No.

Date

2023/3/28.

Assignment 4.

1.

~~五~~. 原问题是凸的, 因为:

obj: $(x_1+x_2)^2 + x_2^2 + x_3^2 + (3x_1 - 4x_2)$.

cons1: $\sqrt{(\sqrt{2}x_1 + \frac{1}{2\sqrt{2}}x_2)^2 + \frac{31}{8}x_2^2 + 4} + \frac{(x_1-x_2+x_3+1)^2}{(x_1+x_2)} \le 6$.

仿射复合　　　　仿射复合

cons2: $x \ge 1$.

~~五~~.

2. 原问题是凸的, 因为:

①. obj 与其后几个 constraints 均为凸, 这显然.

②. 对于约束1: 因为已经有另一约束: $x \ge 0$.

所以 $(x_3+2x_4)^4 = \cancel{((x_3+2x_4))^2}$, 其中 $(\cdot)^4$ 为凸的, 且在 $[0,+\infty)$ 单调↑

而且 (x_3+2x_4) 在其他约束

③. 对于约束1, 作如下说明:

1° 因为 $f(x) = x_3+2x_4$ 为仿射, $g(x) = x^4$ 为凸

故 $g(f(x)) = (x_3+2x_4)^4$ 为凸.

2° 同理, 因为 $f(x) = x_1-x_2$ 为仿射, $g(x) = x^2$ 为凸

故 $g(f(x)) = (x_1-x_2)^2$ 也为凸.

3. 原问题是凸的，因为:

①. 对于目标函数:

$|2x_1+3x_2+x_3|$ 由于仿射复合，故为凸;

$\|x\|^2$ 由于单调复合 ($\|x\|$ 恒 ≥ 0)，故为凸.

$$\sqrt{2x_1^2+4x_1x_2+7x_2^2+10x_2+6} = \sqrt{2(x_1+x_2)^2+5(x_2+1)^2+1} = \left\|\begin{bmatrix}\sqrt{2}(x_1+x_2)\\ \sqrt{5}(x_2+1)\\ 1\end{bmatrix}\right\|_2$$，故为凸.

②. 对于约束:

约束1: 令 quad-over-linear 函数 $f(x,y) \triangleq \frac{x^Tx}{y}$，其中 $y>0$.

故原式 $\Leftrightarrow f([x_1,1],x_2)+2(x_1+x_2+\frac{1}{2}x_3)^2+3x_2^2+\frac{19}{2}x_3^2 \le 7$ 为凸. (因为约束4已要求 $x_2\ge 1>0$).

约束2: 因为 x_1+x_2, x_3, x_1-x_3 均为仿射(即凸)

故"逐点最大值": $\max\{x_1+x_2,\ x_3,\ x_1-x_3\}\le 19$ 也为凸.

4. 原问题是凸的，因为:

①. 对于目标函数:

第一项 $=\|[\sqrt{2}(x_1+x_3),\ x_2,\ x_3,\ \sqrt{7}]\|_2$ $\Rightarrow$ 由仿射复合，第一项为凸.

第二项 $=f(g(x))$，其中 $g(x)=x_1^2+x_2^2+x_3^2+1$ 为凸且恒正
$f(x)=x^2$ 为凸且在 $[0,+\infty)$ 上单调↑. } $\Rightarrow$ 第二项为凸.

故目标函数为凸

②. 对于约束:

约束1 $\Leftrightarrow$ quad-over-lin$(x_1+x_2,\ x_3+1) + x_1^8 \le 7$.

其中由约束4: $x\ge 0$ 得 x_3+1 必定 >0; 而 x_1^8 由仿射复合为凸.

约束2 $\Leftrightarrow (x_1+x_2+x_3)^2+3x_3^2\le 10$，由仿射复合为凸.

约束3 $\Leftrightarrow f(g(x))$，其中 $g(x)=|x_1+x_2-x_3|$ 为凸且恒 ≥ 0 (由于仿射复合).
$f(x)=x^2$ 为凸且在 $[0,+\infty)$ 上单调↑

故约束也均为凸.

