
Machine Learning

Answer Sheet for Homework 5

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Problem 1

The hard-margin support vector machine is with $d + 1$ variables. For soft-margin support vector machine, there are N more variables ξ_n , $1 \leq n \leq N$.

So soft-margin support vector machine is a quadratic programming problem with $N + d + 1$ variables.

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Problem 2

I wrote a `Q02.py` to help me get the answer. By using Python package `cvxopt`, with

$$\mathbf{z} = \begin{bmatrix} 1 & -2 \\ 4 & -5 \\ 4 & -1 \\ 5 & -2 \\ 7 & -7 \\ 7 & 1 \\ 7 & 1 \end{bmatrix}, \mathbf{y} = \begin{bmatrix} -1 \\ -1 \\ -1 \\ +1 \\ +1 \\ +1 \\ +1 \end{bmatrix} \quad (1)$$

and

$$\mathbf{Q} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \mathbf{p} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad (2)$$

$$\mathbf{A}^T = \begin{bmatrix} -1 & -1 & 2 \\ -1 & -4 & 5 \\ -1 & -4 & 1 \\ 1 & 5 & -2 \\ 1 & 7 & -7 \\ 1 & 7 & 1 \\ 1 & 7 & 1 \end{bmatrix}, \mathbf{c} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad (3)$$

To use this package, I gave `solvers.qp(Q, p, -AT, -c)` and got

$$b = -9, \mathbf{w} = [2, 0] \quad (4)$$

So the hyperplane is

$$2z_1 - 9 = 0 \Rightarrow z_1 = 4.5 \quad (5)$$

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Problem 3

I wrote a `Q03.py` to help me get the answer. By using Python package `cvxopt`, with

$$\mathbf{Q} = \begin{bmatrix} 4 & 1 & 1 & 0 & -1 & -1 & -1 \\ 1 & 4 & 0 & -1 & -9 & -1 & -1 \\ 1 & 0 & 4 & -1 & -1 & -9 & -1 \\ 0 & -1 & -1 & 4 & 1 & 1 & 9 \\ -1 & -9 & -1 & 1 & 25 & 9 & 1 \\ -1 & -1 & -9 & 1 & 9 & 25 & 1 \\ -1 & -1 & -1 & 9 & 1 & 1 & 25 \end{bmatrix}, \mathbf{p} = \begin{bmatrix} -1 \\ -1 \\ -1 \\ -1 \\ -1 \\ -1 \\ -1 \end{bmatrix}, \quad (6)$$

$$-\mathbf{A}^T = \begin{bmatrix} -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}, \mathbf{c} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (7)$$

with

$$\mathbf{G} = \begin{bmatrix} -1 & -1 & -1 & 1 & 1 & 1 & 1 \end{bmatrix} \text{ and } h = 0 \quad (8)$$

and To use this package, I gave `solvers.qp(Q, p, -AT, c, G, h)` and got

$$\alpha = [4.32 \times 10^{-9}, 0.704, 0.704, 0.889, 0.259, 0.259, 5.27 \times 10^{-10}] \quad (9)$$

where `cvxopt` needs conditions

$$-\mathbf{A}^T \boldsymbol{\alpha} \preceq \mathbf{c} \text{ and } \mathbf{G} \boldsymbol{\alpha} = h \quad (10)$$

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Problem 4

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Problem 5

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Problem 6

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Problem 7

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Problem 8

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Problem 9

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Problem 10

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Problem 11

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Problem 12

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Problem 13

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Problem 14

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Problem 15

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Problem 16

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Problem 17

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Problem 18



Problem 19



Problem 20



Reference

- [1] Lecture Notes by Hsuan-Tien LIN, Department of Computer Science and Information Engineering, National Taiwan University, Taipei 106, Taiwan.