

Problem Set 3

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1. Kernels

(a) $K_\beta(x, z) = (1 + \beta x^T z)^3$

$$= 1^3 + 3\beta x^T z + 3\beta^2 z^T x x^T z + \cancel{3\beta^3 x^T z z^T x x^T z}$$

$$\therefore x^T z = x_1 z_1 + x_2 z_2$$

$$\therefore K_\beta(x, z) = 1 + 3\beta(x_1 z_1 + x_2 z_2) + 3\beta^2(z_1 x_1 + z_2 x_2)^2 + \beta^3(z_1 x_1 + z_2 x_2)^3$$

$$= 1 + 3\beta x_1 z_1 + 3\beta x_2 z_2 + 3\beta^2 z_1^2 x_1^2 + 6\beta^2 z_1 x_1 z_2 x_2 + 3\beta^2 z_2^2 x_2^2 + \beta^3(z_1^3 x_1^3 + 3z_1^2 x_1^2 z_2 x_2 + 3z_1 x_1 z_2^2 x_2 + z_2^3 x_2^3)$$

$$= 1 + 3\beta x_1 z_1 + 3\beta x_2 z_2 + 3\beta^2 z_1^2 x_1^2 + 6\beta^2 z_1 x_1 z_2 x_2 + 3\beta^2 z_2^2 x_2^2 + \beta^3 z_1^3 x_1^3 + 3\beta^3 z_1^2 z_2 x_1^2 x_2 + 3\beta^3 z_1 z_2^2 x_1 x_2^2 + \beta^3 z_2^3 x_2^3$$

(b) From the expanded cubic,

$$\therefore \phi_\beta(x)^T \phi_\beta(z) = K_\beta(x, z)$$

$$\therefore \phi_\beta(x)^T \phi_\beta(z) = \begin{bmatrix} 1 & \sqrt{3\beta} x_1 & \sqrt{3\beta} x_2 & \sqrt{3\beta} x_1^2 & \sqrt{6\beta} x_1 x_2 & \sqrt{3\beta} x_2^2 & \sqrt{\beta} x_1^3 & \sqrt{3\beta} x_1^2 x_2 & \sqrt{3\beta} x_1 x_2^2 & \sqrt{\beta} x_2^3 \end{bmatrix}$$

$$\therefore \phi_\beta(x) = \begin{bmatrix} 1 \\ \sqrt{3\beta} x_1 \\ \sqrt{3\beta} x_2 \\ \sqrt{3\beta} x_1^2 \\ \sqrt{6\beta} x_1 x_2 \\ \sqrt{3\beta} x_2^2 \\ \sqrt{\beta} x_1^3 \\ \sqrt{3\beta} x_1^2 x_2 \\ \sqrt{3\beta} x_1 x_2^2 \\ \sqrt{\beta} x_2^3 \end{bmatrix}$$

$$\begin{bmatrix} 1 \\ \sqrt{3\beta} z_1 \\ \sqrt{3\beta} z_2 \\ \sqrt{3\beta} z_1^2 \\ \sqrt{6\beta} z_1 z_2 \\ \sqrt{3\beta} z_2^2 \\ \sqrt{\beta} z_1^3 \\ \sqrt{3\beta} z_1^2 z_2 \\ \sqrt{3\beta} z_1 z_2^2 \\ \sqrt{\beta} z_2^3 \end{bmatrix}$$

(c) When $\beta \rightarrow 0$, $K_\beta(x, z) \rightarrow 1$ $\beta \rightarrow \infty$, $K_\beta(x, z) \rightarrow \infty$ $\beta = 1$, $K_\beta(x, z) = K(x, z)$

Similarities: The same number of entries and the same computational complexity.

