

THE CHINESE UNIVERSITY OF HONG KONG, SHENZHEN

**DDA3020**

**MACHINE LEARNING**

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*Assignment2 Report*

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**Apr 2, 2023**

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# 1 Written Questions

## 1.1 Question 1

### 1.1.1 (1)

False. When  $\lambda > 0$ , there will only one optimal solution for the minimizing problem.

### 1.1.2 (2)

False. For l2 regularization, the solution of  $w$  will be more likely to be close to 0 but not 0 because of the property of Gaussian distribution, and the solution is less likely to be located in the axis, which means not sparse.

### 1.1.3 (3)

True. Since  $\lambda = 0$ ,  $w$  can separates the data, and the log-likelihood function is increasing when  $w$  is increasing, thus the optimal choice of  $w$  maybe infinite for some  $w_j$ .

### 1.1.4 (4)

False. If  $\lambda$  increases, the effect of the regularization term will increase, then the effect to  $w$  will be higher, and the fitness of the model will decrease, which means the log-likelihood will decrease.

## 1.1.5 (5)

False. increasing  $\lambda$  will somehow reduce the effect of overfitting, however, if  $\lambda$  is too big,  $w$  will be pretty small and the significant level will be small, which may not be the good predictor.

## 1.2 Question 2

## 1.2.1 (1)

Assume one optimal solution is under the condition of  $\varepsilon < 0$ , then it means

$$y_i(w^T x_i + b) \geq 1 - \varepsilon \implies y_i(w^T x_i + b) \geq 1 \quad (1)$$

However under the condition of  $y_i(w^T x_i + b) \geq 1$ , i.e,  $\varepsilon = 0$ , the value of the objective function will sure to be small due to slacker constraints and smaller  $\varepsilon$ . Thus the assumption is not true, which means the optimal could only shown up when  $\varepsilon \geq 0$ .

## 1.2.2 (2)

The Lagrange function is:

$$L(w, b, \varepsilon, \alpha) = \frac{1}{2} \|w\|^2 + \frac{C}{2} \sum_{i=1}^m \varepsilon_i^2 + \sum_{i=1}^m [\alpha_i (1 - \varepsilon_i - y_i(w^T x_i + b))]$$

$$\alpha_i \geq 0, \forall i \quad (2)$$

## 1.2.3 (3)

$$\frac{\partial L}{\partial w} = w - \sum_{i=1}^m \alpha_i y_i x_i = 0 \implies w = \sum_{i=1}^m \alpha_i y_i x_i \quad (3)$$

$$\frac{\partial L}{\partial b} = - \sum_{i=1}^m \alpha_i y_i = 0 \implies \sum_{i=1}^m \alpha_i y_i = 0 \quad (4)$$

$$\frac{\partial L}{\partial \varepsilon_i} = 0 \implies C\varepsilon_i - \alpha_i = 0 \implies C\varepsilon_i = \alpha_i, \forall i \quad (5)$$

## 1.2.4 (4)

The function becomes

$F(\alpha) = L(w, b, \varepsilon, \alpha)$  (Plug in the stationarity conditions)

$$\begin{aligned} &= \frac{1}{2} \left( \sum_{i=1}^m \alpha_i y_i x_i \right)^T \left( \sum_{i=1}^m \alpha_i y_i x_i \right) + \frac{1}{2} \sum_{i=1}^m \alpha_i \varepsilon_i + \sum_{i=1}^m \alpha_i (1 - \varepsilon_i - y_i \left( \sum_{i=1}^m \alpha_i y_i x_i \right)^T x_i + b) \\ &= -\frac{1}{2} \sum_{i=1}^m \sum_{j=1}^m (\alpha_i y_i x_i)^T (\alpha_j y_j x_j) - \frac{1}{2} \sum_{i=1}^m \alpha_i \varepsilon_i + \sum_{i=1}^m \alpha_i - \sum_{i=1}^m \alpha_i y_i b \\ &= -\frac{1}{2} \sum_{i=1}^m \sum_{j=1}^m (\alpha_i y_i x_i)^T (\alpha_j y_j x_j) - \frac{1}{2} \sum_{i=1}^m \frac{\alpha_i^2}{C} + \sum_{i=1}^m \alpha_i \\ &= -\frac{1}{2} \sum_{i=1}^m \sum_{j=1}^m \alpha_i \alpha_j y_i y_j x_i^T x_j - \frac{1}{2} \sum_{i=1}^m \frac{\alpha_i^2}{C} + \sum_{i=1}^m \alpha_i \end{aligned} \quad (6)$$

Thus the dual problem is:

$$\begin{aligned} \max_{\alpha} \quad & -\frac{1}{2} \sum_{i=1}^m \sum_{j=1}^m \alpha_i \alpha_j y_i y_j x_i^T x_j - \frac{1}{2} \sum_{i=1}^m \frac{\alpha_i^2}{C} + \sum_{i=1}^m \alpha_i \\ & \sum_{i=1}^m \alpha_i y_i = 0, \alpha_i \geq 0, \forall i \end{aligned} \quad (7)$$

### 1.3 Question 3

#### 1.3.1 (1)

No. By drawing the graph we can find that the three points in Class -1 are right in the triangle constructed by the three points in Class +1, which means there is no straight line such that can separate the two classes perfectly, so there is no such kind of svm classifier without slack variable.

#### 1.3.2 (2)

After the transformation, we get the class -1: (0 1), (1/2 1/2) and class +1: (0 2), (1 1). Obviously we can find that class -1 constructs the line of  $x_1^2 + x_2^2 = 1$ , class +1 constructs the line of  $x_1^2 + x_2^2 = 2$ . Clearly that the optimal svm is  $x_1^2 + x_2^2 - \frac{3}{2}$  (Using that mathematical result that in two parallel lines, the line with the largest margin will be the middle line). Where the data belongs to class -1 if  $x_1^2 + x_2^2 - \frac{3}{2} < 0$ , and belongs to class +1 if  $x_1^2 + x_2^2 - \frac{3}{2} > 0$ .

Thus for the new data,  $x_1^2 + x_2^2 - \frac{3}{2} = \frac{1}{2} + 2 - \frac{3}{2} = 1 > 0$ , thus the newdata belongs to class +1.

## 1.4 Question 4

### 1.4.1 (1)

$$\begin{aligned}
 H(Passed) &= -\frac{1}{3}\log_2\left(\frac{1}{3}\right) - \frac{2}{3}\log_2\left(\frac{2}{3}\right) \\
 &= \frac{1}{3}\log_2(3) - \frac{2}{3}(1 - \log_2(3)) \\
 &= 0.933333
 \end{aligned} \tag{8}$$

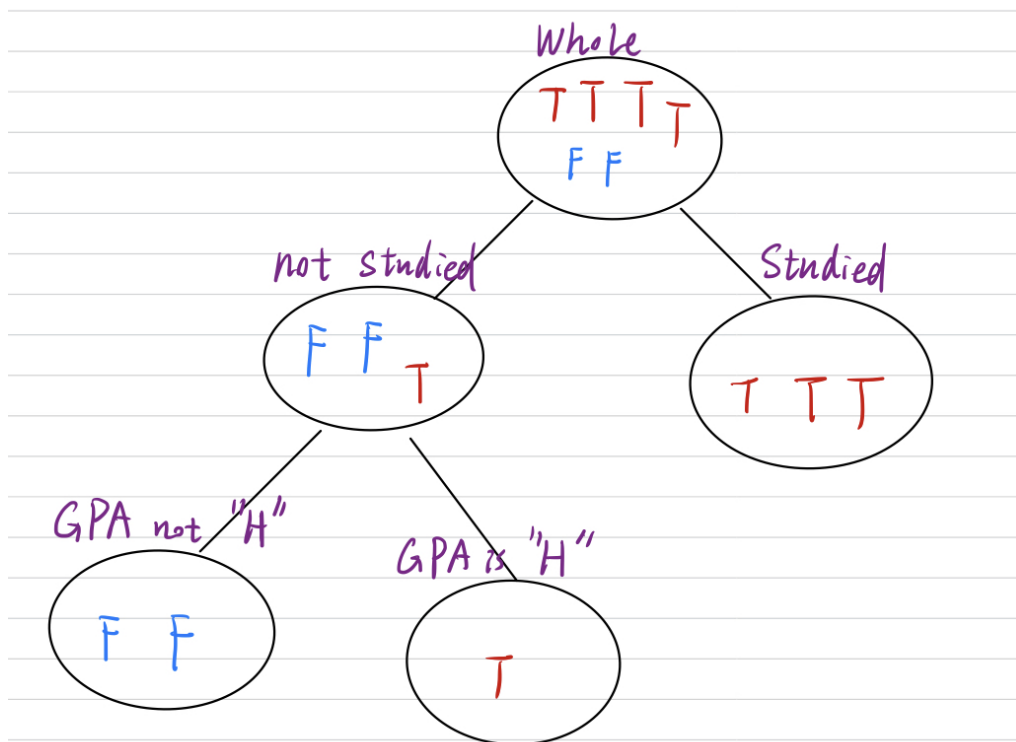
### 1.4.2 (2)

$$\begin{aligned}
 H(Passed|GPA) &= \frac{1}{3}H\left(\frac{1}{2}, \frac{1}{2}\right) + \frac{1}{3}H\left(\frac{1}{2}, \frac{1}{2}\right) + \frac{1}{3}H\left(\frac{0}{2}, \frac{2}{2}\right) \\
 &= \frac{2}{3}
 \end{aligned} \tag{9}$$

