

After we train a kernel SVM model, we will be getting support vectors and their corresponding coefficients α_i

Check the documentation for better understanding of these attributes:

<https://scikit-learn.org/stable/modules/generated/sklearn.svm.SVC.html>

As a part of this assignment you will be implementing the `decision_function()` of kernel SVM, here `decision_function()` means based on the value return by `decision_function()` model will classify the data point either as positive or negative

Ex 1: In logistic regression After training the models with the optimal weights w we get, we will find the value $\frac{1}{1 + \exp(-(wx + b))}$, if this value comes out to be < 0.5 we will mark it as negative class, else its positive class

Ex 2: In Linear SVM After training the models with the optimal weights w we get, we will find the value of $\text{sign}(wx + b)$, if this value comes out to be -ve we will mark it as negative class, else its positive class.

Similarly in Kernel SVM After training the models with the coefficients α_i we get, we will find the value of $\text{sign}\left(\sum_{i=1}^n (y_i \alpha_i K(x_i, x_q)) + \text{intercept}\right)$, here $K(x_i, x_q)$ is the RBF kernel. If this value comes out to be -ve we will mark x_q as negative class, else its positive class.

RBF kernel is defined as: $K(x_i, x_q) = \exp(-\gamma \|x_i - x_q\|^2)$

For better understanding check this link:

<https://scikit-learn.org/stable/modules/svm.html#svm-mathematical-formulation>

Task E

1. Split the data into $X_{train}(60)$, $X_{cv}(20)$, $X_{test}(20)$
1. Train $SVC(\text{gamma}=0.001, C=100.)$ on the (X_{train}, y_{train})
1. Get the decision boundary values f_{cv} on the X_{cv} data i.e. $f_{cv} = \text{decision_function}(X_{cv})$ you need to implement this `decision_function()`

```
import numpy as np
import pandas as pd
from sklearn.datasets import make_classification
import numpy as np
from sklearn.svm import SVC
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
```

```
X, y = make_classification(n_samples=5000, n_features=5,
n_redundant=2,
                           n_classes=2, weights=[0.7], class_sep=0.7,
```

```

random_state=15)
print(type(X))

<class 'numpy.ndarray'>

```

Pseudo code

```
clf = SVC(gamma=0.001, C=100.) clf.fit(Xtrain, ytrain)
```

def decision_function(Xcv, ...): #use appropriate parameters for a data point x_q in Xcv:
 #write code to implement $\left(\sum_{i=1}^{\text{all the support vectors}} (y_i \alpha_i K(x_i, x_q)) + intercept \right)$, here the values y_i, α_i ,
 and *intercept* can be obtained from the trained model return # the decision_function
 output for all the data points in the Xcv

fcv = decision_function(Xcv, ...) # based on your requirement you can pass any other
 parameters

Note: Make sure the values you get as fcv, should be equal to outputs of
 clf.decision_function(Xcv)

you can write your code here

```
import math
```

```
#Split the data into Xtrain(60), Xcv(20), Xtest(20)
print("Total Dataset (Before splitting): ",X.shape)
```

```
X_train, X_test, y_train, y_test = train_test_split( X, y,
test_size=0.2, random_state=12)
X_train, X_CV, y_train, y_CV = train_test_split( X_train, y_train,
test_size=0.25, random_state=12)
```

```
print("X_train (60%):", X_train.shape)
print("X_CV (20%):",X_CV.shape)
print("X_test (20%):",X_test.shape)
```

```
Total Dataset (Before splitting): (5000, 5)
X_train (60%): (3000, 5)
X_CV (20%): (1000, 5)
X_test (20%): (1000, 5)
```

```
#Train SVC(gamma=0.001,C=100) on the ( Xtrain , ytrain )
#Ref: https://stackoverflow.com/questions/20113206/scikit-learn-svc-
decision-function-and-predict#:~:text=Python%27s%20SVM
%20implementation%20uses%20one-vs-one.%20That%27s%20exactly%20what,the
%20just%20the%20regular%20binary%20SVM%20decision%20boundary
```

```
clf = SVC(gamma=0.001,C=100,random_state=12)
```

```

clf.fit(X_train,y_train)

#Get the decision boundry values fcv on the Xcv data i.e. fcv =
decision_function( Xcv ) you need to implement this
decision_function()
#Define decision_function for svm

gamma = 0.001
def decision_function( sv, nv, a, b, X):
    # calculate the kernels
    k = [math.exp(-gamma * np.dot((vi - X), vi - X)) for vi in sv]
    #print(k.shape)

    # define the start and end index for support vectors for each
class
    start = [sum(nv[:i]) for i in range(len(nv))]
    end = [start[i] + nv[i] for i in range(len(nv))]
    #print(len(nv))
    #print(start)
    #print(end)

    # calculate: sum(a_p * k(x_p, x)) between every 2 classes

    c = [ sum(a[i][p] * k[p] for p in range(start[j], end[j])) +
          sum(a[j-1][p] * k[p] for p in range(start[i], end[i]))
          for i in range(len(nv)) for j in range(i+1,len(nv))]

    # add the intercept
    return [sum(x) for x in zip(c, b)]
#print(clf.support_vectors_)
#k = kernel(clf.support_vectors_, X_CV[0])
#print(len(k))

fcv = []
for i,X in enumerate(X_CV):

    fcv.append(decision_function(clf.support_vectors_,clf.n_support_,clf.d
ual_coef_,clf.intercept_,X)[0])

decision_Func_CV_fromsvm = clf.decision_function(X_CV)
print("*****fcv*****")
print(fcv[0:10])
print("*****clf.decision_function(Xcv)*****")

print(decision_Func_CV_fromsvm[0:10])

*****fcv*****
[-3.4302657404611487, -3.0443986142697064, -1.188622388183543, -