 $\beta \in (0, 1)$, $K_\beta(x, z)$ has more weight on low-order terms ^{such as x_1, x_2} $\beta > 1$, $K_\beta(x, z)$ has more weight on high-order terms

based on their orders \therefore Comparing with $K(x, z)$, $K_\beta(x, z)$ has the parameter β which weights the terms differently with different choices of β 's values. Different β lead to different weighting strategies. ~~β scales the entries.~~

2. SVM

$$(a). \begin{cases} y_1 w^T x_1 \geq 1 \\ y_2 w^T x_2 \geq 1 \end{cases} \Rightarrow \begin{cases} w_1 + w_2 \geq 1 \\ -(w_1 + 0) \geq 1 \end{cases}$$

$$\therefore w_1 + w_2 \geq 1 \quad (1)$$

$$\therefore -w_1 \geq 1 \quad (2)$$

$$(2) \Rightarrow w_1 \leq -1$$

$$\therefore w_1 + w_2 \leq -1 + w_2$$

if w_1 decrease, w_1^2 would increase, and $\frac{1}{2}\|w\|^2 = w_1^2 + w_2^2$

$$\therefore \text{let } w_1 = -1, -1 + w_2 \geq 1$$

$$w_2 \geq 2$$

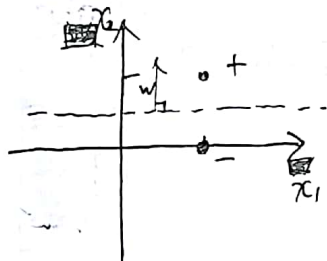
$$\therefore \min \frac{1}{2}\|w\|^2 = \frac{1}{2}((-1)^2 + 2^2)$$

$$= \frac{5}{2}$$

$$\therefore w^* = (-1, 2)^T$$

$$(b). \text{ For part (a), margin } \gamma = \frac{y_1 w^T x_1}{\|w\|} = \frac{1}{\|(-1, 2)\|} = \frac{1}{\sqrt{5}}$$

$$\begin{cases} y_1 (w^T x_1 + b) \geq 1 \\ y_2 (w^T x_2 + b) \geq 1 \end{cases} \therefore \begin{cases} w_1 + w_2 + b \geq 1 \quad (1) \\ -(w_1 + 0) - b \geq 1 \quad (2) \end{cases}$$



Geometrically, to ~~minimize~~ maximize the margin, we need $w_1 = 0$ ~~s.t. w is vertically~~

$$\therefore \text{let } w = (0, w_2)^T, \begin{cases} w_2 + b \geq 1 \\ -b \geq 1 \end{cases}$$

$$\therefore b \leq -1,$$

$$w_2 + b \leq w_2 - 1$$

$$\therefore w_2 - 1 \geq 1$$

$$\Rightarrow w_2 \geq 2. \text{ when } w_2 = 2, b = -1$$

$$\therefore w^* = (0, 2) \text{ with } b^* = -1$$

$$\gamma = \frac{1}{2} > \frac{1}{\sqrt{5}}$$

\therefore The margin is larger with offset than without offset.

$$\min \frac{1}{2}\|w\|^2 = \frac{1}{2}(2^2) = 2$$

3. Twitter analysis using SVMs

3.1. (a). Implemented

(b). Implemented

(c). Implemented

(d). The feature matrix X has dimensionality: (630, 1811)

(Dimensionality of training data is (560, 1811); of test data is (70, 1811))

3.2. (a). Implemented

(b). It ~~might be~~ ^{is} beneficial to maintain class proportions across the folds because in this way, each ~~split~~ ^{split} will have training data ~~class proportions~~ ^{class proportions} resemble that ~~of the~~ ^{of the} original ~~to training~~ ^{data} distribution ~~more than the cases with various proportions.~~

Maintaining class proportions will make the class proportion more similar to that of the ^{total} training data, which is ~~also~~ ^{also} similar to that of the test data, so the results will be representative.

~~(c). Implemented~~ If it is not maintained, there might be some classes in some splits relatively too small, which ~~lead~~ ^{would} to strange results.

