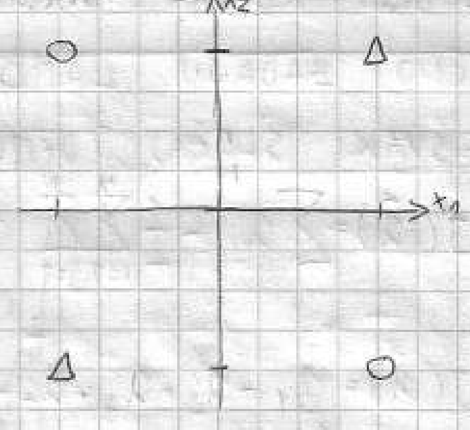
JEZGRENI SVM - XOR PRIMJER

$\omega_1 = \{[-1\ \ 1]^T, [1\ \ -1]^T\}$ o

$\omega_2 = \{[-1\ \ -1]^T, [1\ \ 1]^T\}$ Δ



JEZGRO: $K(\vec{x},\vec{x}_i) = (1+\vec{x}^T\vec{x}_i)^2$

$$\vec{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad \vec{x}_i = \begin{bmatrix} x_{i1} \\ x_{i2} \end{bmatrix}$$

$$K(\vec{x},\vec{x}_i) = \left(1 + [x_1\ \ x_2]\begin{bmatrix} x_{i1} \\ x_{i2} \end{bmatrix}\right)^2 = 1 + 2[x_1\ x_2]\begin{bmatrix} x_{i1} \\ x_{i2} \end{bmatrix} + \left([x_1\ x_2]\begin{bmatrix} x \\ x \end{bmatrix}\right.$$

$$= 1 + 2(x_1 x_{i1} + x_2 x_{i2}) + (x_1 x_{i1} + x_2 x_{i2})^2 =$$

$$1 + 2x_1x_{i1} + 2x_2x_{i2} + x_1^2 x_{i1}^2 + 2x_1x_{i1}x_2x_{i2} + x_2^2 x_{i2}^2 =$$

SLIKA ULAZNOG PROSTORA:

$$\varphi(\vec{x}) = [1, x_1^2, \sqrt{2}\, x_1x_2, x_2^2, \sqrt{2}x_1, \sqrt{2}x_2]$$

$$\varphi(\vec{x}_i) = [1, x_{i2}^2, \sqrt{2}\, x_{i1}x_{i2}, x_{i2}^2, \sqrt{2}x_{i1}, \sqrt{2}\, x_{i2}]$$

OTKUD TI ELEMENTI? $\Rightarrow \sqrt{2}\, x_1 \cdot \sqrt{2} x_{i1} = 2x_1x_{i1}$

KONSTRUIRA SE **K** MATRICA ŠTO JE ISTO KAO I Q U DUALNOM SVM U, SAMO SU PRIMJERI PROVUČENI KROZ JEZ

$$\varphi(x_1) = \varphi([-1\ \ 1]^T) = [1\ \ 1\ \ -\sqrt{2}\ \ 1\ \ -\sqrt{2}\ \ \sqrt{2}]$$

$$\varphi(x_2) = \varphi([1\ \ -1]^T) = [1\ \ 1\ \ -\sqrt{2}\ \ 1\ \ \sqrt{2}\ \ -\sqrt{2}]$$

$$\varphi(x_3) = \varphi([-1\ \ -1]^T) = [1\ \ 1\ \ \sqrt{2}\ \ 1\ \ -\sqrt{2}\ \ -\sqrt{2}]$$

$$\varphi(x_4) = \varphi([1\ \ 1]^T) = [1\ \ 1\ \ \sqrt{2}\ \ 1\ \ \sqrt{2}\ \ \sqrt{2}]$$