5. 原问题是凸的因为：

① 对于目标函数：

1° $\frac{x_1^4}{x_2^2}+\frac{x_2^4}{x_1^2}+2x_1x_2=\left(\frac{x_1^2}{x_2}+\frac{x_2^2}{x_1}\right)^2$，而 $\frac{x_1^2}{x_2}$ 与 $\frac{x_2^2}{x_1}$ 均为 quadratic-over-linear 与仿射复合，均为凸

且由约束 3, 4，~~恒~~ 二者均恒正，故由单调复合，上式为凸.

2° $|x_i+x_j|$ $(1\le i<j\le 3)$ 由仿射复合，必为凸.

②. 对于约束：

约束1：第一项记为 $f(g(h(x)))$

其中 $h(x)=x_1^2+x_2^2+x_3^2+1$ 为凸且恒正

$g(x)=x^2+1$ 为凸且在 $x\ge 0$ 单调↑

故 $g(h(x))$ 为凸，且恒正.

又因为 $f(x)=x^2$ 为凸且在 $x\ge 0$ 单调↑，故 $f(g(h(x)))$ 为凸.

约束2：$\max\{(x_1+2x_2)^2+5x_2^2,\ x_1,\ x_2\}\le 4$.

其中 $(x_1+2x_2)^2+5x_2^2$ 为凸，x_1, x_2 均仿射，故整体为凸.

6. 原问题是凸的，因为：

“maximum margin line” $\Leftrightarrow$ 找到支持向量机中的超平面.

即找到 $H(w,\beta)=\{x\in\mathbb{R}^2: w^Tx+\beta=0\}$. 满足以下优化问题.

$$\max_{w,\beta}\ \min_{i=1,\dots,m+p}\frac{|w^Tx_i+\beta|}{\|w\|_2}$$，其中 $x_i\ (1\le i\le m+p)$ 为 $(m+p)$ 个样本点.

$$\text{s.t.}\quad w^Tx_i+\beta>0,\ i=1,2,\dots m.$$

$$w^Tx_i+\beta<0,\ i=m+1,\dots m+p.$$

该优化问题 $\Leftrightarrow$ $\min \frac{1}{2}\|w\|_2^2$

$$\text{s.t.}\quad b_i\cdot(w^Tx_i+\beta)\geq 1,\ i=1,2,\dots m+p.$$

这个等价的优化问题是凸问题. 故原问题也是一个凸问题.

Assignment 04 - 21307140003(Qirun Dai)

