实　验　报　告

（2017 / 2018 学年　第 2 学期）

课程名称	机器学习导论
实验名称	Support vector machine
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1 问题重述

- 给定数据集（文件 data1_Task.mat）如下图所示，参考 Demo 1 和 Demo 2，编程实现一个高斯核 SVM 进行分类。输出训练参数 C, sigma 分别取 0.01, 0.03, 0.1, 0.3, 1, 3, 10, 30 时 (共 64 组参数组合) 的训练集上的准确率。
- 编程实现一个垃圾邮件 SVM 线性分类器，分别在训练集和测试集上计算准确率。训练数据文件：spamTrain.mat，要求导入数据时输出样本数和特征维度。测试数据文件：spamTest.mat，要求导入数据时输出样本数和特征维度。

2 Python Code for SVM

2.1 SVM

```python
# -*- coding: utf-8 -*-
"""
@author : Haoran You

"""
import time
import numpy as np
import matplotlib.pyplot as plt

class SVM():
    def name(self):
        return 'svm classifier'

    def svmTrain_SMO(self, X, y, C, kernal_function='linear', tol=1e-3, max_iter=5, **kargs):
        """
        :param X:
        :param y:
        :param C: punishment coefficient
        :param kernal_function: type of kernal function; for nonlinear function, input K directly
        :param tol: error-tolerant rate
        :param max_iter: maximum iterations
        :param kargs:
        :return: model['kernelFunction]: kernal function type
        :return: model['X']: support vector
        :return: model['y']: label
        :return: model['alpha']: corresponding lagrange parameters
        :return: model['w'], model['b']: model parameters
        """
        start_time = time.clock()

        m, n = X.shape
        X = np.mat(X)
        y = np.mat(y, dtype='float64')
        y[np.where(y==0)] = -1
        alpha = np.mat(np.zeros((m, 1)))
        b = 0.0
        E = np.mat(np.zeros((m, 1)))
        iters = 0
        eta = 0.0
        L = 0.0
        H = 0.0

        if kernal_function == 'linear':
            K = X*X.T
        elif kernal_function == 'gaussian':
            K = kargs['K_matrix']
        else:
            print('Kernal Error')
            return None

        print('Training ...', end='')
        dots = 12
        while iters < max_iter:
            num_changed_alpha = 0
            for i in range(m):
                E[i] = b + np.sum(np.multiply(np.multiply(alpha, y), K[:, i])) - y[i]
                if (y[i]*E[i] < -tol and alpha[i] < C) or (y[i]*E[i] > tol and alpha[i] > 0):
                    j = np.random.randint(m)
                    while j == i:
                        j = np.random.randint(m)
                    E[j] = b + np.sum(np.multiply(np.multiply(alpha, y), K[:, j])) - y[j]

                    alpha_i_old = alpha[i].copy()
                    alpha_j_old = alpha[j].copy()

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                    if y[i] == y[j]:
                        L = max(0, alpha[j] + alpha[i] - C)
                        H = min(C, alpha[j] + alpha[i])
                    else:
                        L = max(0, alpha[j] - alpha[i])
                        H = min(C, C + alpha[j] - alpha[i])

                    if L == H:
                        continue

                    eta = 2 * K[i, j] - K[i, i] - K[j, j]
                    if eta >= 0:
                        continue

                    alpha[j] = alpha[j] - (y[j]*(E[i] - E[j])) / eta
                    alpha[j] = min(H, alpha[j])
                    alpha[j] = max(L, alpha[j])

                    if abs(alpha[j] - alpha_j_old) < tol:
                        alpha[j] = alpha_j_old
                        continue

                    alpha[i] = alpha[i] + y[i] * y[j] * (alpha_j_old - alpha[j])

                    b1 = b - E[i]\
                     - y[i] * (alpha[i] - alpha_i_old) * K[i, j]\
                     - y[j] * (alpha[j] - alpha_j_old) * K[i, j]

                    b2 = b - E[j]\
                     - y[i] * (alpha[i] - alpha_i_old) * K[i, j]\
                     - y[j] * (alpha[j] - alpha_j_old) * K[i, j]

                    if (0 < alpha[i] and alpha[i] < C):
                        b = b1
                    elif (0 < alpha[j] and alpha[j] < C):
                        b = b2
                    else:
                        b = (b1 + b2) / 2.0