NPR:

$$K_{12} = \varphi(x_1)\varphi(x_2) = 1 + 1 + 2 + 1 - 2 - 2 = 1$$

$$K_{11} = \varphi(x_1)\varphi(x_2) = 1 + 1 + 2 + 1 + 2 + 2 = 9$$

$$K = \begin{bmatrix} 9 & 1 & 1 & 1 \\ 1 & 9 & 1 & 1 \\ 1 & 1 & 9 & 1 \\ 1 & 1 & 1 & 9 \end{bmatrix}$$

SLJEDEĆI KORAK VJEROJATNO NIJE POTREBAN JER SE NA ISPITU OBIČNO ZADAJU LAMBDE IZRAČUNATE PREKO quadprog() ALI ZA SVAKI SLUČAJ, IDEMO RUČNO NAĆI LAMBDE.

$$J(\vec{\lambda}) = \sum \lambda_i - \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \lambda_i \lambda_j d_i d_j \cdot K(\vec{x}_i, \vec{x}_j)$$

$$J(\vec{\lambda}) = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 -$$

$$\frac{1}{2}\Big(\lambda_1^2 \cdot 1 \cdot 1 \cdot 9 + \lambda_1 \lambda_2 \cdot 1 \cdot 1 \cdot 1 - \lambda_1 \lambda_3 \cdot 1 \cdot 1 \cdot 1 - \lambda_1 \cdot \lambda_4 \cdot 1 \cdot 1 \cdot 1$$
$$+ \lambda_1 \lambda_2 \cdot 1 \cdot 1 \cdot 1 + \lambda_2^2 \cdot 1 \cdot 1 \cdot 9 - \lambda_2 \lambda_3 \cdot 1 \cdot 1 \cdot 1 - \lambda_2 \lambda_4 \cdot 1 \cdot 1 \cdot 1$$
$$- \lambda_1 \lambda_3 \cdot 1 \cdot 1 \cdot 1 - \lambda_2 \lambda_3 \cdot 1 \cdot 1 \cdot 1 + \lambda_3^2 \cdot 1 \cdot 1 \cdot 9 + \lambda_3 \lambda_4 \cdot 1 \cdot 1 \cdot 1$$
$$- \lambda_1 \lambda_4 \cdot 1 \cdot 1 \cdot 1 - \lambda_2 \lambda_4 \cdot 1 \cdot 1 \cdot 1 + \lambda_3 \lambda_4 \cdot 1 \cdot 1 \cdot 1 + \lambda_4^2 \cdot 1 \cdot 1 \cdot 9 \Big)$$

$$= \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4$$
$$- \frac{1}{2}\Big(9\lambda_1^2 + 9\lambda_2^2 + 9\lambda_3^2 + 9\lambda_4^2 + 2\lambda_1\lambda_2 - 2\lambda_1\lambda_3 - 2\lambda_1\lambda_4$$
$$- 2\lambda_2\lambda_3 - 2\lambda_2 \cdot \lambda_4 + 2\lambda_3\lambda_4 \Big)$$

PARCIJALNO DERIVIRAJ PO SVIM LAMBDAMA I IZJEDNAČI S NULOM

$$\frac{\partial J}{\partial \lambda_1} = 1 - 9\lambda_1 - \lambda_2 + \lambda_3 + \lambda_4 = 0$$

$$\frac{\partial J}{\partial \lambda_2} = 1 - 9\lambda_2 - \lambda_1 + \lambda_3 + \lambda_4 = 0$$

$$\frac{\partial J}{\partial \lambda_3} = 1 - 9\lambda_3 + \lambda_1 + \lambda_2 - \lambda_4 = 0$$

$$\frac{\partial J}{\partial \lambda_4} = 1 - 9\lambda_4 + \lambda_1 + \lambda_2 - \lambda_3 = 0$$