Table of Contents

Problem 01

```
cvx_begin
    variable x(3);
    obj = (x(1)+x(2))^2 + x(2)^2 + x(3)^2 + 3*x(1) - 4*x(2);
    a = [sqrt(2)*(x(1)+0.25*x(2)), sqrt(31/8)*x(2), 2];

    minimize( obj );
    subject to
        norm( a ) + quad_over_lin( x(1)-x(2)+x(3)+1, x(1)+x(2) ) <= 6;
        x >= 1;
cvx_end

fprintf('Optimal solution is:')
x
```

```
Calling SeDuMi 1.3.4: 20 variables, 8 equality constraints
   For improved efficiency, SeDuMi is solving the dual problem.
------------------------------------------------------------
SeDuMi 1.3.4 by AdvOL, 2005-2008 and Jos F. Sturm, 1998-2003.
Alg = 2: xz-corrector, Adaptive Step-Differentiation, theta = 0.250, beta =
 0.500
eqs m = 8, order n = 15, dim = 21, blocks = 6
nnz(A) = 28 + 0, nnz(ADA) = 34, nnz(L) = 21
 it :     b*y       gap    delta  rate   t/tP*  t/tD*   feas cg cg  prec
  0 :            1.62E+01 0.000
  1 :   3.11E+00 5.39E+00 0.000 0.3322 0.9000 0.9000   1.97  1  1  1.8E+00
  2 :  -1.31E+00 2.00E+00 0.000 0.3714 0.9000 0.9000   0.83  1  1  1.7E+00
  3 :  -1.99E+00 4.00E-01 0.000 0.1996 0.9000 0.9000   1.17  1  1  4.4E-01
  4 :  -1.94E+00 8.76E-02 0.000 0.2190 0.9000 0.9000   1.30  1  1  7.9E-02
  5 :  -2.00E+00 3.34E-03 0.000 0.0382 0.9900 0.9900   1.09  1  1  2.8E-03
  6 :  -2.00E+00 2.50E-07 0.314 0.0001 1.0000 1.0000   1.00  1  1  2.1E-07
  7 :  -2.00E+00 8.94E-09 0.496 0.0358 0.9904 0.9900   1.00  3  3  7.7E-09

iter seconds digits       c*x               b*y
```

```
  7      0.0   8.0 -1.9999999750e+00 -1.9999999941e+00
|Ax-b| =   2.4e-09, [Ay-c]_+ =   3.6E-09, |x|=  8.6e+00, |y|=  5.3e+00

Detailed timing (sec)
   Pre          IPM          Post
7.001E-03    2.900E-02    2.002E-03
Max-norms: ||b||=3, ||c|| = 6,
Cholesky |add|=1, |skip| = 0, ||L.L|| = 4.00025.
------------------------------------------------------------
Status: Solved
Optimal value (cvx_optval): +5

Optimal solution is:
x =

    1.0000
    1.0000
    1.0000
```

Problem 02

```
cvx_begin
    variable x(4);
    minimize ( x(1)+x(2)+x(3)+x(4) );
    subject to
        (x(1) - x(2))^2 + (x(3)+2*x(4))^4 <= 5;
        x(1) + 2*x(2) + 3*x(3) + 4*x(4) <= 6;
        x >= 0;
cvx_end

fprintf('Optimal solution is:')
x
```

```
Calling SeDuMi 1.3.4: 15 variables, 8 equality constraints
------------------------------------------------------------
SeDuMi 1.3.4 by AdvOL, 2005-2008 and Jos F. Sturm, 1998-2003.
Alg = 2: xz-corrector, Adaptive Step-Differentiation, theta = 0.250, beta =
 0.500
eqs m = 8, order n = 13, dim = 16, blocks = 4
nnz(A) = 27 + 0, nnz(ADA) = 44, nnz(L) = 26
 it :     b*y       gap    delta  rate   t/tP*  t/tD*   feas cg cg  prec
  0 :            9.02E+00 0.000
  1 :  -1.02E+00 3.03E+00 0.000 0.3363 0.9000 0.9000   2.71  1  1  2.2E+00
  2 :  -7.10E-01 1.02E+00 0.000 0.3376 0.9000 0.9000   1.82  1  1  1.1E+00
  3 :  -1.73E-01 2.10E-01 0.000 0.2047 0.9000 0.9000   1.30  1  1  4.8E-01
  4 :  -4.19E-03 6.16E-03 0.000 0.0294 0.9900 0.9900   1.05  1  1  4.7E-01
  5 :  -1.13E-08 1.43E-08 0.000 0.0000 1.0000 1.0000   1.00  1  1  4.1E-06
  6 :   8.28E-15 4.71E-15 0.000 0.0000 1.0000 1.0000   1.00  1  1  9.3E-13

iter seconds digits       c*x               b*y
  6      0.0   Inf  1.8159556866e-16  8.2757120847e-15
```

```
|Ax-b| =   1.2e-14, [Ay-c]_+ =   1.2E-15, |x|=  6.6e+00, |y|=  1.4e+00

Detailed timing (sec)
   Pre          IPM          Post
6.991E-03    2.100E-02    1.006E-03
Max-norms: ||b||=6, ||c|| = 2,
Cholesky |add|=0, |skip| = 0, ||L.L|| = 1.
------------------------------------------------------------
Status: Solved
Optimal value (cvx_optval): +1.81596e-16

Optimal solution is:
x =

   1.0e-14 *

    0.0406
    0.0648
    0.0662
   -0.1534
```