                    num_changed_alpha = num_changed_alpha + 1

            if num_changed_alpha == 0:
                iters = iters + 1
            else:
                iters = 0

            print('.', end='')
            dots = dots + 1
            if dots > 78:
                dots = 0
                print()

        print('Done', end='')
        end_time = time.clock()
        print('( ' + str(end_time - start_time) + 's )')
        print()

        idx = np.where(alpha > 0)
        model = {
            'X': X[idx[0], :],
            'y': y[idx],
            'kernelFunction': str(kernal_function),
            'b': b,
            'alpha':alpha[idx],
            'w': (np.multiply(alpha, y).T * X).T
        }
        return model

    def visualizeBoundaryLinear(self, X, y, model, title=None):
        fig = plt.figure()
        ax = fig.add_subplot(111)

        w = model['w']
        b = model['b']
        xp = np.linspace(min(X[:, 0]), max(X[:, 0]), 100)
        yp = np.squeeze(np.array(- (w[0] * xp + b) / w[1]))

        ax.plot(xp, yp)

        # scatter
        X_pos = []
        X_neg = []

        sampleArray = np.concatenate((X, y), axis=1)
        for array in list(sampleArray):
            if array[-1]:
                X_pos.append(array)
            else:
```

```
                X_neg.append(array)

        X_pos = np.array(X_pos)
        X_neg = np.array(X_neg)

        if title: ax.set_title(title)

        pos = plt.scatter(X_pos[:, 0], X_pos[:, 1], marker='+', c='b')
        neg = plt.scatter(X_neg[:, 0], X_neg[:, 1], marker='o', c='y')

        plt.legend((pos, neg), ('postive', 'negtive'), loc=2)

        plt.show()

    def gaussianKernelSub(self, x1, x2, sigma):
        X1 = np.mat(x1).reshape(-1, 1)
        X2 = np.mat(x2).reshape(-1, 1)
        n = -(x1-x2).T * (x1 - x2) / (2*sigma**2)
        return np.exp(n)

    def gaussianKernel(self, X, sigma):
        start = time.clock()

        print('GaussianKernel Computing ...', end='')
        m = X.shape[0]
        X = np.mat(X)
        K = np.mat(np.zeros((m, m)))
        dots = 280
        for i in range(m):
            if dots % 10 == 0: print('.', end='')
            dots = dots + 1
            if dots > 780:
                dots = 0
                print()
            for j in range(m):
                K[i, j] = self.gaussianKernelSub(X[i, :].T, X[j, :].T, sigma)
                K[j, i] = K[i, j].copy()

        print('Done', end='')
        end = time.clock()
        print('( ' + str(end - start) + 's )')
        print()
        return K

    def svmPredict(self, model, X, *arg):
        m = X.shape[0]
        p = np.mat(np.zeros((m, 1)))
        pred = np.mat(np.zeros((m, 1)))

        if model['kernelFunction'] == 'linear':
            p = X * model['w'] + model['b']
        else:
            for i in range(m):
                prediction = 0
                for j in range(model['X'].shape[0]):
                    prediction += model['alpha'][:, j] * model['y'][:, j] * \
                                  self.gaussianKernelSub(X[i, :].T, model['X'][j, :].T, *arg)

                p[i] = prediction + model['b']

        pred[np.where(p >= 0)] = 1
        pred[np.where(p < 0)] = 0

        return pred

    def visualizeBoundaryGaussian(self, X, y, model, sigma):
        fig = plt.figure()
        ax = fig.add_subplot(111)

        x1plot = np.linspace(min(X[:, 0]), max(X[:, 0]), 100)
        x2plot = np.linspace(min(X[:, 1]), max(X[:, 1]), 100)
        X1, X2 = np.meshgrid(x1plot, x2plot)
        X1 = np.mat(X1)
        X2 = np.mat(X2)
        vals = np.mat(np.zeros(X1.shape))

        print('Predicting ...', end='')
        dots = 14
        for i in range(X1.shape[1]):
            print('.', end='')
            dots += 1
            if dots == 78:
                dots = 0
                print()
            this_X = np.concatenate((X1[:, i], X2[:, i]), axis=1)
            vals[:, i] = self.svmPredict(model, this_X, sigma)
        print('Done')