– RJEŠAVANJEM GORNJEG SUSTAVA JEDNADŽBI DOBIVA SE:

$$\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \frac{1}{8}$$

UVRSTIMO LAMBDE U FORMULU

$$\vec{w}_0 = \sum_{i=1}^{N} \lambda_i d_i \varphi(\vec{x}_i) + b$$

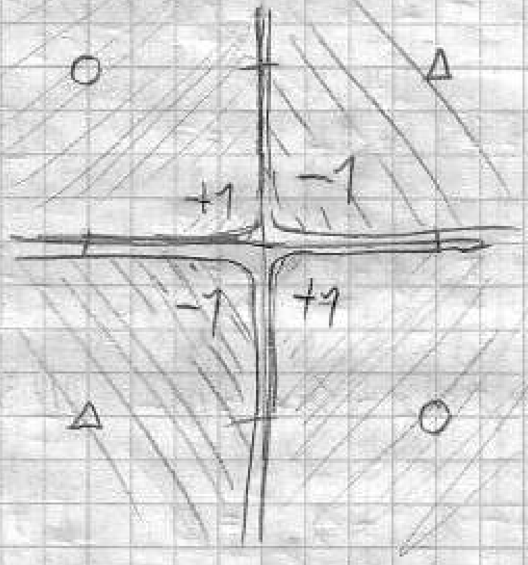
b

$$w = \frac{1}{8} \cdot \left(\begin{bmatrix} 1 \\ 1 \\ -\sqrt{2} \\ 1 \\ -\sqrt{2} \\ \sqrt{2} \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ -\sqrt{2} \\ 1 \\ \sqrt{2} \\ -\sqrt{2} \end{bmatrix} - \begin{bmatrix} 1 \\ 1 \\ \sqrt{2} \\ 1 \\ -\sqrt{2} \\ -\sqrt{2} \end{bmatrix} - \begin{bmatrix} 1 \\ 1 \\ \sqrt{2} \\ 1 \\ \sqrt{2} \\ \sqrt{2} \end{bmatrix} \right) = \begin{bmatrix} 0 \\ 0 \\ \frac{-4\sqrt{2}}{8} \\ 0 \\ 0 \\ 0 \end{bmatrix} \leftarrow -\frac{\sqrt{2}}{2} = -\frac{1}{\sqrt{2}}$$

IZRAČUNAMO DECIZIJSKU FUNKCIJU

$$\vec{w}^T \vec{\varphi}(\vec{x}) = \emptyset$$

$$\begin{bmatrix} 0 & 0 & -\frac{1}{\sqrt{2}} & 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ x_1^2 \\ \sqrt{2} x_1 x_2 \\ x_2^2 \\ \sqrt{2} x_1 \\ \sqrt{2} x_2 \end{bmatrix} = \emptyset \Rightarrow \boxed{-x_1 x_2 = 0}$$



JEZGRENI SVM - AUDITORNE 2009/2010

$\omega_1 = \{ [0\ 0]^T, [1\ 1]^T \}$

$\omega_2 = \{ [0\ 1]^T, [1\ 0]^T \}$

$K(\vec{x}, \vec{x}_i) = (\vec{x}\vec{x}_i + 1)^2$

$$K = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 9 & 4 & 4 \\ 1 & 4 & 4 & 1 \\ 1 & 4 & 1 & 4 \end{bmatrix}$$

- U OVOM ZADATKU SU ZADANE LAMBDE $\lambda = [\frac{10}{3}\ \ 2\ \ \frac{8}{3}\ \ \frac{8}{3}]$ ALI ĆU RJEŠIT KLASIČNIM POSTUPKOM RADI VJEŽBE

$$J(\vec{\lambda}) = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4$$
$$- \frac{1}{2} (\lambda_1^2 + \lambda_1\lambda_2 - \lambda_1\lambda_3 - \lambda_1\lambda_4$$
$$+ \lambda_1\lambda_2 + 9\lambda_2^2 - 4\lambda_2\lambda_3 - 4\lambda_2\lambda_4$$
$$- \lambda_1\lambda_3 - 4\lambda_2\lambda_3 + 4\lambda_3^2 + \lambda_3\lambda_4$$
$$- \lambda_1\lambda_4 - 4\lambda_2\lambda_4 + \lambda_3\lambda_4 + \lambda_4^2)$$