Problem 03

```
cvx_begin
    variable x(3)
    obj1 = abs(2*x(1) + 3*x(2) + x(3));
    obj2 = square_pos(norm(x));
    obj3 = norm([sqrt(2)*(x(1)+x(2)), sqrt(5)*(x(2)+1), 1]);

    minimize (obj1 + obj2 + obj3)
    subject to
        quad_over_lin([x(1), 1], x(2)) + 2*(x(1)+x(2)+0.5*x(3))^2 + 3*x(2)^2 +
 19/2*x(3)^2 <= 7;
        max([x(1)+x(2), x(3), x(1)-x(3)]) <= 19;
        x(1) >= 0;
        x(2) >= 1;
cvx_end

fprintf('Optimal solution is:')
x
```

```
Calling SeDuMi 1.3.4: 35 variables, 14 equality constraints
   For improved efficiency, SeDuMi is solving the dual problem.
------------------------------------------------------------
SeDuMi 1.3.4 by AdvOL, 2005-2008 and Jos F. Sturm, 1998-2003.
Alg = 2: xz-corrector, Adaptive Step-Differentiation, theta = 0.250, beta =
 0.500
eqs m = 14, order n = 26, dim = 36, blocks = 8
nnz(A) = 58 + 0, nnz(ADA) = 98, nnz(L) = 56
 it :     b*y       gap    delta  rate   t/tP*  t/tD*   feas cg cg  prec
  0 :            3.35E+01 0.000
```

```
  1 :  -2.45E-02 1.24E+01 0.000 0.3694 0.9000 0.9000   2.89  1  1  3.0E+00
  2 :  -1.42E+00 5.03E+00 0.000 0.4066 0.9000 0.9000   1.60  1  1  1.3E+00
  3 :  -4.41E+00 2.11E+00 0.000 0.4202 0.9000 0.9000   0.85  1  1  8.0E-01
  4 :  -6.95E+00 6.15E-01 0.000 0.2908 0.9000 0.9000   0.64  1  1  2.4E-01
  5 :  -8.03E+00 1.64E-01 0.000 0.2669 0.9000 0.9000   0.83  1  1  6.8E-02
  6 :  -8.45E+00 3.34E-02 0.000 0.2037 0.9000 0.9000   1.02  1  1  1.4E-02
  7 :  -8.53E+00 8.13E-03 0.000 0.2432 0.9008 0.9000   1.06  1  1  3.3E-03
  8 :  -8.53E+00 1.21E-05 0.133 0.0015 0.9000 0.0000   1.03  1  1  9.0E-04
  9 :  -8.54E+00 1.39E-06 0.000 0.1146 0.9153 0.9000   1.01  1  1  1.4E-04
 10 :  -8.55E+00 1.13E-07 0.000 0.0814 0.9900 0.9902   1.02  1  1  1.2E-05
 11 :  -8.55E+00 8.99E-09 0.124 0.0794 0.9900 0.9548   1.00  2  3  9.3E-07
 12 :  -8.55E+00 1.55E-09 0.175 0.1730 0.9104 0.9000   1.00  1  3  1.5E-07
 13 :  -8.55E+00 4.54E-10 0.130 0.2919 0.9240 0.9000   1.00  3  3  4.1E-08
 14 :  -8.55E+00 2.11E-11 0.000 0.0465 0.7911 0.9900   1.00  3  3  2.4E-09

iter seconds digits       c*x               b*y
 14      0.0   Inf -8.5505013425e+00 -8.5505013094e+00
|Ax-b| =   6.1e-10, [Ay-c]_+ =   1.3E-08, |x|=  9.5e+00, |y|=  8.6e+00

Detailed timing (sec)
   Pre          IPM          Post
7.001E-03    3.100E-02    9.958E-04
Max-norms: ||b||=1, ||c|| = 19,
Cholesky |add|=1, |skip| = 0, ||L.L|| = 3.
------------------------------------------------------------
Status: Solved
Optimal value (cvx_optval): +8.5505

Optimal solution is:
x =

   -0.0000
    1.0000
   -0.4317
```