### 1.4.3 (3)

$$\begin{aligned}
 H(Passed|Studied) &= \frac{1}{2}H\left(\frac{2}{3}, \frac{1}{3}\right) + \frac{1}{2}H\left(\frac{0}{3}, \frac{3}{3}\right) \\
 &= \frac{1}{2}\left(\frac{1}{3}\log_2(3) - \frac{2}{3}(1 - \log_2(3))\right) \\
 &= 0.466666
 \end{aligned} \tag{10}$$





1.4.4 (4)

## 2 Programming Questions

2.1 (a)

### 2.1.1 Optimization Problem

In this question we use the strictly linear SVM without slack variables. (As the question has said, we set  $C = 1e5$  to estimate it.) For each data point,  $x_i, y_i$  represents its features and the class. In our strategy of 'ovr',  $y_i$  is set to be  $+1$  for the corresponding class in each SVM and  $-1$  for others. Our goal is to maximize the margin over all training data points, while given a hyperplane to well classify the data points. Since

we only want correct  $f_{w,b}$ , and recall  $y_i \in \{+1, -1\}$ , we have  $\gamma = \min_i \frac{y_i f_{x,b}(x_i)}{\|w\|}$  and we want to maximize it. We observe that  $(w, b)$  can be scaled by any factor  $c$ , then we can fix scale such that  $y_i(w^T x_i + b) = 1$ . Thus the above optimization is simplified to

$$\begin{aligned} \min_{w,b} \quad & \frac{1}{2} \|w\|^2 \\ \text{Subject to} \quad & y_i(w^T x_i + b) \geq 1, \forall i \end{aligned} \quad (11)$$

We obtain the Lagrange function is

$$L(w, b, \alpha) = \frac{1}{2} \|w\|^2 + \sum_i^m \alpha_i (1 - y_i(w^T x_i + b)) \quad (12)$$

With KKT conditions we have  $w = \sum_i^m \alpha_i y_i x_i$ ,  $\sum_i^m \alpha_i y_i = 0$ , plug in we have the dual problem of

$$\begin{aligned} \max_{\alpha} \quad & \sum_i^m \alpha_i - \frac{1}{2} \sum_{i,j}^m \alpha_i \alpha_j y_i y_j x_i^T x_j, \\ \text{s.t.} \quad & \sum_i^m \alpha_i y_i = 0, \alpha_i \geq 0, \forall i \end{aligned} \quad (13)$$

Which gives a primal solution  $w = \sum_i^m \alpha_i y_i x_i$ , and we can solve  $b = \frac{1}{|S|} \sum_{j \in S} (y_i - \sum_i^m \alpha_i y_i x_i^T x_j)$

### 2.1.2 Formulation and Results

In this task, the data has 13 features, which is  $x$  with 13-dimensions. There are three classes, 0,1,2, and they will be  $y$  (In each SVM, they will be signed as +1 and -1).

The training error is the wrong prediction percentage based on the training data, and the testing error is the wrong prediction percentage based on the testing data. The model's coefficients and the intercepts are the corresponding  $w, b$  in the SVM model.

The support vector represents the points' location that formulate the SVM model.

Here I randomly pick 80/100 datasets as the training set and the rest as the testing set, and get the results below:

Training error: 0.0

Testing error: 0.05555555555555558

w of wine type 0: 6.62338390e-01, 6.69624687e-01, 2.01271245e+00, -2.05179972e-01, 1.00544273e-02, -3.07231148e-01, 4.63822304e-01, 4.78811218e-01, -2.80014366e-01, 4.24086602e-01, -2.55917232e-01, 4.47596063e-01, 4.84210551e-03

b of wine type 0: -18.40689248

support vector indices of wine type 0: [1.324e+01, 3.980e+00, 2.290e+00, 1.750e+01, 1.030e+02, 2.640e+00, 2.630e+00, 3.200e-01, 1.660e+00, 4.360e+00, 8.200e-01, 3.000e+00, 6.800e+02], [1.305e+01, 1.770e+00, 2.100e+00, 1.700e+01, 1.070e+02, 3.000e+00, 3.000e+00, 2.800e-01, 2.030e+00, 5.040e+00, 8.800e-01, 3.350e+00, 8.850e+02], [1.305e+01, 2.050e+00, 3.220e+00, 2.500e+01, 1.240e+02, 2.630e+00, 2.680e+00, 4.700e-01, 1.920e+00, 3.580e+00, 1.130e+00, 3.200e+00, 8.300e+02], [1.307e+01, 1.500e+00, 2.100e+00, 1.550e+01, 9.800e+01, 2.400e+00, 2.640e+00,

2.800e-01, 1.370e+00, 3.700e+00, 1.180e+00, 2.690e+00, 1.020e+03], [1.341e+01, 3.840e+00, 2.120e+00, 1.880e+01, 9.000e+01, 2.450e+00, 2.680e+00, 2.700e-01, 1.480e+00, 4.280e+00, 9.100e-01, 3.000e+00, 1.035e+03], [1.293e+01, 3.800e+00, 2.650e+00, 1.860e+01, 1.020e+02, 2.410e+00, 2.410e+00, 2.500e-01, 1.980e+00, 4.500e+00, 1.030e+00, 3.520e+00, 7.700e+02]

w of wine type 1: 5.14091396e-02, 9.93875738e-03, 5.40213305e-02, -1.34013571e-01, 2.37352663e-02, 2.71627697e-01, 4.71939086e-01, -1.66591868e-02, 1.35995743e-01, -1.73465190e-01, 6.41431400e-02, 3.18156672e-01, 1.45687772e-03

b of wine type 1: -3.36080405

support vector indices of wine type 1: [1.229e+01, 1.610e+00, 2.210e+00, 2.040e+01, 1.030e+02, 1.100e+00, 1.020e+00, 3.700e-01, 1.460e+00, 3.050e+00, 9.060e-01, 1.820e+00, 8.700e+02], [1.334e+01, 9.400e-01, 2.360e+00, 1.700e+01, 1.100e+02, 2.530e+00, 1.300e+00, 5.500e-01, 4.200e-01, 3.170e+00, 1.020e+00, 1.930e+00, 7.500e+02], [1.264e+01, 1.360e+00, 2.020e+00, 1.680e+01, 1.000e+02, 2.020e+00, 1.410e+00, 5.300e-01, 6.200e-01, 5.750e+00, 9.800e-01, 1.590e+00, 4.500e+02], [1.305e+01, 5.800e+00, 2.130e+00, 2.150e+01, 8.600e+01, 2.620e+00, 2.650e+00, 3.000e-01, 2.010e+00, 2.600e+00, 7.300e-01, 3.100e+00, 3.800e+02], [1.247e+01, 1.520e+00, 2.200e+00, 1.900e+01, 1.620e+02, 2.500e+00, 2.270e+00, 3.200e-01, 3.280e+00, 2.600e+00, 1.160e+00, 2.630e+00, 9.370e+02], [1.299e+01, 1.670e+00,