$$= \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \frac{1}{2} (-\lambda_1^2 - 9\lambda_2^2 - 4\lambda_3^2 - 4\lambda_4^2 - 2\lambda_1\lambda_2 + 2\lambda_1\lambda_3$$
$$+ 2\lambda_1\lambda_4 + 8\lambda_2\lambda_3 + 8\lambda_2\lambda_4 - 2\lambda_3\lambda_4)$$

$$\frac{\partial J}{\partial \lambda_1} = 1 - \lambda_1 - \lambda_2 + \lambda_3 + \lambda_4 = \emptyset \quad [1]$$

$$\frac{\partial J}{\partial \lambda_2} = 1 - 9\lambda_2 - \lambda_1 + 4\lambda_3 + 4\lambda_4 = \emptyset \quad [2]$$

$$\frac{\partial J}{\partial \lambda_3} = 1 - 4\lambda_3 + \lambda_1 + 4\lambda_2 - \lambda_4 = \emptyset \quad [3]$$

$$\frac{\partial J}{\partial \lambda_4} = 1 - 4\lambda_4 + \lambda_1 + 4\lambda_2 - \lambda_3 = \emptyset \quad [4]$$

[3]−[4]: $+4\lambda_4 - 4\lambda_3 + \lambda_3 - \lambda_4 = 0 \Rightarrow \boxed{\lambda_3 = \lambda_4}$ [5]

[1]+[3]: $2 - \cancel{\lambda_1} - 4\lambda_3 - \lambda_2 + \cancel{\lambda_1} + \lambda_3 + 4\lambda_2 + \cancel{\lambda_4} - \cancel{\lambda_4} = 0$

$$2 - 3\lambda_3 + 3\lambda_2 = 0 \Rightarrow \boxed{\lambda_2 = \frac{3\lambda_3 - 2}{3}} \quad [6]$$

[1]−[2] = $9\lambda_2 - \cancel{\lambda_1} + \cancel{\lambda_1} - \lambda_2 - 4\lambda_3 + \lambda_3 - 4\lambda_4 + \lambda_4 = 0$

$$8\lambda_2 - 3\lambda_3 - 3\lambda_4 = 0 \Leftarrow [6]$$

$$8\lambda_2 - 6\lambda_3 = 0$$

$$\boxed{\lambda_2 = \frac{6}{8}\lambda_3}$$

$$\frac{6}{8}\lambda_3 = \frac{3\lambda_3 - 2}{3} \;/\cdot 3 \Rightarrow \frac{9}{4}\lambda_3 = 3\lambda_3 - 2 \Rightarrow \frac{3}{4}\lambda_3 = 2$$

$$\boxed{\lambda_4 = \lambda_3 = \frac{8}{3}} \quad [7]$$

$$\lambda_2 = \frac{6}{\cancel{8}}\cdot\frac{\cancel{8}}{3} = 2 \Rightarrow \boxed{\lambda_2 = 2} \quad [8] \Rightarrow \lambda_1 + 2 - \frac{8}{3} - \frac{8}{3} = 0$$

$$\lambda_1 = \boxed{\frac{10}{3}}$$

$$1 - \lambda_1 - 2 + 2\cdot\frac{8}{3} = 0 \Rightarrow \boxed{\lambda_1 \neq \frac{13}{3}}$$

OVO BI VRIJEDILO KADA NE BI POSTO
UVJET $\sum d_i \lambda_i = 0$, ZATO JE $\lambda_1 = 10/3$ JER
JE TO NAJMANJA VRIJEDNOST FUNKCIJE
KOJA MOŽE BITI UZ TAJ UVJET