(c). Implemented

(d).

C	accuracy	F1-score	AUROC
10^{-3}	0.7089	0.8297	0.5000
10^{-2}	0.7107	0.8306	0.5031
10^{-1}	0.8060	0.8751	0.7188
10^0	0.8146	0.8749	0.7531
10^1	0.8182	0.8766	0.7592
10^2	0.8182	0.8766	0.7592

best C ~~10⁻³~~ ~~10⁻²~~ ~~10⁻¹~~ ~~10⁰~~ ~~10¹~~ ~~10²~~ ~~10³~~ ~~10⁴~~ ~~10⁵~~ ~~10⁶~~ ~~10⁷~~ ~~10⁸~~ ~~10⁹~~ ~~10¹⁰~~ ~~10¹¹~~ ~~10¹²~~ ~~10¹³~~ ~~10¹⁴~~ ~~10¹⁵~~ ~~10¹⁶~~ ~~10¹⁷~~ ~~10¹⁸~~ ~~10¹⁹~~ ~~10²⁰~~ ~~10²¹~~ ~~10²²~~ ~~10²³~~ ~~10²⁴~~ ~~10²⁵~~ ~~10²⁶~~ ~~10²⁷~~ ~~10²⁸~~ ~~10²⁹~~ ~~10³⁰~~ ~~10³¹~~ ~~10³²~~ ~~10³³~~ ~~10³⁴~~ ~~10³⁵~~ ~~10³⁶~~ ~~10³⁷~~ ~~10³⁸~~ ~~10³⁹~~ ~~10⁴⁰~~ ~~10⁴¹~~ ~~10⁴²~~ ~~10⁴³~~ ~~10⁴⁴~~ ~~10⁴⁵~~ ~~10⁴⁶~~ ~~10⁴⁷~~ ~~10⁴⁸~~ ~~10⁴⁹~~ ~~10⁵⁰~~ ~~10⁵¹~~ ~~10⁵²~~ ~~10⁵³~~ ~~10⁵⁴~~ ~~10⁵⁵~~ ~~10⁵⁶~~ ~~10⁵⁷~~ ~~10⁵⁸~~ ~~10⁵⁹~~ ~~10⁶⁰~~ ~~10⁶¹~~ ~~10⁶²~~ ~~10⁶³~~ ~~10⁶⁴~~ ~~10⁶⁵~~ ~~10⁶⁶~~ ~~10⁶⁷~~ ~~10⁶⁸~~ ~~10⁶⁹~~ ~~10⁷⁰~~ ~~10⁷¹~~ ~~10⁷²~~ ~~10⁷³~~ ~~10⁷⁴~~ ~~10⁷⁵~~ ~~10⁷⁶~~ ~~10⁷⁷~~ ~~10⁷⁸~~ ~~10⁷⁹~~ ~~10⁸⁰~~ ~~10⁸¹~~ ~~10⁸²~~ ~~10⁸³~~ ~~10⁸⁴~~ ~~10⁸⁵~~ ~~10⁸⁶~~ ~~10⁸⁷~~ ~~10⁸⁸~~ ~~10⁸⁹~~ ~~10⁹⁰~~ ~~10⁹¹~~ ~~10⁹²~~ ~~10⁹³~~ ~~10⁹⁴~~ ~~10⁹⁵~~ ~~10⁹⁶~~ ~~10⁹⁷~~ ~~10⁹⁸~~ ~~10⁹⁹~~ ~~10¹⁰⁰~~ ~~10¹⁰¹~~ ~~10¹⁰²~~ ~~10¹⁰³~~ ~~10¹⁰⁴~~ ~~10¹⁰⁵~~ ~~10¹⁰⁶~~ 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3.3 (a) Implemented

(b) Implemented

(c) Choice : $C = \text{10}$

	accuracy	F1-score	AUROC
Scores:	0.7429	0.4375	0.6959