2.600e+00, 3.000e+01, 1.390e+02, 3.300e+00, 2.890e+00, 2.100e-01, 1.960e+00,  
3.350e+00, 1.310e+00, 3.500e+00, 9.850e+02], [1.272e+01, 1.810e+00, 2.200e+00,  
1.880e+01, 8.600e+01, 2.200e+00, 2.530e+00, 2.600e-01, 1.770e+00, 3.900e+00,  
1.160e+00, 3.140e+00, 7.140e+02], [1.237e+01, 1.210e+00, 2.560e+00, 1.810e+01,  
9.800e+01, 2.420e+00, 2.650e+00, 3.700e-01, 2.080e+00, 4.600e+00, 1.190e+00,  
2.300e+00, 6.780e+02], [1.305e+01, 3.860e+00, 2.320e+00, 2.250e+01, 8.500e+01,  
1.650e+00, 1.590e+00, 6.100e-01, 1.620e+00, 4.800e+00, 8.400e-01, 2.010e+00,  
5.150e+02]

w of wine type 2: -5.03568746e-01, -4.82149281e-01, -6.46960506e-01, -4.83103995e-  
02, -4.17102312e-03, 1.50966184e-01, 1.48765429e+00, 2.83272950e-01, 6.33932305e-  
01, -1.25974069e+00, 4.02912964e-01, 6.11229261e-01, -7.12349596e-03

b of wine type 2: 16.68685232

support vector indices of wine type 2: [1.296e+01, 3.450e+00, 2.350e+00, 1.850e+01,  
1.060e+02, 1.390e+00, 7.000e-01, 4.000e-01, 9.400e-01, 5.280e+00, 6.800e-01,  
1.750e+00, 6.750e+02], [1.316e+01, 3.570e+00, 2.150e+00, 2.100e+01, 1.020e+02,  
1.500e+00, 5.500e-01, 4.300e-01, 1.300e+00, 4.000e+00, 6.000e-01, 1.680e+00,  
8.300e+02], [1.288e+01, 2.990e+00, 2.400e+00, 2.000e+01, 1.040e+02, 1.300e+00,  
1.220e+00, 2.400e-01, 8.300e-01, 5.400e+00, 7.400e-01, 1.420e+00, 5.300e+02],  
[1.251e+01, 1.240e+00, 2.250e+00, 1.750e+01, 8.500e+01, 2.000e+00, 5.800e-01,

6.000e-01, 1.250e+00, 5.450e+00, 7.500e-01, 1.510e+00, 6.500e+02], [1.225e+01, 3.880e+00, 2.200e+00, 1.850e+01, 1.120e+02, 1.380e+00, 7.800e-01, 2.900e-01, 1.140e+00, 8.210e+00, 6.500e-01, 2.000e+00, 8.550e+02], [1.362e+01, 4.950e+00, 2.350e+00, 2.000e+01, 9.200e+01, 2.000e+00, 8.000e-01, 4.700e-01, 1.020e+00, 4.400e+00, 9.100e-01, 2.050e+00, 5.500e+02], [1.352e+01, 3.170e+00, 2.720e+00, 2.350e+01, 9.700e+01, 1.550e+00, 5.200e-01, 5.000e-01, 5.500e-01, 4.350e+00, 8.900e-01, 2.060e+00, 5.200e+02]

### 2.1.3 Parameters Settings

In the first question there are no parameters to judge about, the only thing different is the splitting of the training and the testing sets. With different sets we may obtain that the error of the testing sets maybe 0 or not, while the training error is always zero, and the support vectors are changing as well.

### 2.1.4 Linearly separable

To judge whether the classes are linearly separable, we can use the strategy by changing the labels and transform the 3-classes problem into two classes problem, and use the whole datasets as the training data to see if there is any error, if there is no error, then the corresponding class is linearly separable. After the experiment we find that all the classes are linearly separable.

True	0	1	All	True	0	1	All	True	1	2	All
predict				predict				predict			
0	59	0	59	0	107	0	107	1	130	0	130
1	0	119	119	1	0	71	71	2	0	48	48
All	59	119	178	All	107	71	178	All	130	48	178

## 2.2 b

### 2.2.1 Optimization Problem

Now we consider the SVM with the slack variables. For each data we introduce slack variable  $\varepsilon_i \geq 0$ , then we allow some errors for training data  $y_i(w^T x_i + b) \geq 1 - \varepsilon_i \forall i$ .

Thus the problem becomes

$$\begin{aligned} \min_{w, b, \varepsilon} & \frac{1}{2} \|w\|^2 + C \sum_i^m \varepsilon_i \\ \text{s.t.} & 1 - \varepsilon_i - y_i(w^T x_i + b) \leq 0, -\varepsilon_i \leq 0, \forall i \end{aligned} \quad (14)$$

The lagrange function is

$$L(w, b, \varepsilon, \alpha, \mu) = \frac{1}{2} \|w\|^2 + C \sum_i^m \varepsilon_i + \sum_i^m [\alpha_i(1 - \varepsilon_i - y_i(w^T x_i + b)) + \mu_i(-\varepsilon_i)] \quad (15)$$

By KKT conditions we have  $w = \sum_i^m \alpha_i y_i x_i$ ,  $\sum_i^m \alpha_i y_i = 0$ ,  $\alpha_i = C - \mu_i, \forall i$ . Plug in we get the dual problem

$$\begin{aligned} \max_{\alpha} & \sum_i^m \alpha_i - \frac{1}{2} \sum_{i, j} \alpha_i \alpha_j y_i y_j x_i^T x_j, \\ \text{s.t.} & \sum_i^m \alpha_i y_i = 0, 0 \leq \alpha_i \leq C, \forall i \end{aligned} \quad (16)$$

We can solve that  $b = \frac{1}{|M|} \sum_{j \in M} (y_j - \sum_i^m \alpha_i y_i x_i^T x_j)$ ,  $M := \{i | 0 < \alpha < C\}$

### 2.2.2 Formulation and Results

The main part is the same as the first question. Here we add addition values of  $C$  and slack variables.  $C$  can be represented as the tolerance of the strict linearly, which means that large  $C$  will lead to more slack variables. Slack variables is some training error points that we can tolerant, to avoid the effect of overfitting. For right classified class, the slack variable will stay between  $w^T x + b = 0$  and  $w^T x + b = 1$ , while for the wrongli classified they will between  $w^T x + b = 0$  and  $w^T x + b = -1$ .

Below are the results for this question:

Now the  $C$  is 0.1

Training error is 0.021126760563380254

Testing error is 0.05555555555555558

w for class 0 is [ 0.36001659 0.50045565 0.2336517 -0.12820641 -0.00878086 -  
0.02185188 0.15424484 0.04539897 -0.09494953 0.36460161 -0.074198 0.14619181  
0.0055183 ]

b for class 0 is -9.31425172135894

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]



[1.305e+01 1.650e+00 2.550e+00 1.800e+01 9.800e+01 2.450e+00 2.430e+00  
2.900e-01 1.440e+00 4.250e+00 1.120e+00 2.510e+00 1.105e+03] [1.305e+01  
1.770e+00 2.100e+00 1.700e+01 1.070e+02 3.000e+00 3.000e+00 2.800e-01 2.030e+00  
5.040e+00 8.800e-01 3.350e+00 8.850e+02] [1.324e+01 3.980e+00 2.290e+00  
1.750e+01 1.030e+02 2.640e+00 2.630e+00 3.200e-01 1.660e+00 4.360e+00 8.200e-  
01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00 3.220e+00 2.500e+01 1.240e+02  
2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00 1.130e+00 3.200e+00 8.300e+02]  
[1.406e+01 1.630e+00 2.280e+00 1.600e+01 1.260e+02 3.000e+00 3.170e+00  
2.400e-01 2.100e+00 5.650e+00 1.090e+00 3.710e+00 7.800e+02] [1.293e+01  
3.800e+00 2.650e+00 1.860e+01 1.020e+02 2.410e+00 2.410e+00 2.500e-01 1.980e+00  
4.500e+00 1.030e+00 3.520e+00 7.700e+02] [1.324e+01 2.590e+00 2.870e+00  
2.100e+01 1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00  
2.930e+00 7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01  
2.200e+00 2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02]  
[1.181e+01 2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-  
01 1.560e+00 2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.367e+01 1.250e+00  
1.920e+00 1.800e+01 9.400e+01 2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00  
1.230e+00 2.460e+00 6.300e+02] [1.299e+01 1.670e+00 2.600e+00 3.000e+01  
1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00