ECIZIJSKA FJA

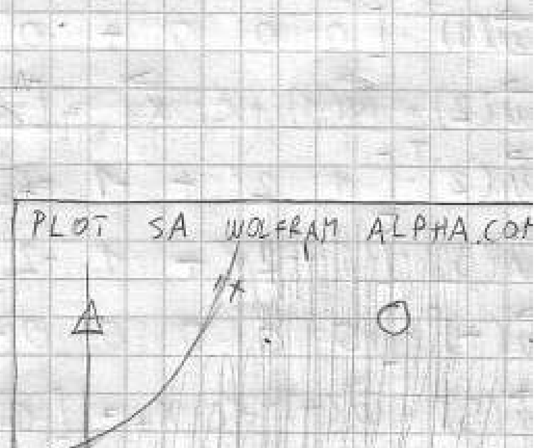
$$d(\vec{x}) = \sum_{i=1}^{N} \lambda_i d_i K(\vec{x}_i, \vec{x}) + \vec{b}$$

$$d(\vec{x}) = \frac{10}{3}\left[1 + 2\cdot 0x_1 + 2\cdot 0x_2 + 0x_1^2 + 2\cdot 0\cdot 0x_1x_2 + 0x_2^2\right]$$
$$+ 2\left[1 + 2\cdot 1x_1 + 2\cdot 1x_2 + 1x_1^2 + 2\cdot 1\cdot 1x_1x_2 + 1x_2^2\right]$$
$$- \frac{8}{3}\left[1 + 2\cdot 0x_1 + 2\cdot 1x_2 + 0x_1^2 + 2\cdot 0\cdot 1x_1x_2 + 1x_2^2\right]$$
$$- \frac{8}{3}\left[1 + 2\cdot 1x_1 + 2\cdot 0x_2 + 1x_1^2 + 2\cdot 0\cdot 1x_1x_2 + 0x_2^2\right] + b$$
$$= 0 + \frac{4}{3}x_1 - \frac{4}{3}x_2 - \frac{2}{3}x_1^2 + 4x_1x_2 - \frac{2}{3}x_2^2 + b$$

b

$$\frac{4}{3}\cdot 0 - \frac{4}{3}\cdot 0 - \frac{2}{3}\cdot 0^2 + 4\cdot 0\cdot 0 - \frac{2}{3}\cdot 0^2 + b = 1$$

$$\boxed{b = 1}$$



$$d(\vec{x}) = -\frac{2}{3}x_1^2 - \frac{2}{3}x_2^2 - \frac{4}{3}x_1 - \frac{4}{3}x_2 + 4x_1x_2 + 1$$

(6 bodova) Za skup uzoraka

$\omega_1 = \{[0, 0]^T\}$

$\omega_2 = \{[0, 1]^T, [1, 0]^T, [0, -1]^T\}$

Tražimo granicu između razreda strojem s potpornim vektorima i to u obliku polinoma drugog stupnja. Rješavanjem dualnog problema SVM dobili smo rješenje

$[\lambda_1\ \ \lambda_2\ \ \lambda_3\ \ \lambda_4] = [8/3\ \ 1\ \ 2/3\ \ 1]$

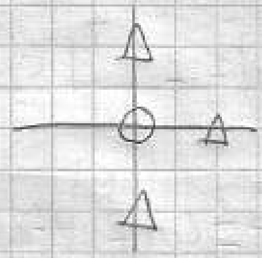
Kako glasi jednadžba granice između razreda u obliku

$ax_1^2 + bx_2^2 + cx_1x_2 + dx_1 + ex_2 + f = 0$

JEZGRENI SVM - ZAVRŠNI 2008/2009

$\omega_1 = \{[0\ 0]^T\}$ O

$\omega_2 = \{[0\ 1]^T, [1\ 0]^T, [0\ -1]^T\}$ Δ



$\lambda = \left[\frac{8}{3}\ 1\ \frac{2}{3}\ 1\right]^T$

$\varphi(X) = [x_1^2\ \ x_2^2\ \ \sqrt{2}x_1x_2\ \ \sqrt{2}x_1\ \ \sqrt{2}x_2\ \ 1]$