```

```
        ax.contour(X1, X2, vals, colors='black')
        # scatter
        X_pos = []
        X_neg = []

        sampleArray = np.concatenate((X, y), axis=1)
        for array in list(sampleArray):
            if array[-1]:
                X_pos.append(array)
            else:
                X_neg.append(array)

        X_pos = np.array(X_pos)
        X_neg = np.array(X_neg)

        pos = plt.scatter(X_pos[:, 0], X_pos[:, 1], marker='+', c='b')
        neg = plt.scatter(X_neg[:, 0], X_neg[:, 1], marker='o', c='y')

        plt.legend((pos, neg), ('postive', 'negtive'), loc=2)

        plt.show()
```

2.2 data

```
# -*- coding: utf-8 -*-
"""
@author : Haoran You

"""
from scipy.io import loadmat
import numpy as np
import matplotlib.pyplot as plt

def loadData(filename):
    dataDict = loadmat(filename)
    return dataDict['X'], dataDict['y']

def plotData(X, y, title=None):
    X_pos = []
    X_neg = []

    sampleArray = np.concatenate((X, y), axis=1)
    for array in list(sampleArray):
        if array[-1]:
            X_pos.append(array)
        else:
            X_neg.append(array)

    X_pos = np.array(X_pos)
    X_neg = np.array(X_neg)

    fig = plt.figure()

    ax = fig.add_subplot(111)

    if title: ax.set_title(title)

    pos = plt.scatter(X_pos[:, 0], X_pos[:, 1], marker='+', c='b')
    neg = plt.scatter(X_neg[:, 0], X_neg[:, 1], marker='o', c='y')

    plt.legend((pos, neg), ('postive', 'negtive'), loc=2)

    plt.show()
```