9.850e+02] [1.200e+01 1.510e+00 2.420e+00 2.200e+01 8.600e+01 1.450e+00  
1.250e+00 5.000e-01 1.630e+00 3.600e+00 1.050e+00 2.650e+00 4.500e+02] [1.311e+01  
1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00  
1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-  
01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]  
[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-  
01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.208e+01 2.080e+00  
1.700e+00 1.750e+01 9.700e+01 2.230e+00 2.170e+00 2.600e-01 1.400e+00 3.300e+00  
1.270e+00 2.960e+00 7.100e+02] [1.247e+01 1.520e+00 2.200e+00 1.900e+01  
1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00 2.630e+00  
9.370e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00  
1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01  
2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-  
01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00  
2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-  
01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02  
1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02]

[1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.288e+01 2.990e+00 2.400e+00 2.000e+01 1.040e+02 1.300e+00 1.220e+00 2.400e-01 8.300e-01 5.400e+00 7.400e-01 1.420e+00 5.300e+02]]

Slack variables for class 0 is 42

w for class 1 is [ 5.20382260e-02 6.57179780e-02 9.57964774e-02 -5.76814866e-02 7.84342168e-03 2.87734230e-01 4.56259369e-01 -3.73436634e-04 1.70952809e-01 -1.01920744e-01 6.69602857e-02 3.66106220e-01 1.65560298e-03]

b for class 1 is -4.213569533805448

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02] [1.305e+01 1.650e+00 2.550e+00 1.800e+01 9.800e+01 2.450e+00 2.430e+00 2.900e-01 1.440e+00 4.250e+00 1.120e+00 2.510e+00 1.105e+03] [1.305e+01 1.770e+00 2.100e+00 1.700e+01 1.070e+02 3.000e+00 3.000e+00 2.800e-01 2.030e+00 5.040e+00 8.800e-01 3.350e+00 8.850e+02] [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00 3.200e-01 1.660e+00 4.360e+00 8.200e-

01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00 3.220e+00 2.500e+01 1.240e+02  
2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00 1.130e+00 3.200e+00 8.300e+02]  
[1.406e+01 1.630e+00 2.280e+00 1.600e+01 1.260e+02 3.000e+00 3.170e+00  
2.400e-01 2.100e+00 5.650e+00 1.090e+00 3.710e+00 7.800e+02] [1.293e+01  
3.800e+00 2.650e+00 1.860e+01 1.020e+02 2.410e+00 2.410e+00 2.500e-01 1.980e+00  
4.500e+00 1.030e+00 3.520e+00 7.700e+02] [1.324e+01 2.590e+00 2.870e+00  
2.100e+01 1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00  
2.930e+00 7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01  
2.200e+00 2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02]  
[1.181e+01 2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-  
01 1.560e+00 2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.367e+01 1.250e+00  
1.920e+00 1.800e+01 9.400e+01 2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00  
1.230e+00 2.460e+00 6.300e+02] [1.299e+01 1.670e+00 2.600e+00 3.000e+01  
1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00  
9.850e+02] [1.200e+01 1.510e+00 2.420e+00 2.200e+01 8.600e+01 1.450e+00  
1.250e+00 5.000e-01 1.630e+00 3.600e+00 1.050e+00 2.650e+00 4.500e+02] [1.311e+01  
1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00  
1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-

01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]  
[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-  
01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.208e+01 2.080e+00  
1.700e+00 1.750e+01 9.700e+01 2.230e+00 2.170e+00 2.600e-01 1.400e+00 3.300e+00  
1.270e+00 2.960e+00 7.100e+02] [1.247e+01 1.520e+00 2.200e+00 1.900e+01  
1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00 2.630e+00  
9.370e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00  
1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01  
2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-  
01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00  
2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-  
01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02  
1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02]  
[1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-  
01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00  
2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00  
8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01  
1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00

8.550e+02] [1.288e+01 2.990e+00 2.400e+00 2.000e+01 1.040e+02 1.300e+00  
1.220e+00 2.400e-01 8.300e-01 5.400e+00 7.400e-01 1.420e+00 5.300e+02]]

Slack variables for class 1 is 51

w for class 2 is [-0.07429969 -0.32018575 -0.06608931 -0.0557477 0.00061941  
0.15302991 0.33565143 -0.03329272 0.12205233 -0.52679543 0.07076107 0.31137439  
-0.00138895]

b for class 2 is 4.507554165757067

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.305e+01 1.650e+00 2.550e+00 1.800e+01 9.800e+01 2.450e+00 2.430e+00  
2.900e-01 1.440e+00 4.250e+00 1.120e+00 2.510e+00 1.105e+03] [1.305e+01  
1.770e+00 2.100e+00 1.700e+01 1.070e+02 3.000e+00 3.000e+00 2.800e-01 2.030e+00  
5.040e+00 8.800e-01 3.350e+00 8.850e+02] [1.324e+01 3.980e+00 2.290e+00  
1.750e+01 1.030e+02 2.640e+00 2.630e+00 3.200e-01 1.660e+00 4.360e+00 8.200e-  
01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00 3.220e+00 2.500e+01 1.240e+02  
2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00 1.130e+00 3.200e+00 8.300e+02]  
[1.406e+01 1.630e+00 2.280e+00 1.600e+01 1.260e+02 3.000e+00 3.170e+00  
2.400e-01 2.100e+00 5.650e+00 1.090e+00 3.710e+00 7.800e+02] [1.293e+01  
3.800e+00 2.650e+00 1.860e+01 1.020e+02 2.410e+00 2.410e+00 2.500e-01 1.980e+00

4.500e+00 1.030e+00 3.520e+00 7.700e+02] [1.324e+01 2.590e+00 2.870e+00  
2.100e+01 1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00  
2.930e+00 7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01  
2.200e+00 2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02]  
[1.181e+01 2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-  
01 1.560e+00 2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.367e+01 1.250e+00  
1.920e+00 1.800e+01 9.400e+01 2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00  
1.230e+00 2.460e+00 6.300e+02] [1.299e+01 1.670e+00 2.600e+00 3.000e+01  
1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00  
9.850e+02] [1.200e+01 1.510e+00 2.420e+00 2.200e+01 8.600e+01 1.450e+00  
1.250e+00 5.000e-01 1.630e+00 3.600e+00 1.050e+00 2.650e+00 4.500e+02] [1.311e+01  
1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00  
1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-  
01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]  
[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-  
01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.208e+01 2.080e+00  
1.700e+00 1.750e+01 9.700e+01 2.230e+00 2.170e+00 2.600e-01 1.400e+00 3.300e+00

1.270e+00 2.960e+00 7.100e+02] [1.247e+01 1.520e+00 2.200e+00 1.900e+01  
1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00 2.630e+00  
9.370e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00  
1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01  
2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-  
01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00  
2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-  
01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02  
1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02]  
[1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-  
01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00  
2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00  
8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01  
1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00  
8.550e+02] [1.288e+01 2.990e+00 2.400e+00 2.000e+01 1.040e+02 1.300e+00  
1.220e+00 2.400e-01 8.300e-01 5.400e+00 7.400e-01 1.420e+00 5.300e+02]]

Slack variables for class 2 is 140

Now the C is 0.2

Training error is 0.007042253521126751



Testing error is 0.05555555555555558

w for class 0 is [ 0.41177808 0.55810833 0.35760662 -0.14511297 -0.00868094 -  
0.04935675 0.17070539 0.06466756 -0.11060423 0.38970035 -0.06469166 0.22272926  
0.00581288]

b for class 0 is -10.48732195447678

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.305e+01 5.800e+00 2.130e+00  
2.150e+01 8.600e+01 2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-  
01 3.100e+00 3.800e+02] [1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02  
3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02]

[1.311e+01 1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00  
2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01  
3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-  
01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00  
2.100e+01 1.010e+02 3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-  
01 3.130e+00 8.860e+02] [1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02  
2.530e+00 1.300e+00 5.500e-01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02]  
[1.247e+01 1.520e+00 2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00  
3.200e-01 3.280e+00 2.600e+00 1.160e+00 2.630e+00 9.370e+02] [1.237e+01  
1.210e+00 2.560e+00 1.810e+01 9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00  
4.600e+00 1.190e+00 2.300e+00 6.780e+02] [1.349e+01 1.660e+00 2.240e+00  
2.400e+01 8.700e+01 1.880e+00 1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-  
01 2.780e+00 4.720e+02] [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02  
2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02]  
[1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-  
01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00  
2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00  
7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01  
9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00