$\vec{w} = \sum \lambda_i d_i \varphi(x_i)$

$$\vec{w} = \frac{8}{3}\begin{bmatrix}0\\0\\0\\0\\0\\1\end{bmatrix} - \begin{bmatrix}0\\1\\0\\0\\\sqrt{2}\\1\end{bmatrix} - \frac{2}{3}\begin{bmatrix}1\\0\\0\\\sqrt{2}\\0\\1\end{bmatrix} - \begin{bmatrix}0\\1\\0\\0\\-\sqrt{2}\\1\end{bmatrix} = \begin{bmatrix}-\frac{2}{3}\\-2\\0\\\frac{-2\sqrt{2}}{3}\\0\\0\end{bmatrix}$$

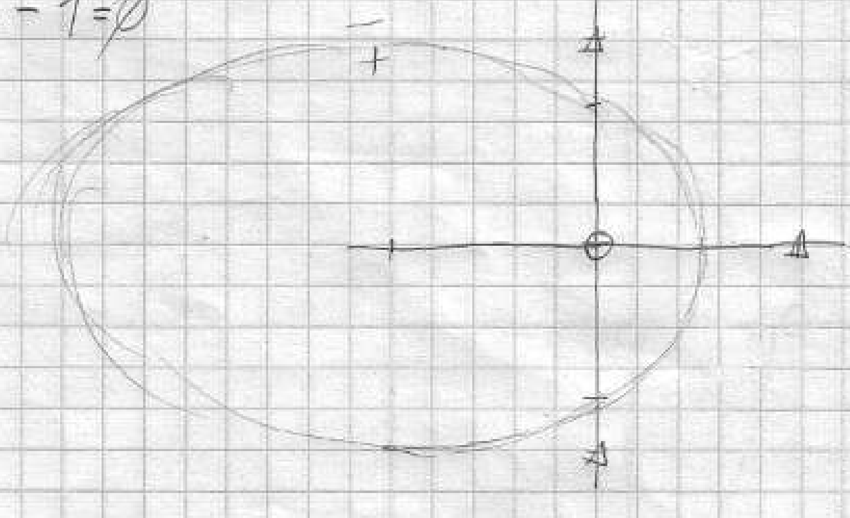
$w - \frac{2}{3}x_1^2 - 2x_2^2 - \frac{4}{3}x_1 + b = 0$

- UBACIMO [0 0] KOJEM JE UDALJENOST 1

$b = 1$

$\frac{2}{3}x_1^2 + 2x_2^2 + \frac{4}{3}x_1 - 1 = 0$

WOLFRAMALPHA.COM PLOT



(7 bodova) Zadani su dvodimenzionalni uzorci iz dvaju razreda za koje se pretpostavlja da slijede višedimenzionalnu normalnu razdiobu. Uzorci iz prvoga razreda su

$\omega_1 = \{[1, 3]^T, [2, 0]^T, [2, 6]^T, [3, 3]^T\}$

Uzorci iz ω_2 imaju središte u ishodištu i kovarijacijsku matricu $C_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

Pretpostavlja se da su vjerojatnosi pojavljivanja uzoraka iz oba razreda jednake. Napišite jednadžbu granice između razreda i to u obliku:

$a \cdot x_1^2 + b \cdot x_2^2 + c \cdot x_1 \cdot x_2 + d \cdot x_1 + e \cdot x_2 + f = 0$

