6e-07
 6:  1.0200e+01  1.0200e+01  7e-08  1e-09  3e-08  6e-09
Optimal solution found.
[ 6.00e-01]
[ 1.20e+00]
[ 1.02e+01]
 10.19999998544809
```

Question 2

```
# Objective Function = 2t12 + 3t13 + 3t15 + 2t23 + 4t24 + 1t34 + 2t35 + 3t46 + 1t56
# t12 + t13 + t15 = 1 (node 1)
# t12 - t24 - t23 = -3 (node 2)
# t13 + t23 - t34 - t35 = 0 (node 3)
# t24 + t34 - t46 = 0 (node 4)
# t15 + t35 - t56 = 0 (node 5)
# t46 + t56 = 4 (node 6)
# t12, t13, t15, t23, t24, t34, t35, t46, t56 >= 0

c = np.array([[2.0],[3.0],[3.0],[2.0],[4.0],[1.0],[2.0],[3.0],[1.0]], dtype=np.float64)
A = np.array([
    [1, 1, 1, 0, 0, 0, 0, 0, 0],
    [-1, -1, -1, 0, 0, 0, 0, 0, 0],
    [1, 0, 0, -1, -1, 0, 0, 0, 0],
    [-1, 0, 0, 1, 1, 0, 0, 0, 0],
    [0, 1, 0, 1, 0, -1, -1, 0, 0],
    [0, -1, 0, -1, 0, 1, 1, 0, 0],
    [0, 0, 0, 0, 1, 1, 0, -1, 0],
    [0, 0, 0, 0, -1, -1, 0, 1, 0],
    [0, 0, 1, 0, 0, 0, 1, 0, -1],
    [0, 0, -1, 0, 0, 0, -1, 0, 1],
    [0, 0, 0, 0, 0, 0, 0, 1, 1],
    [0, 0, 0, 0, 0, 0, 0, -1,-1],
    [-1, 0, 0, 0, 0, 0, 0, 0, 0],
    [0, -1, 0, 0, 0, 0, 0, 0, 0],
    [0, 0, -1, 0, 0, 0, 0, 0, 0],
    [0, 0, 0, -1, 0, 0, 0, 0, 0],
    [0, 0, 0, 0, -1, 0, 0, 0, 0],
    [0, 0, 0, 0, 0, -1, 0, 0, 0],
    [0, 0, 0, 0, 0, 0, -1, 0, 0],
    [0, 0, 0, 0, 0, 0, 0, -1, 0],
    [0, 0, 0, 0, 0, 0, 0, 0, -1]

])

b = np.array([[1], [-1], [-3], [3], [0], [0], [0], [0], [0], [0], [4], [-4], [0],
              [0], [0], [0], [0], [0], [0], [0], [0]], dtype=np.float64)
sol = cp.solvers.lp(cp.matrix(c,tc='d'), cp.matrix(A,tc='d'),cp.matrix(b,tc='d'))
print(sol['x'],sol['primal objective'])
```

```
     pcost       dcost       gap    pres   dres   k/t
 0:  1.6755e+01  1.6755e+01  1e+02  1e+00  9e-01  1e+00
 1:  1.9879e+01  2.0379e+01  1e+01  2e-01  1e-01  7e-01
 2:  1.9159e+01  1.9241e+01  2e+00  3e-02  2e-02  1e-01
 3:  1.9002e+01  1.9003e+01  2e-02  3e-04  3e-04  1e-03
 4:  1.9000e+01  1.9000e+01  2e-04  3e-06  3e-06  1e-05
 5:  1.9000e+01  1.9000e+01  2e-06  3e-08  3e-08  1e-07
Optimal solution found.
[-8.62e-09]
[ 1.27e-08]
[ 1.00e+00]
[ 3.00e+00]
[-1.26e-08]
[ 2.48e-07]
```

```
      [ 3.00e+00]
      [ 2.36e-07]
      [ 4.00e+00]
       19.00000016093491
```

Question 3

```
c = np.array([[5.0],[1.0],[1.0],[2.0],[4.0]])
A = np.array([[-1, 0, 0, 0, 0],
           [ 0,-1, 0, 0, 0],
            [ 0, 0,-1, 0, 0],
            [ 0, 0, 0,-1, 0],
            [ 0, 0, 0, 0,-1],
            [ 1, 0, 0, 0, 0],
            [ 0, 1, 0, 0, 0],
            [ 0, 0, 1, 0, 0],
            [ 0, 0, 0, 1, 0],
            [ 0, 0, 0, 0, 1]])

b = np.array([[0],[0],[0],[0],[0],[3],[1],[2],[3],[2]])

Aeq = np.array([[ 1 ,  1,  0 ,  0,  0],
              [ 0 , -1,  1 ,  0,  1],
              [-1 ,  0, -1 ,  1,  0],
              [ 0 ,  0,  0 , -1, -1]])

beq = np.array([[2],[2],[-2],[-2]])

sol = cp.solvers.lp(cp.matrix(c,tc='d'), cp.matrix(A,tc='d'),cp.matrix(b,tc='d'),
                    cp.matrix(Aeq,tc='d'),cp.matrix(beq,tc='d'), solver = 'glpk')

print(sol['x'],sol['primal objective'])
print("Minimum value of objective function = ",sol['primal objective'])
```

```
     [ 1.00e+00]
     [ 1.00e+00]
     [ 2.00e+00]
     [ 1.00e+00]
     [ 1.00e+00]
      14.0
     Minimum value of objective function =  14.0
```

Question 4