5.500e+02] [1.352e+01 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00  
5.200e-01 5.000e-01 5.500e-01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01  
3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00  
8.210e+00 6.500e-01 2.000e+00 8.550e+02]]

Slack variables for class 0 is 42

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955  
0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932  
0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00

2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.305e+01 5.800e+00 2.130e+00  
2.150e+01 8.600e+01 2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-  
01 3.100e+00 3.800e+02] [1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02  
3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02]  
[1.311e+01 1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00  
2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01  
3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-  
01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00  
2.100e+01 1.010e+02 3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-  
01 3.130e+00 8.860e+02] [1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02  
2.530e+00 1.300e+00 5.500e-01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02]  
[1.247e+01 1.520e+00 2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00  
3.200e-01 3.280e+00 2.600e+00 1.160e+00 2.630e+00 9.370e+02] [1.237e+01  
1.210e+00 2.560e+00 1.810e+01 9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00  
4.600e+00 1.190e+00 2.300e+00 6.780e+02] [1.349e+01 1.660e+00 2.240e+00  
2.400e+01 8.700e+01 1.880e+00 1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-  
01 2.780e+00 4.720e+02] [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02  
2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02]  
[1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-

01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00  
 2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00  
 7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01  
 9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00  
 5.500e+02] [1.352e+01 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00  
 5.200e-01 5.000e-01 5.500e-01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01  
 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00  
 8.210e+00 6.500e-01 2.000e+00 8.550e+02]]

Slack variables for class 1 is 50

w for class 2 is [-0.23171778 -0.30014964 -0.08783748 -0.0697561 -0.01013321  
 0.19743795 0.41570989 -0.04362713 0.18859761 -0.62256344 0.06000753 0.38465732  
 -0.00109988]

b for class 2 is 7.778933780425047

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
 [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
 3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
 1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01

1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.305e+01 5.800e+00 2.130e+00  
2.150e+01 8.600e+01 2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-  
01 3.100e+00 3.800e+02] [1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02  
3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02]  
[1.311e+01 1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00  
2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01  
3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-  
01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00  
2.100e+01 1.010e+02 3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-  
01 3.130e+00 8.860e+02] [1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02  
2.530e+00 1.300e+00 5.500e-01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02]  
[1.247e+01 1.520e+00 2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00  
3.200e-01 3.280e+00 2.600e+00 1.160e+00 2.630e+00 9.370e+02] [1.237e+01  
1.210e+00 2.560e+00 1.810e+01 9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00  
4.600e+00 1.190e+00 2.300e+00 6.780e+02] [1.349e+01 1.660e+00 2.240e+00

2.400e+01 8.700e+01 1.880e+00 1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00 8.550e+02]]

Slack variables for class 2 is 140

Now the C is 0.3

Training error is 0.007042253521126751

Testing error is 0.05555555555555558

w for class 0 is [ 0.45662395 0.53729193 0.51134607 -0.15338124 -0.00939322 -0.04766088 0.17955698 0.08762293 -0.08235606 0.35179057 -0.07703139 0.28781213 0.00574874]

b for class 0 is -11.196225937428268

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00  
2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02] [1.311e+01  
1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00



1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-  
01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]  
[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-  
01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00  
2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00  
1.160e+00 2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01  
9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00  
6.780e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00  
1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01  
2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-  
01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00  
2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-  
01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02  
1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02]  
[1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-  
01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00  
2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00  
8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01

1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00  
8.550e+02]]

Slack variables for class 0 is 40

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955  
0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932  
0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-

01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00  
2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02] [1.311e+01  
1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00  
1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-  
01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]  
[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-  
01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00  
2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00  
1.160e+00 2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01  
9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00  
6.780e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00  
1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01  
2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-  
01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00  
2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-

01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02  
 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02]  
 [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-  
 01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00  
 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00  
 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01  
 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00  
 8.550e+02]]

Slack variables for class 1 is 50

w for class 2 is [-0.26098765 -0.2999299 -0.04894119 -0.06324285 -0.01436337  
 0.24328431 0.34410664 -0.03409968 0.19256906 -0.69368892 0.08558781 0.42216143  
 -0.00091823]

b for class 2 is 8.391653991014923

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
 [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
 3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
 1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01

1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00  
2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02] [1.311e+01  
1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00  
1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-  
01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]  
[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-  
01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00  
2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00  
1.160e+00 2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01

9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00  
 6.780e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00  
 1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01  
 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-  
 01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00  
 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-  
 01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02  
 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02]  
 [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-  
 01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00  
 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00  
 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01  
 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00  
 8.550e+02]]

Slack variables for class 2 is 139

Now the C is 0.4

Training error is 0.007042253521126751

Testing error is 0.05555555555555558

w for class 0 is [ 0.50146987 0.51647626 0.66508617 -0.16164925 -0.01010538 -

0.04596567 0.18840877 0.11057844 -0.05410815 0.31388185 -0.08937105 0.35289439  
0.00568458]

b for class 0 is -11.905145723971735

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00  
2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02] [1.311e+01

1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00  
1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-  
01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]  
[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-  
01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00  
2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00  
1.160e+00 2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01  
9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00  
6.780e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00  
1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01  
2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-  
01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00  
2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-  
01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02  
1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02]  
[1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-  
01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00



2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00  
8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01  
1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00  
8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00  
4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 0 is 39

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955  
0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932  
0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01

2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00  
2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02] [1.311e+01  
1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00  
1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-  
01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]  
[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-  
01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00  
2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00  
1.160e+00 2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01  
9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00  
6.780e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00  
1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01

2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-  
 01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00  
 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-  
 01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02  
 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02]  
 [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-  
 01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00  
 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00  
 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01  
 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00  
 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00  
 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 1 is 50

w for class 2 is [-2.74137634e-01 -2.71048979e-01 4.37862362e-04 -5.97588581e-  
 02 -1.57886582e-02 2.78795445e-01 3.40243177e-01 2.37655238e-03 1.53395422e-  
 01 -7.43220613e-01 8.97434462e-02 4.80662679e-01 -8.04109923e-04]

b for class 2 is 8.385306623617545

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]

[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00  
2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02] [1.311e+01  
1.010e+00 1.700e+00 1.500e+01 7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00  
5.300e+00 1.120e+00 3.180e+00 5.020e+02] [1.277e+01 3.430e+00 1.980e+00  
1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-  
01 2.120e+00 3.720e+02] [1.196e+01 1.090e+00 2.300e+00 2.100e+01 1.010e+02  
3.380e+00 2.140e+00 1.300e-01 1.650e+00 3.210e+00 9.900e-01 3.130e+00 8.860e+02]

[1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00 2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01 2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02] [1.349e+01 1.660e+00 2.240e+00 2.400e+01 8.700e+01 1.880e+00 1.840e+00 2.700e-01 1.030e+00 3.740e+00 9.800e-01 2.780e+00 4.720e+02] [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 2 is 136

Now the C is 0.5

Training error is 0.007042253521126751

Testing error is 0.05555555555555558

w for class 0 is [ 0.57865513 0.58866457 0.81655015 -0.18536988 -0.00850155 -  
0.02509407 0.21451472 0.13485216 -0.07997291 0.38881661 -0.11383435 0.40920614  
0.00612516]

b for class 0 is -13.876064078362193

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00

2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.367e+01 1.250e+00 1.920e+00 1.800e+01 9.400e+01  
2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00 1.230e+00 2.460e+00 6.300e+02]  
[1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01 2.620e+00 2.650e+00  
3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01

1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01  
 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-  
 01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00  
 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-  
 01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01  
 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 0 is 38

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955  
 0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932  
 0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
 [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
 3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
 1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01



1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.367e+01 1.250e+00 1.920e+00 1.800e+01 9.400e+01  
2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00 1.230e+00 2.460e+00 6.300e+02]  
[1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01 2.620e+00 2.650e+00  
3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01