JEZGRENI SVM - ZAVRŠNI 2010/2011

ZADATAK JE ISTI KAO 1 OD 2008/2009, UZ DODATAK IZRAČU

MATRICA:

$$\varphi(\vec{x}) = [\, x_1^2 \;\; x_2^2 \;\; x_1 x_2 \;\; x_1 \;\; x_2 \;\; 1 \,]^T$$

$$K(x, x_i) = \left(1 + [x_{11}\, x_{12}] \begin{bmatrix} x_{21} \\ x_{22} \end{bmatrix} \right)^2$$

$$K = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 4 & 1 & 0 \\ 1 & 1 & 4 & 1 \\ 1 & 0 & 1 & 4 \end{bmatrix} \qquad Q = d_i d_j K_{ij} = \begin{bmatrix} 1 & -1 & -1 & -1 \\ -1 & 4 & 1 & 0 \\ -1 & 1 & 4 & 1 \\ -1 & 0 & 1 & 4 \end{bmatrix}$$

$$c = [-1 \;\; -1 \;\; -1 \;\; -1]^T$$

$\boxed{\text{UVJET} \quad A\vec{x} \leq b}$

$$A = -I = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

$$b = [\, 0 \;\; 0 \;\; 0 \;\; 0 \,]$$

$\boxed{\text{UVJET} \quad E\vec{x} = \vec{d}}$

$$E = [\, 1 \;\; -1 \;\; -1 \;\; -1 \,]$$

$$d = [\, 0 \,]$$

U MATLABU PROVJERENE MATRICE, DOBIVAJU SE TOČNE LAMBDE! :)

Za općeniti problem kvadratnog programiranja:

$$\min_x \quad \frac{1}{2} x^T Q x + c^T x$$

uz uvjete

Ax $\leq b$

Ex=d

naći vrijednost matrica Q, A, E te vektora c, b i d tako da rješenje gornjeg problema daje rješenje dualnog problema SVM za skup uzoraka

$\omega_1 = \{[0,0]^T\}$

$\omega_2 = \{[0,1]^T, \ [1,0]^T, \ [-1,-1]^T\}$

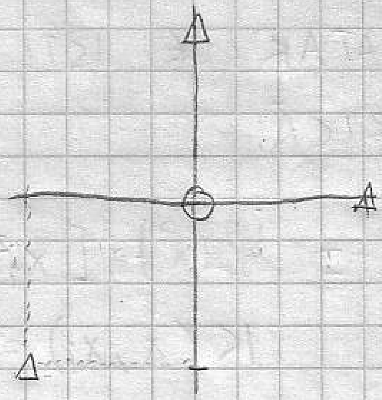
Pretpostavite da tražimo nelinearnu decizijsku funkciju pomoću jezgrene funkcije

K(x, x_i)= $e^{-\frac{1}{2\sigma^2}\|\mathbf{x}-x_i\|^2}$ uz $\sigma = 1$.

JEZGRENI SVM - 2.MI 2008/2009

$\omega_1 = \{[0 \ 0]^T\} - o$

$\omega_2 = \{[0 \ 1]^T, [1 \ 0]^T, [-1 \ -1]^T\} - \Delta$



$$K(x, x_i) = e^{-\frac{1}{2}\|x - x_i\|^2}$$

$$K = \begin{bmatrix} 1 & 0.6 & 0.6 & 0.37 \\ 0.6 & 1 & 0.37 & 0.08 \\ 0.6 & 0.37 & 1 & 0.08 \\ 0.36 & 0.08 & 0.08 & 1 \end{bmatrix} \quad Q = \begin{bmatrix} 1 & -0.6 & -0.6 & -0.37 \\ -0.6 & 1 & 0.37 & 0.08 \\ -0.6 & 0.37 & 1 & 0.08 \\ -0.37 & 0.08 & 0.08 & 1 \end{bmatrix}$$

OSTALE MATRICE ISTE KAO I U PROŠLOM ZADATKU
(ZAVRŠNI 2010/2011)