Problem 04

```
cvx_begin
    variable x(3)
    obj1 = norm([sqrt(2)*(x(1)+x(2)), x(2), x(3), sqrt(7)]);
    obj2 = square_pos(x(1)^2 + x(2)^2 + x(3)^2 + 1);

    minimize (obj1 + obj2);
    subject to
        quad_over_lin(x(1)+x(2), x(3)+1) + x(1)^8 <= 7;
        (x(1) + x(2) + x(3))^2 + 3*x(3)^2 <= 10;
        square_pos(abs(x(1)+x(2)-x(3))) <= 20;
        x >= 0;
cvx_end

fprintf('Optimal solution is:')
x
```

```
Calling SeDuMi 1.3.4: 50 variables, 20 equality constraints
   For improved efficiency, SeDuMi is solving the dual problem.
------------------------------------------------------------
SeDuMi 1.3.4 by AdvOL, 2005-2008 and Jos F. Sturm, 1998-2003.
Alg = 2: xz-corrector, Adaptive Step-Differentiation, theta = 0.250, beta =
 0.500
eqs m = 20, order n = 37, dim = 51, blocks = 13
nnz(A) = 77 + 0, nnz(ADA) = 128, nnz(L) = 76
 it :     b*y       gap    delta  rate   t/tP*  t/tD*   feas cg cg  prec
  0 :            2.11E+01 0.000
  1 :   2.92E+00 9.20E+00 0.000 0.4358 0.9000 0.9000   3.26  1  1  2.0E+00
  2 :  -1.09E+00 4.60E+00 0.000 0.5000 0.9000 0.9000   2.30  1  1  8.6E-01
  3 :  -2.46E+00 1.14E+00 0.000 0.2477 0.9000 0.9000   1.73  1  1  2.3E-01
  4 :  -2.89E+00 5.58E-01 0.000 0.4899 0.9000 0.9000   0.82  1  1  1.2E-01
  5 :  -3.32E+00 2.05E-01 0.000 0.3663 0.9000 0.9000   0.89  1  1  4.6E-02
  6 :  -3.51E+00 7.47E-02 0.000 0.3653 0.9000 0.9000   0.89  1  1  1.8E-02
  7 :  -3.64E+00 5.25E-03 0.000 0.0702 0.9900 0.9900   1.01  1  1  1.3E-03
  8 :  -3.64E+00 7.16E-06 0.000 0.0014 0.9000 0.0000   1.01  1  1  3.5E-04
  9 :  -3.64E+00 1.58E-06 0.000 0.2213 0.9105 0.9000   1.01  1  1  7.6E-05
 10 :  -3.64E+00 4.12E-07 0.000 0.2598 0.9056 0.9000   1.01  1  1  1.9E-05
 11 :  -3.65E+00 1.26E-07 0.000 0.3048 0.9035 0.9000   1.01  1  1  5.6E-06
 12 :  -3.65E+00 2.61E-08 0.000 0.2083 0.9000 0.9010   1.00  1  1  1.4E-06
 13 :  -3.65E+00 8.91E-09 0.000 0.3409 0.9000 0.9000   1.00  1  1  4.7E-07
 14 :  -3.65E+00 2.52E-09 0.000 0.2829 0.9057 0.9000   1.00  1  1  1.3E-07
 15 :  -3.65E+00 6.84E-10 0.000 0.2715 0.9000 0.9016   1.00  1  1  3.5E-08
 16 :  -3.65E+00 1.79E-10 0.000 0.2615 0.9000 0.8956   1.00  1  1  9.5E-09

iter seconds digits       c*x               b*y
 16      0.0   Inf -3.6457509415e+00 -3.6457509267e+00
|Ax-b| =   7.4e-09, [Ay-c]_+ =   4.4E-08, |x|=  4.2e+00, |y|=  9.2e+00

Detailed timing (sec)
   Pre          IPM          Post
7.996E-03    2.701E-02    9.958E-04
Max-norms: ||b||=1, ||c|| = 2.100000e+01,
Cholesky |add|=0, |skip| = 0, ||L.L|| = 2297.59.
------------------------------------------------------------
Status: Solved
Optimal value (cvx_optval): +3.64575

Optimal solution is:
x =

   1.0e-04 *

    0.8288
    0.7660
    0.8844
```