2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
 [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
 01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01  
 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-  
 01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00  
 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-  
 01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01  
 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 1 is 50

w for class 2 is [-2.90683599e-01 -2.55705313e-01 3.88850786e-02 -5.86102529e-  
 02 -1.67089637e-02 2.98001128e-01 3.28877911e-01 2.93113396e-02 1.06732850e-  
 01 -7.74921797e-01 1.19395239e-01 5.50673899e-01 -7.68459136e-04]

b for class 2 is 8.459095265252992

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01

2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.367e+01 1.250e+00 1.920e+00 1.800e+01 9.400e+01  
2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00 1.230e+00 2.460e+00 6.300e+02]  
[1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01 2.620e+00 2.650e+00  
3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00

1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01  
3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-  
01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00  
1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-  
01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01  
1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 2 is 135

Now the C is 0.6

Training error is 0.0

Testing error is 0.05555555555555558

w for class 0 is [ 0.67656728 0.63795162 0.98656538 -0.19881496 -0.00172868 -  
0.02528295 0.24307955 0.16709878 -0.12965083 0.50582423 -0.13070121 0.44200038  
0.00577747]

b for class 0 is -16.338104550711428

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-

01 3.690e+00 4.650e+02] [1.367e+01 1.250e+00 1.920e+00 1.800e+01 9.400e+01  
2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00 1.230e+00 2.460e+00 6.300e+02]  
[1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01 2.620e+00 2.650e+00  
3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02] [1.233e+01 9.900e-  
01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-01 2.760e+00  
3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00 2.600e+00  
3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00  
3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01 7.800e+01  
2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00 5.020e+02]  
[1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00 1.250e+00  
4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01 9.400e-  
01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-01  
3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00

6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01  
 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-  
 01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00  
 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-  
 01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01  
 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 0 is 41

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955  
 0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932  
 0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
 [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
 3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00

1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.367e+01 1.250e+00 1.920e+00 1.800e+01 9.400e+01  
2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00 1.230e+00 2.460e+00 6.300e+02]  
[1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01 2.620e+00 2.650e+00  
3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02] [1.233e+01 9.900e-  
01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-01 2.760e+00  
3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00 2.600e+00  
3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00  
3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01 7.800e+01  
2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00 5.020e+02]  
[1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00 1.250e+00  
4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01 9.400e-  
01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-01



3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
 2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
 2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
 [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
 01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01  
 3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-  
 01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00  
 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-  
 01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01  
 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 1 is 50

w for class 2 is [-2.86952722e-01 -2.42964929e-01 6.38704045e-02 -4.03599089e-  
 02 -2.10084682e-02 3.76867816e-01 3.13662183e-01 5.56917672e-02 1.06890936e-

01 -8.81894709e-01 1.32501251e-01 6.34018690e-01 -6.59779199e-04]

b for class 2 is 8.387915940727066

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.367e+01 1.250e+00 1.920e+00 1.800e+01 9.400e+01  
2.100e+00 1.790e+00 3.200e-01 7.300e-01 3.800e+00 1.230e+00 2.460e+00 6.300e+02]  
[1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01 2.620e+00 2.650e+00  
3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02] [1.233e+01 9.900e-  
01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-01 2.760e+00

3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00 2.600e+00  
3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00 1.310e+00  
3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01 7.800e+01  
2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00 5.020e+02]  
[1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00 1.250e+00  
4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01 9.400e-  
01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-01  
3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.352e+01  
3.170e+00 2.720e+00 2.350e+01 9.700e+01 1.550e+00 5.200e-01 5.000e-01 5.500e-

01 4.350e+00 8.900e-01 2.060e+00 5.200e+02] [1.225e+01 3.880e+00 2.200e+00  
1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-  
01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01  
1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 2 is 135

Now the C is 0.7

Training error is 0.0

Testing error is 0.055555555555555558

w for class 0 is [ 0.75957259 0.67118927 1.13707435 -0.2091171 0.00390248 -  
0.0272589 0.26760604 0.19678209 -0.16663529 0.59554248 -0.14520204 0.47135178  
0.00542651]

b for class 0 is -18.368965417901336

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00

7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]

[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 0 is 41

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955 0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932 0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02] [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00

3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-

01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
 2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
 2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
 [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
 01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.225e+01  
 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00  
 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00  
 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-  
 01 1.270e+00 7.200e+02]]

Slack variables for class 1 is 50

w for class 2 is [-2.93783391e-01 -2.44597302e-01 7.10511532e-02 -3.50320312e-  
 02 -2.46353267e-02 4.19711038e-01 2.89006592e-01 8.57106397e-02 1.63925497e-  
 01 -9.29787371e-01 1.43910690e-01 7.13284800e-01 -4.44336907e-04]



b for class 2 is 8.479814640592789

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01

7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.225e+01  
3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00  
8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00  
2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-  
01 1.270e+00 7.200e+02]]

Slack variables for class 2 is 135

Now the C is 0.8

Training error is 0.0

Testing error is 0.05555555555555558

w for class 0 is [ 0.77677147 0.63369958 1.20124421 -0.20556689 0.00446772 -  
0.03719701 0.27398211 0.21515204 -0.14775192 0.56401356 -0.14929236 0.48543077  
0.00506597]

b for class 0 is -18.492367544599553

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00

2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01

1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.225e+01  
 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00  
 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00  
 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-  
 01 1.270e+00 7.200e+02]]

Slack variables for class 0 is 41

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955  
 0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932  
 0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
 [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
 3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
 1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
 1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00

7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]

[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 1 is 50

w for class 2 is [-2.93783391e-01 -2.44597302e-01 7.10511532e-02 -3.50320312e-02 -2.46353267e-02 4.19711038e-01 2.89006592e-01 8.57106397e-02 1.63925497e-01 -9.29787371e-01 1.43910690e-01 7.13284800e-01 -4.44336907e-04]

b for class 2 is 8.479814640592789

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02] [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00

3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-



01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.237e+01 1.210e+00 2.560e+00 1.810e+01 9.800e+01  
2.420e+00 2.650e+00 3.700e-01 2.080e+00 4.600e+00 1.190e+00 2.300e+00 6.780e+02]  
[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-  
01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.225e+01  
3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00  
8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00  
2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-  
01 1.270e+00 7.200e+02]]

Slack variables for class 2 is 135

Now the C is 0.9

Training error is 0.0

Testing error is 0.05555555555555558

w for class 0 is [ 0.81937569 0.59543631 1.25495818 -0.20395645 0.0060324 -  
0.03400668 0.28093614 0.232538 -0.13915098 0.52967883 -0.15539214 0.52025444  
0.00462687]

b for class 0 is -19.005723335748076

support vector for class 0 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-

01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02  
2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02]  
[1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-  
01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00  
2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00  
7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01  
9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00  
5.500e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00  
7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01  
4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-

01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 0 is 39

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955

0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932

0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01

2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]

[1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00

3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00

3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00

1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01

1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00

7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00

2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01

2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00

2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00

2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-

01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01

2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02  
2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02]  
[1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-  
01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00  
2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00  
7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01  
9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00  
5.500e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00

7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01  
 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-  
 01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 1 is 50

w for class 2 is [-2.93783391e-01 -2.44597302e-01 7.10511532e-02 -3.50320312e-  
 02 -2.46353267e-02 4.19711038e-01 2.89006592e-01 8.57106397e-02 1.63925497e-  
 01 -9.29787371e-01 1.43910690e-01 7.13284800e-01 -4.44336907e-04]

b for class 2 is 8.479814640592789

support vector for class 2 is [[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01  
 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02]  
 [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00  
 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00  
 3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00  
 1.130e+00 3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01  
 1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00  
 7.350e+02] [1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00  
 2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
 2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
 2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00

2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.311e+01 1.010e+00 1.700e+00 1.500e+01  
7.800e+01 2.980e+00 3.180e+00 2.600e-01 2.280e+00 5.300e+00 1.120e+00 3.180e+00  
5.020e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00  
1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01  
9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-  
01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00  
1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00  
2.630e+00 9.370e+02] [1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02  
2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02]  
[1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-  
01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00  
2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00  
7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01

9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00  
 5.500e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00  
 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01  
 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-  
 01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 2 is 135