Za općeniti problem kvadratnog programiranja:

$$\min_{\vec{x}} \frac{1}{2} \vec{x}^T Q \vec{x} + \vec{c}^T \vec{x}$$

uz uvjete

$$A\vec{x} \leq \vec{b}$$

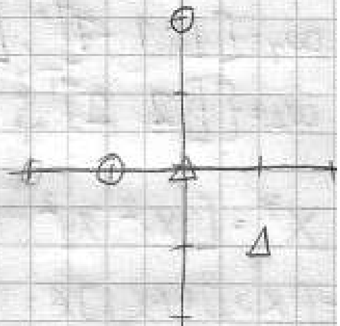
$$E\vec{x} = \vec{d}$$

naći vrijednosti matrica Q, A i E, te vektora c, b i d tako da rješenje gornjeg problema daje rješenje dualnog problema SVM za skup uzoraka $[0, 2]^T \in \omega_1$, $[-1, 0]^T \in \omega_1$, $[0, 0]^T \in \omega_2$, $[1, -1]^T \in \omega_2$. Pretpostavite da tražimo decizijsku funkciju u obliku polinoma trećeg stupnja.

JEZGRENI SVM - POLINOM 3. STUPNJA - ISPIT 29.06.2006.

$\omega_1 = \{[-0\ \ 2], [-1\ \ 0]\}$ o $\qquad K = (1 + x^T x_i)^3$

$\omega_2 = \{[0\ \ 0], [1\ \ -1]\}$ Δ



$$K = \begin{bmatrix} 125 & -1 & 1 & -1 \\ -1 & 8 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ -1 & 0 & 1 & 27 \end{bmatrix} \quad Q = \begin{bmatrix} 125 & -1 & -1 & 1 \\ 1 & 8 & -1 & 0 \\ -1 & -1 & 1 & 1 \\ 1 & 0 & 1 & 27 \end{bmatrix}$$

- OSTALE MATRICE ISTE KO U PROŠLOM ZADATKU
  OSIM $e = [1\ 1\ -1\ -1]$

- MATLAB DAJE LAMBDE:

$$\lambda = [\,0.0161 \quad 0.2857 \quad 0.3018 \quad 0\,]^T$$

$$K(x, x_i) = x_1^3 x_{i1}^3 + 3x_1^2 x_{i1}^2 + 3x_1^2 x_2 x_{i1}^2 x_{i2} + 3x_2^2 x_1 x_{i2}^2 x_{i1} + 3x_1 x_{i1} + 6x_1 x_2 x_{i1} x_{i2} + x_2^3 x_{i2}^3 + 3x_2^2 x_{i2}^2 + 3x_2 x_{i2} + 1$$

$$\varphi(\vec{x}) = [\,x_1^3 \ \ \sqrt{3}x_1^2 \ \ \sqrt{3}x_1^2 x_2 \ \ \sqrt{3}x_2^2 x_1 \ \ \sqrt{3}x_1 \ \ \sqrt{6}x_1 x_2 \ \ x_2^3 \ \ \sqrt{3}x_2^2 \ \ \sqrt{3}x_2 \ \ 1\,]^T$$

$$\vec{w} = \sum(\lambda_i d_i \varphi(x_i)) + b$$

$$= 0.0161 \cdot [\,0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 8\ \ 4\sqrt{3}\ \ 2\sqrt{3}\ \ 1\,]^T$$

$$+ 0.2857 \cdot [\,1\ \ \sqrt{3}\ \ 0\ \ 0\ \ -\sqrt{3}\ \ 0\ \ 0\ \ 0\ \ 0\ \ 1\,]^T$$

$$- 0.3018 \cdot [\,0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 1\,]^T$$

$$= [\,0.2857\ \ 0.4948\ \ 0\ \ 0\ \ -0.4948\ \ 0\ \ 0.1288\ \ 0.1115\ \ 0.0558\ \ 0\,]^T$$

UBACIMO $[0\ 0] \Rightarrow b = -1$

$$d(\vec{x}) = 0.2857x_1^3 + 0.857x_1^2 - 0.857x_1 + 0.1288x_2^3 + 0.1931x_2^2 + 0.0966x_2 - 1$$