Problem 05

```
cvx_begin
    variable x(3)
    obj0 = square_pos(quad_over_lin(x(1), x(2)) + quad_over_lin(x(2), x(1)));
    obj1 = abs(x(1)+5);
    obj2 = abs(x(2)+5);
    obj3 = abs(x(3)+5);

    minimize( obj0 + obj1 + obj2 + obj3 )
    subject to
        square_pos(square_pos(x(1)^2 + x(2)^2 + x(3)^2 + 1) + 1) + x(1)^4 +
 x(2)^4 + x(3)^4 <= 200;
        max([(x(1)+2*x(2))^2 + 5*x(2)^2, x(1), x(2)]) <= 40;
        x(1) >= 1;
        x(2) >= 1;
cvx_end

fprintf('Optimal solution is:')
x
```

```
Calling SeDuMi 1.3.4: 67 variables, 29 equality constraints
   For improved efficiency, SeDuMi is solving the dual problem.
------------------------------------------------------------
SeDuMi 1.3.4 by AdvOL, 2005-2008 and Jos F. Sturm, 1998-2003.
Alg = 2: xz-corrector, Adaptive Step-Differentiation, theta = 0.250, beta =
 0.500
eqs m = 29, order n = 52, dim = 68, blocks = 17
nnz(A) = 108 + 0, nnz(ADA) = 163, nnz(L) = 108
 it :     b*y       gap    delta  rate   t/tP*  t/tD*   feas cg cg  prec
  0 :            7.88E+01 0.000
  1 :   3.79E+01 2.74E+01 0.000 0.3480 0.9000 0.9000   3.83  1  1  1.9E+00
  2 :   4.52E+00 8.91E+00 0.000 0.3249 0.9000 0.9000   1.73  1  1  6.1E-01
  3 :  -8.92E+00 2.99E+00 0.000 0.3355 0.9000 0.9000   1.51  1  1  2.5E-01
  4 :  -1.37E+01 9.85E-01 0.000 0.3295 0.9000 0.9000   1.20  1  1  6.8E-02
  5 :  -1.52E+01 4.53E-01 0.000 0.4594 0.9000 0.9000   0.63  1  1  4.1E-02
  6 :  -1.64E+01 2.67E-01 0.000 0.5894 0.9000 0.9000   0.36  1  1  3.0E-02
  7 :  -1.73E+01 1.58E-01 0.000 0.5932 0.9000 0.9000   0.28  1  1  2.4E-02
  8 :  -1.90E+01 5.35E-02 0.000 0.3378 0.9000 0.9000   0.66  1  1  9.8E-03
  9 :  -1.97E+01 2.17E-02 0.000 0.4062 0.9000 0.9000   0.63  1  1  5.1E-03
 10 :  -2.01E+01 4.97E-03 0.000 0.2290 0.9000 0.9000   0.96  1  1  1.2E-03
 11 :  -2.02E+01 2.14E-04 0.000 0.0430 0.9900 0.9900   1.00  1  1  6.3E-05
 12 :  -2.02E+01 8.71E-09 0.334 0.0000 0.9000 0.0000   1.00  1  1  1.1E-05
 13 :  -2.02E+01 2.75E-10 0.000 0.0316 0.9908 0.9900   1.00  1  1  5.4E-07
 14 :  -2.02E+01 5.02E-11 0.000 0.1827 0.4775 0.9000   1.00  3  3  1.2E-07
 15 :  -2.02E+01 1.33E-11 0.000 0.2656 0.7800 0.9000   1.00  3  3  3.3E-08
 16 :  -2.02E+01 1.17E-12 0.000 0.0879 0.9900 0.9900   1.00  3  3  2.9E-09

iter seconds digits       c*x               b*y
 16      0.0   Inf -2.0216691566e+01 -2.0216691426e+01
|Ax-b| =   8.6e-10, [Ay-c]_+ =   1.5E-07, |x|=  1.4e+01, |y|=  2.0e+01
```

```
Detailed timing (sec)
   Pre          IPM          Post
7.001E-03    3.300E-02    2.002E-03
Max-norms: ||b||=1, ||c|| = 2.010000e+02,
Cholesky |add|=1, |skip| = 0, ||L.L|| = 61.4277.
------------------------------------------------------------
Status: Solved
Optimal value (cvx_optval): +20.2167

Optimal solution is:
x =

    1.0000
    1.0000
   -0.7833
```