Now the C is 1.0

Training error is 0.0

Testing error is 0.055555555555555558

w for class 0 is [ 0.87462163 0.58502206 1.3090265 -0.20534433 0.00791275 -  
 0.0264883 0.28527611 0.251201 -0.14808758 0.49330209 -0.16508294 0.55178168  
 0.0043974 ]

b for class 0 is -19.840056324023916 support vector for class 0 is [[1.307e+01  
 1.500e+00 2.100e+00 1.550e+01 9.800e+01 2.400e+00 2.640e+00 2.800e-01 1.370e+00  
 3.700e+00 1.180e+00 2.690e+00 1.020e+03] [1.350e+01 1.810e+00 2.610e+00  
 2.000e+01 9.600e+01 2.530e+00 2.610e+00 2.800e-01 1.660e+00 3.520e+00 1.120e+00  
 3.820e+00 8.450e+02] [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02  
 2.640e+00 2.630e+00 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02]  
 [1.305e+01 2.050e+00 3.220e+00 2.500e+01 1.240e+02 2.630e+00 2.680e+00



4.700e-01 1.920e+00 3.580e+00 1.130e+00 3.200e+00 8.300e+02] [1.324e+01  
2.590e+00 2.870e+00 2.100e+01 1.180e+02 2.800e+00 2.690e+00 3.900e-01 1.820e+00  
4.320e+00 1.040e+00 2.930e+00 7.350e+02] [1.272e+01 1.810e+00 2.200e+00  
1.880e+01 8.600e+01 2.200e+00 2.530e+00 2.600e-01 1.770e+00 3.900e+00 1.160e+00  
3.140e+00 7.140e+02] [1.181e+01 2.120e+00 2.740e+00 2.150e+01 1.340e+02  
1.600e+00 9.900e-01 1.400e-01 1.560e+00 2.500e+00 9.500e-01 2.260e+00 6.250e+02]  
[1.156e+01 2.050e+00 3.230e+00 2.850e+01 1.190e+02 3.180e+00 5.080e+00  
4.700e-01 1.870e+00 6.000e+00 9.300e-01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00  
2.130e+00 2.150e+01 8.600e+01 2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00  
7.300e-01 3.100e+00 3.800e+02] [1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02  
1.900e+00 1.850e+00 3.500e-01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02]  
[1.299e+01 1.670e+00 2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00  
2.100e-01 1.960e+00 3.350e+00 1.310e+00 3.500e+00 9.850e+02] [1.277e+01  
3.430e+00 1.980e+00 1.600e+01 8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-  
01 3.400e+00 7.000e-01 2.120e+00 3.720e+02] [1.334e+01 9.400e-01 2.360e+00  
1.700e+01 1.100e+02 2.530e+00 1.300e+00 5.500e-01 4.200e-01 3.170e+00 1.020e+00  
1.930e+00 7.500e+02] [1.247e+01 1.520e+00 2.200e+00 1.900e+01 1.620e+02  
2.500e+00 2.270e+00 3.200e-01 3.280e+00 2.600e+00 1.160e+00 2.630e+00 9.370e+02]  
[1.284e+01 2.960e+00 2.610e+00 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-

01 8.100e-01 4.920e+00 8.900e-01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00  
 2.150e+00 2.100e+01 1.020e+02 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00  
 6.000e-01 1.680e+00 8.300e+02] [1.286e+01 1.350e+00 2.320e+00 1.800e+01  
 1.220e+02 1.510e+00 1.250e+00 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00  
 6.300e+02] [1.362e+01 4.950e+00 2.350e+00 2.000e+01 9.200e+01 2.000e+00  
 8.000e-01 4.700e-01 1.020e+00 4.400e+00 9.100e-01 2.050e+00 5.500e+02] [1.225e+01  
 3.880e+00 2.200e+00 1.850e+01 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00  
 8.210e+00 6.500e-01 2.000e+00 8.550e+02] [1.225e+01 4.720e+00 2.540e+00  
 2.100e+01 8.900e+01 1.380e+00 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-  
 01 1.270e+00 7.200e+02]]

Slack variables for class 0 is 36

w for class 1 is [ 0.06994741 0.1041537 0.07834315 -0.07731081 0.01131955  
 0.31916848 0.49566399 0.00532709 0.18240283 -0.11562847 0.05264112 0.37415932  
 0.00176901]

b for class 1 is -4.649597136762206

support vector for class 1 is [[1.307e+01 1.500e+00 2.100e+00 1.550e+01 9.800e+01  
 2.400e+00 2.640e+00 2.800e-01 1.370e+00 3.700e+00 1.180e+00 2.690e+00 1.020e+03]  
 [1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01 2.530e+00 2.610e+00  
 2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02] [1.324e+01

3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00 3.200e-01 1.660e+00  
4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00 3.220e+00  
2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00 1.130e+00  
3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01 1.180e+02  
2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00 7.350e+02]  
[1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00 2.530e+00  
2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01  
8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00  
3.720e+02] [1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00  
1.300e+00 5.500e-01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01

1.520e+00 2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00  
 2.600e+00 1.160e+00 2.630e+00 9.370e+02] [1.284e+01 2.960e+00 2.610e+00  
 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-  
 01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02  
 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02]  
 [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00  
 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00  
 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00  
 9.100e-01 2.050e+00 5.500e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01  
 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00  
 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00  
 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 1 is 50

w for class 2 is [-2.93783391e-01 -2.44597302e-01 7.10511532e-02 -3.50320312e-  
 02 -2.46353267e-02 4.19711038e-01 2.89006592e-01 8.57106397e-02 1.63925497e-  
 01 -9.29787371e-01 1.43910690e-01 7.13284800e-01 -4.44336907e-04]

b for class 2 is 8.479814640592789

support vector for class 2 is [[1.307e+01 1.500e+00 2.100e+00 1.550e+01 9.800e+01  
 2.400e+00 2.640e+00 2.800e-01 1.370e+00 3.700e+00 1.180e+00 2.690e+00 1.020e+03]

[1.350e+01 1.810e+00 2.610e+00 2.000e+01 9.600e+01 2.530e+00 2.610e+00  
2.800e-01 1.660e+00 3.520e+00 1.120e+00 3.820e+00 8.450e+02] [1.324e+01  
3.980e+00 2.290e+00 1.750e+01 1.030e+02 2.640e+00 2.630e+00 3.200e-01 1.660e+00  
4.360e+00 8.200e-01 3.000e+00 6.800e+02] [1.305e+01 2.050e+00 3.220e+00  
2.500e+01 1.240e+02 2.630e+00 2.680e+00 4.700e-01 1.920e+00 3.580e+00 1.130e+00  
3.200e+00 8.300e+02] [1.324e+01 2.590e+00 2.870e+00 2.100e+01 1.180e+02  
2.800e+00 2.690e+00 3.900e-01 1.820e+00 4.320e+00 1.040e+00 2.930e+00 7.350e+02]  
[1.272e+01 1.810e+00 2.200e+00 1.880e+01 8.600e+01 2.200e+00 2.530e+00  
2.600e-01 1.770e+00 3.900e+00 1.160e+00 3.140e+00 7.140e+02] [1.181e+01  
2.120e+00 2.740e+00 2.150e+01 1.340e+02 1.600e+00 9.900e-01 1.400e-01 1.560e+00  
2.500e+00 9.500e-01 2.260e+00 6.250e+02] [1.156e+01 2.050e+00 3.230e+00  
2.850e+01 1.190e+02 3.180e+00 5.080e+00 4.700e-01 1.870e+00 6.000e+00 9.300e-  
01 3.690e+00 4.650e+02] [1.305e+01 5.800e+00 2.130e+00 2.150e+01 8.600e+01  
2.620e+00 2.650e+00 3.000e-01 2.010e+00 2.600e+00 7.300e-01 3.100e+00 3.800e+02]  
[1.233e+01 9.900e-01 1.950e+00 1.480e+01 1.360e+02 1.900e+00 1.850e+00 3.500e-  
01 2.760e+00 3.400e+00 1.060e+00 2.310e+00 7.500e+02] [1.299e+01 1.670e+00  
2.600e+00 3.000e+01 1.390e+02 3.300e+00 2.890e+00 2.100e-01 1.960e+00 3.350e+00  
1.310e+00 3.500e+00 9.850e+02] [1.277e+01 3.430e+00 1.980e+00 1.600e+01  
8.000e+01 1.630e+00 1.250e+00 4.300e-01 8.300e-01 3.400e+00 7.000e-01 2.120e+00