```
c=np.array([[4.0],[6.0],[6.0],[6.0],[8.0],[9.0],[5.0],[4.0],[6.0],[5.0],
            [5.0],[7.0],[6.0],[8.0],[4.0],[9.0],[3.0],[7.0],[9.0],[6.0]])
b=np.zeros((20, 1))
A=np.negative(np.identity(20,dtype='int'))
Aeq=np.array([[ 1 ,  1,  1 ,  0,  0,  0,  0,  0,  0, 0, 0 ,
               0,  0 ,  0,  0,  0,  0,  0,  0, 0],
              [-1 ,  0,  0 ,  1,  1,  1,  0,  0,
```

```
                 0, 0, 0 ,  0,  0 ,  0,  0,  0,  0,  0,  0, 0],
                [ 0 , -1,  0 ,  0,  0,  0,  1,  1,
                 1, 0, 0 ,  0,  0 ,  0,  0,  0,  0,  0,  0, 0],
                [ 0 ,  0, -1 ,  0,  0,  0,  0,  0,
                 0, 1, 1 ,  1,  0 ,  0,  0,  0,  0,  0,  0, 0],
                [ 0 ,  0,  0 , -1,  0,  0, -1,  0,
                 0,-1, 0 ,  0,  1 ,  1,  0,  0,  0,  0,  0, 0],
                [ 0 ,  0,  0 ,  0, -1,  0,  0, -1,
                 0, 0,-1 ,  0,  0 ,  0,  1,  1,  0,  0,  0, 0],
                [ 0 ,  0,  0 ,  0,  0, -1,  0,  0,
                 -1, 0, 0 , -1,  0 ,  0,  0,  0,  1,  1,  0, 0],
                [ 0 ,  0,  0 ,  0,  0,  0,  0,  0,
                 0, 0, 0 ,  0, -1 ,  0, -1,  0, -1,  0,  1, 0],
                [ 0 ,  0,  0 ,  0,  0,  0,  0,  0,
                 0, 0, 0 ,  0,  0 , -1,  0, -1,  0, -1,  0, 1],
                [ 0 ,  0,  0 ,  0,  0,  0,  0,  0,
                 0, 0, 0 ,  0,  0 ,  0,  0,  0,  0,  0, -1,-1],
                ])
beq=np.array([[1],
              [0],
              [0],
              [0],
              [0],
              [0],
              [0],
              [0],
              [0],
              [0],
              [-1]
              ])
sol =cp.solvers.lp(cp.matrix(c,tc='d'),cp.matrix(A,tc='d'),cp.matrix(b,tc='d'),
                   cp.matrix(Aeq,tc='d'),cp.matrix(beq,tc='d'),solver='glpk')

print(sol['x'],sol['primal objective'])
print("Minimum value of objective function is :",sol['primal objective'])
```

```
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
      23.0
     Minimum value of objective function is : 23.0
```

Question 5

```
c=np.array([20,28,19,13,15,30,31,28,40,21,20,17,21,28,26,12])
b=np.zeros((16, 1))
A=np.negative(np.identity(16,dtype='int'))
beq=np.array([[1],[1],[1],[1],[-1],[-1],[-1],[-1]])
Aeq=np.array([[1,0,0,0,1,0,0,0,1,0,0,0,1,0,0,0],
            [0,1,0,0,0,1,0,0,0,1,0,0,0,1,0,0],
            [0,0,1,0,0,0,1,0,0,0,1,0,0,0,1,0],
            [0,0,0,1,0,0,0,1,0,0,0,1,0,0,0,1],
            [-1,-1,-1,-1,0,0,0,0,0,0,0,0,0,0,0,0],
            [0,0,0,0,-1,-1,-1,-1,0,0,0,0,0,0,0,0],
            [0,0,0,0,0,0,0,0,-1,-1,-1,-1,0,0,0,0],
            [0,0,0,0,0,0,0,0,0,0,0,0,-1,-1,-1,-1]])

sol = cp.solvers.lp(cp.matrix(c, tc = 'd'), cp.matrix(A, tc = 'd'),
                    cp.matrix(b, tc = 'd'), cp.matrix(Aeq, tc = 'd'),
                    cp.matrix(beq, tc = 'd'), solver = 'glpk')
print(sol['x'],sol['primal objective'])
print("Minimum value of objective function = ",sol['primal objective'])
```

```
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
      67.0
     Minimum value of objective function =  67.0
```

Question 6

```
c=np.array([37.7,32.9,33.8,37.0,35.4,43.4,33.1,42.2,34.7,41.8,33.3,
            28.5,38.9,30.4,33.6,29.2,26.4,29.6,28.5,31.1,0,0,0,0,0])
b=np.zeros((25, 1))
A=np.negative(np.identity(25,dtype='int'))
beq=np.array([[1],[1],[1],[1],[1],[-1],[-1],[-1],[-1],[-1]])

Aeq=np.array([
              [1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0],
              [0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0],
```

```
                [0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0],
                [0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0],
                [0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1,0,0,0,0,1],
                [-1,-1,-1,-1,-1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0],
                [0,0,0,0,0,-1,-1,-1,-1,-1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0],
                [0,0,0,0,0,0,0,0,0,0,-1,-1,-1,-1,-1,0,0,0,0,0,0,0,0,0,0],
                [0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,-1,-1,-1,-1,0,0,0,0,0],
                [0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,-1,-1,-1,-1]
    ])


    sol =cp.solvers.lp(cp.matrix(c,tc='d'),cp.matrix(A,tc='d'),cp.matrix(b,tc='d'),
                       cp.matrix(Aeq,tc='d'),cp.matrix(beq,tc='d'),solver='glpk')

    print(sol['x'],sol['primal objective'])

    print("Minimum value of objective function is :",sol['primal objective'])
```

```
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 0.00e+00]
     [ 1.00e+00]
      126.2
    Minimum value of objective function is : 126.2
```

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