Problem 06

```
rand('seed',21307140003);
x=rand(40,1);
y=rand(40,1);
class=[2*x<y+0.5]+1;
A1=[x(find(class==1)),y(find(class==1))];
A2=[x(find(class==2)),y(find(class==2))];
plot(A1(:,1),A1(:,2),'*','MarkerSize',6)
hold on
plot(A2(:,1),A2(:,2),'d','MarkerSize',6)
hold on

x = [A1; A2];   % The set of all points.
b = [ones(21,1); -1*ones(19,1)];    % The set of corresponding labels.
cvx_begin
    variable w(3);
    minimize ( 0.5*(w(1)^2 + w(2)^2) );
    subject to
        for i=1:40
            b(i)*([w(1), w(2)]*x(i,:)' + w(3)) >= 1;
        end
cvx_end

fplot(@(x) -1/w(2)*(w(1)*x+w(3)), [0,1])
hold off
fprintf('The maximum-margin line is: %fx+%fy+%f = 0\n', w(1), w(2), w(3));

fprintf('Optimal solution is:')
w
```

```
Calling SeDuMi 1.3.4: 46 variables, 5 equality constraints
   For improved efficiency, SeDuMi is solving the dual problem.
------------------------------------------------------------
SeDuMi 1.3.4 by AdvOL, 2005-2008 and Jos F. Sturm, 1998-2003.
```