3.720e+02] [1.334e+01 9.400e-01 2.360e+00 1.700e+01 1.100e+02 2.530e+00  
 1.300e+00 5.500e-01 4.200e-01 3.170e+00 1.020e+00 1.930e+00 7.500e+02] [1.247e+01  
 1.520e+00 2.200e+00 1.900e+01 1.620e+02 2.500e+00 2.270e+00 3.200e-01 3.280e+00  
 2.600e+00 1.160e+00 2.630e+00 9.370e+02] [1.284e+01 2.960e+00 2.610e+00  
 2.400e+01 1.010e+02 2.320e+00 6.000e-01 5.300e-01 8.100e-01 4.920e+00 8.900e-  
 01 2.150e+00 5.900e+02] [1.316e+01 3.570e+00 2.150e+00 2.100e+01 1.020e+02  
 1.500e+00 5.500e-01 4.300e-01 1.300e+00 4.000e+00 6.000e-01 1.680e+00 8.300e+02]  
 [1.286e+01 1.350e+00 2.320e+00 1.800e+01 1.220e+02 1.510e+00 1.250e+00  
 2.100e-01 9.400e-01 4.100e+00 7.600e-01 1.290e+00 6.300e+02] [1.362e+01 4.950e+00  
 2.350e+00 2.000e+01 9.200e+01 2.000e+00 8.000e-01 4.700e-01 1.020e+00 4.400e+00  
 9.100e-01 2.050e+00 5.500e+02] [1.225e+01 3.880e+00 2.200e+00 1.850e+01  
 1.120e+02 1.380e+00 7.800e-01 2.900e-01 1.140e+00 8.210e+00 6.500e-01 2.000e+00  
 8.550e+02] [1.225e+01 4.720e+00 2.540e+00 2.100e+01 8.900e+01 1.380e+00  
 4.700e-01 5.300e-01 8.000e-01 3.850e+00 7.500e-01 1.270e+00 7.200e+02]]

Slack variables for class 2 is 135

### 2.2.3 Parameters Settings

In this question we can change  $C$  manually. Here, large  $C$  means less tolerant to the misclassification, in the previous question we set  $C = 1e5$ , now we free it and it may

contain many slack variables.

We first look at the errors,  $C$  from 0.1 to 1, it is clear that the training error keeps decreasing, and the testing error is increasing, this is because when  $C$  is large, the problem of overfitting will arise, and lowering the testing performance.

We second look at the change of the coefficients. Since the coefficients have positive and negative part, we use the norm. After the experiment we find that when  $C$  increases, the  $\|w\|$  for each class will increase, which leads to a positive correlation.

Thirdly we take a look at the number of the total slack variables. It is not hard to see that the number of slack variables is increasing as  $C$  increases, which also satisfies the mathematical results.

(All the data for this part can refer to the ipynb file, though actually the results have contained in the above results part)

## 2.3 c

### 2.3.1 Optimization Problem

In this problem we use the SVM with kernels. We define the following kernel

$k(x_i, x_j) = \phi(x_i)^T \phi(x_j)$ , and utilizing this kernel to replace  $x_i^T x_j$ , we have the following

dual problem

$$\begin{aligned} \max_{\alpha} \quad & \sum_i^m \alpha_i - \frac{1}{2} \sum_{i,j} \alpha_i \alpha_j y_i y_j k(x_i, x_j) \\ \text{s.t.} \quad & \sum_i^m \alpha_i y_i = 0, \alpha_i \geq 0, \forall i \end{aligned} \quad (17)$$

We can solve  $b = \frac{1}{|S|} \sum_{j \in S} (y_j - \sum_i^m \alpha_i y_i k(x_i, x_j))$ . Also we the kernels are:

$$\text{Polynomialkernel} : k(x, x_i) = (1 + \frac{x^T x_i}{\gamma^2})^p, p > 0 \quad (18)$$

$$\text{RBFkernel} : k(x, x_i) = \exp \left\{ -\frac{\|x - x_i\|^2}{2\gamma^2} \right\} \quad (19)$$

$$\text{Sigmoidkernel} : k(x, x_i) = \frac{1}{1 + \exp^{-\frac{x^T x_i + b}{\gamma^2}}} \quad (20)$$

### 2.3.2 Formulation and Results

Here we use four different kernels, they are 2nd-order polynomial kernel, 3rd-order polynomial kernel, Radial Basis Function kernel with  $\gamma = 1$ , Sigmoid kernel with  $\gamma =$

1. The results are below:

For 2nd-order polynomial kernel:

Training error is 0.295774647887324

Testing error is 0.4722222222222222

b for class 0 is -2.6429406575625833

Support vectors for class 0 is [1.35e+01 1.81e+00 2.61e+00 2.00e+01 9.60e+01

2.53e+00 2.61e+00 2.80e-01 1.66e+00 3.52e+00 1.12e+00 3.82e+00 8.45e+02]



b for class 1 is -2.8067778824369634

Support vectors for class 1 is [1.39e+01 1.68e+00 2.12e+00 1.60e+01 1.01e+02  
3.10e+00 3.39e+00 2.10e-01 2.14e+00 6.10e+00 9.10e-01 3.33e+00 9.85e+02]

b for class 2 is 1.1488645188510418

Support vectors for class 2 is [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02  
2.640e+00 2.630e+00 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02]

For 3rd-order polynomial kernel:

Training error is 0.3098591549295775

Testing error is 0.4722222222222222

b for class 0 is -1.9972950315131268

Support vectors for class 0 is [1.35e+01 1.81e+00 2.61e+00 2.00e+01 9.60e+01  
2.53e+00 2.61e+00 2.80e-01 1.66e+00 3.52e+00 1.12e+00 3.82e+00 8.45e+02]

b for class 1 is -2.425517236844636

Support vectors for class 1 is [1.324e+01 3.980e+00 2.290e+00 1.750e+01 1.030e+02  
2.640e+00 2.630e+00 3.200e-01 1.660e+00 4.360e+00 8.200e-01 3.000e+00 6.800e+02]

b for class 2 is 1.0013376342174563

Support vectors for class 2 is [1.422e+01 3.990e+00 2.510e+00 1.320e+01 1.280e+02  
3.000e+00 3.040e+00 2.000e-01 2.080e+00 5.100e+00 8.900e-01 3.530e+00 7.600e+02]

For Radial Basis Function kernel with  $\gamma = 1$ :

Training error is 0.0

Testing error is 0.5833333333333333

b for class 0 is -0.07139977941353917

Support vectors for class 0 is [1.376e+01 1.530e+00 2.700e+00 1.950e+01 1.320e+02  
2.950e+00 2.740e+00 5.000e-01 1.350e+00 5.400e+00 1.250e+00 3.000e+00 1.235e+03]

b for class 1 is 0.3461532759121396

Support vectors for class 1 is [1.373e+01 1.500e+00 2.700e+00 2.250e+01 1.010e+02  
3.000e+00 3.250e+00 2.900e-01 2.380e+00 5.700e+00 1.190e+00 2.710e+00 1.285e+03]

b for class 2 is 0.39283832180900596

Support vectors for class 2 is [1.316e+01 2.360e+00 2.670e+00 1.860e+01 1.010e+02  
2.800e+00 3.240e+00 3.000e-01 2.810e+00 5.680e+00 1.030e+00 3.170e+00 1.185e+03]

For Sigmoid kernel with  $\gamma = 1$ :

Training error is 0.6056338028169015

Testing error is 0.5833333333333333

b for class 0 is -1.0

Support vectors for class 0 is [1.376e+01 1.530e+00 2.700e+00 1.950e+01 1.320e+02  
2.950e+00 2.740e+00 5.000e-01 1.350e+00 5.400e+00 1.250e+00 3.000e+00 1.235e+03]

b for class 1 is 1.0

Support vectors for class 1 is [1.373e+01 1.500e+00 2.700e+00 2.250e+01 1.010e+02

3.000e+00 3.250e+00 2.900e-01 2.380e+00 5.700e+00 1.190e+00 2.710e+00 1.285e+03]

b for class 2 is 1.0

Support vectors for class 2 is [1.316e+01 2.360e+00 2.670e+00 1.860e+01 1.010e+02

2.800e+00 3.240e+00 3.000e-01 2.810e+00 5.680e+00 1.030e+00 3.170e+00 1.185e+03]

### **2.3.3 Parameters Settings**

For this question we only change the kernels. It may have some sense that sigmoid kernel has the most errors and the rbf kernel has the smallest training error, however, they all have huge testing errors, which means these kernels are not suitable for this datasets.