2.3 Main

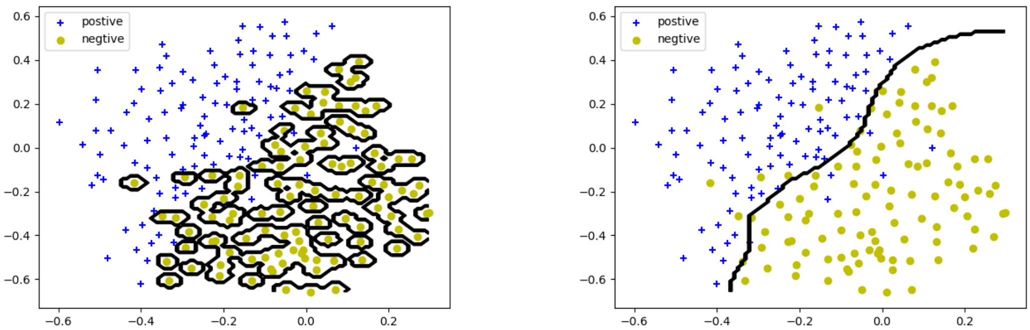
```python
# -*- coding: utf-8 -*-
"""
@author : Haoran You

"""
import os
from data import *
from SVM import SVM

file_path = os.getcwd()

def Task1():
    # load and visulize data
    svm = SVM()
    print('Loading and Visualizing Data ...')
    X, y = loadData(file_path + '\data1_Task.mat')
    plotData(X, y, title='Task 1')

    print('Program paused. Press enter to continue.')
    input()

    # Training
    print('Training SVM with RBF kernel ...')
    param = [0.01, 0.03, 0.1, 0.3, 1, 3, 10, 30]
    acc = []
    for C in param:
        for sigma in param:
            model = svm.svmTrain_SMO(X, y, C, kernal_function='gaussian', K_matrix=svm.gaussianKernel(X, sigma))
            pred = svm.svmPredict(model, np.mat(X), sigma)
            acc.append(1 - np.sum(abs(pred - y)) / len(y))
    print(acc)
    f = open('results.txt', 'a+')
    f.write('sigma\t%.3f\t%.3f\t%.3f\t%.3f\t%.3f\t%.3f\t%.3f\t%.3f\nC\n' \
          % (0.010, 0.030, 0.100, 0.300, 1.000, 3.000, 10.000, 30.000))
    count = 0
    for i in range(len(param)):
        content = '%.3f\t' % param[i]
        for j in range(len(param)):
            content += '%.3f\t' % acc[count]
            count += 1
        content += '\n'
        f.write(content)
    f.close()

    # results visualizing
    # print('Results visualizing ...')
    # svm.visualizeBoundaryGaussian(X, y, model, sigma)

def Task2():
    # load data
    print('Loading data ...')
    X_train, y_train = loadData(file_path + '\spamTrain.mat')
    X_test, y_test = loadData(file_path + '\spamTest.mat')
    # plotData(X_train, y_train, title='Task 2')

    print('Program paused. Press enter to continue.\n')
    input()

    # trainging
    svm = SVM()
    print('Number of samples: {}'.format(X_train.shape[0]))
    print('Number of features: {}'.format(X_train.shape[1]))
    print('Training Linear SVM ...')
    C = 1; sigma = 0.01;
    model = svm.svmTrain_SMO(X_train, y_train, C, max_iter=20)
    pred_train = svm.svmPredict(model, np.mat(X_train), sigma)
    acc_train = 1 - abs(np.sum(pred_train - y_train)) / len(y_train)
    print('Train accuracy: {}'.format(acc_train))

    # test
    print('Number of samples: {}'.format(X_test.shape[0]))
    print('Number of features: {}'.format(X_test.shape[1]))
    pred_test = svm.svmPredict(model, np.mat(X_test), sigma)
    acc_test = 1 - abs(np.sum(pred_test - y_test)) / len(y_test)
    print('Test accuracy: {}'.format(acc_test))

if __name__ == '__main__':
    Task2()
```

2.4 Results

2.4.1 Task1

Table 1: Results for different parameters C & sigma

sigma C	0.01	0.03	0.1	0.3	1	3	10	30
0.01	0.498	0.498	0.502	0.502	0.502	0.498	0.502	0.502
0.03	0.502	0.502	0.502	0.867	0.502	0.498	0.834	0.498
0.1	0.498	0.502	0.943	0.872	0.834	0.81	0.815	0.81
0.3	0.502	0.981	0.948	0.905	0.867	0.81	0.498	0.502
1	1	0.995	0.948	0.934	0.905	0.848	0.815	0.829
3	1	1	0.943	0.943	0.915	0.863	0.825	0.502
10	1	1	0.962	0.934	0.929	0.9	0.848	0.815
30	1	1	0.948	0.943	0.924	0.919	0.867	0.791



C = 1 & sigma = 0.01

C = 1 & sigma = 0.1

Figure 1: Boundary Visualization

2.4.2 Task2

- Train accuracy: 0.98775
  - Number of samples: 4000
  - Number of features: 1899
- Test accuracy: 0.982
  - Number of samples: 1000
  - Number of features: 1899