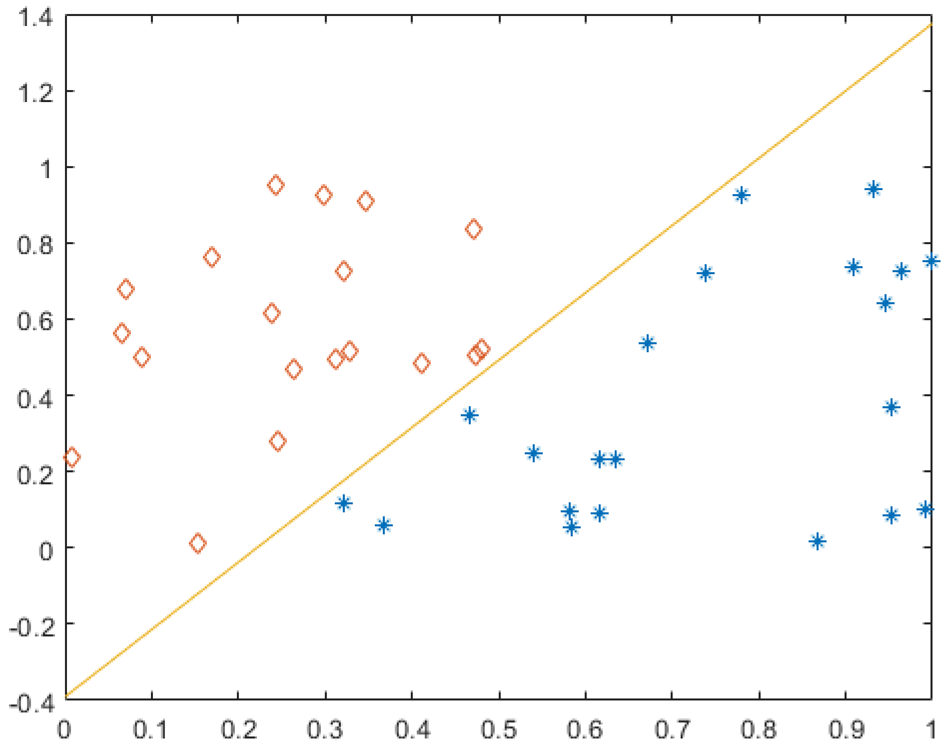
```
Alg = 2: xz-corrector, Adaptive Step-Differentiation, theta = 0.250, beta =
 0.500
eqs m = 5, order n = 45, dim = 47, blocks = 3
nnz(A) = 126 + 0, nnz(ADA) = 15, nnz(L) = 10
 it :     b*y       gap    delta  rate   t/tP*  t/tD*   feas cg cg  prec
  0 :            4.23E+00 0.000
  1 :  -5.63E+00 1.87E+00 0.000 0.4422 0.9000 0.9000  -3.36  1  1  4.4E+01
  2 :  -1.95E+01 7.10E-01 0.000 0.3793 0.9000 0.9000  -0.95  1  1  1.6E+01
  3 :  -4.86E+01 2.45E-01 0.000 0.3453 0.9000 0.9000   0.75  1  1  7.8E+00
  4 :  -1.02E+02 9.34E-02 0.000 0.3809 0.9000 0.9000  -0.15  1  1  5.8E+00
  5 :  -1.85E+02 4.04E-02 0.000 0.4322 0.9000 0.9000  -0.25  1  1  4.4E+00
  6 :  -3.51E+02 1.19E-02 0.000 0.2958 0.9000 0.9000   0.00  1  1  2.0E+00
  7 :  -4.62E+02 3.66E-03 0.000 0.3062 0.9000 0.9000   0.36  1  1  8.1E-01
  8 :  -5.47E+02 1.15E-04 0.000 0.0315 0.9900 0.9900   0.78  1  1  2.8E-02
  9 :  -5.49E+02 3.16E-06 0.000 0.0274 0.9900 0.9900   1.01  1  1  7.6E-04
 10 :  -5.49E+02 1.54E-07 0.000 0.0487 0.9903 0.9900   1.01  1  1  3.8E-05
 11 :  -5.49E+02 4.16E-08 0.000 0.2707 0.9000 0.9052   1.00  1  1  1.0E-05
 12 :  -5.49E+02 5.96E-10 0.000 0.0143 0.9902 0.9900   1.00  1  1  1.5E-07
 13 :  -5.49E+02 1.00E-10 0.000 0.1679 0.9060 0.9000   1.00  1  1  2.5E-08
 14 :  -5.49E+02 6.31E-12 0.238 0.0631 0.9901 0.9900   1.00  1  1  1.5E-09

iter seconds digits       c*x               b*y
 14      0.0   Inf -5.4904627374e+02 -5.4904627334e+02
|Ax-b| =   7.8e-10, [Ay-c]_+ =   5.4E-10, |x|=  7.4e+02, |y|=  8.7e+02

Detailed timing (sec)
   Pre          IPM          Post
7.001E-03    2.300E-02    2.002E-03
Max-norms: ||b||=5.000000e-01, ||c|| = 1.000000e+00,
Cholesky |add|=0, |skip| = 0, ||L.L|| = 57.6688.
------------------------------------------------------------
Status: Solved
Optimal value (cvx_optval): +549.046

The maximum-margin line is: 28.833995x+-16.330747y+-6.376794 = 0
Optimal solution is:
w =

   28.8340
  -16.3307
   -6.3768
```



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