```

```
0.4208564050010717, 1.5256612283167816, 0.1883064121332756, -
2.8687024637862883, -0.47832228149371425, 2.5284867300154623,
2.6875984607807517]
*****clf.decision_function(Xcv)*****
[-3.43026574 -3.04439861 -1.18862239 -0.4208564 1.52566123
0.18830641
-2.86870246 -0.47832228 2.52848673 2.68759846]
```

Check this PDF

TASK F

1. Apply SGD algorithm with (f_{cv}, y_{cv}) and find the weight W intercept b Note: here our data is of one dimensional so we will have a one dimensional weight vector i.e $W.shape (1,)$

Note1: Don't forget to change the values of y_{cv} as mentioned in the above image. you will calculate y_+ , y_- based on data points in train data

Note2: the Sklearn's SGD algorithm doesn't support the real valued outputs, you need to use the code that was done in the 'Logistic Regression with SGD and L2' Assignment after modifying loss function, and use same parameters that used in that assignment. if $Y[i]$ is 1, it will be replaced with y_+ value else it will be replaced with y_- value

1. For a given data point from X_{test} , $P(Y=1 \vee X) = \frac{1}{1 + \exp(-(W * f_{test} + b))}$ where $f_{test} = \text{decision_function}(X_{test})$, W and b will be learned as mentioned in the above step

Note: in the above algorithm, the steps 2, 4 might need hyper parameter tuning, To reduce the complexity of the assignment we are excluding the hyperparameter tuning part, but interested students can try that

If any one wants to try other calibration algorithm isotonic regression also please check these tutorials

1. <http://fa.bianp.net/blog/tag/scikit-learn.html#fn:1>
2. https://drive.google.com/open?id=1MzmA7QaP58RDzocB0RBmRiWfl7Co_VJ7
3. https://drive.google.com/open?id=133odBinMOIVb_rh_GQxxsyMRyW-Zts7a
4. https://stat.fandom.com/wiki/Isotonic_regression#Pool_Adjacent_Violators_Algorithm

#Apply SGD algorithm with (fcvfcv , ycvycv) and find the weight W intercept bb Note: here our data is of one dimensional so we will have a one dimensional weight vector i.e W.shape (1,)

```
from sklearn.linear_model import SGDClassifier
```

```

clf2 = SGDClassifier()
unique, counts = np.unique(y_train, return_counts=True)
#print(unique[0],counts[0])
N_minus = counts[0]
N_plus = counts[1]
y_plus = ((N_plus+1)/(N_plus+2))
y_minus = (1/(N_minus+2))
y_CV_modified = np.where(y_CV == 0, y_minus, y_plus)
print(type(y_CV))
print(type(y_CV_modified))
#print(fcv.shape)
#clf2.fit(fcv.reshape(-1, 1),y_CV_modified)
#class_weights = clf2.coef_[0]
#print(class_weights)

```

```

<class 'numpy.ndarray'>
<class 'numpy.ndarray'>

```

#Initialize weights

```

def initialize_weights(row_vector):
    ''' In this function, we will initialize our weights and bias'''
    #initialize the weights as 1d array consisting of all zeros
    similar to the dimensions of row_vector
    #you use zeros_like function to initialize zero, check this link
    https://docs.scipy.org/doc/numpy/reference/generated/numpy.zeros_like.
    html
    #initialize bias to zero
    w = np.zeros_like(row_vector)
    b = 0
    return w,b

```

```

row_vector = X_train[0]
w,b = initialize_weights(row_vector)
print('w =',(w))
print('b =',str(b))

```

```

w = [0. 0. 0. 0. 0.]
b = 0

```

#Grader function - 1

```

dim=X_train[0]
w,b = initialize_weights(dim)
def grader_weights(w,b):
    assert((len(w)==len(dim)) and b==0 and np.sum(w)==0.0)
    return True
grader_weights(w,b)

```

True

```
#Compute sigmoid
```

```
#$sigmoid(z)= 1/(1+exp(-z))$
```

```
import math
```

```
def sigmoid(z):  
    ''' In this function, we will return sigmoid of z'''  
    # compute sigmoid(z) and return  
    sigmoid = 1/(1+math.exp(-z))  
    return sigmoid
```

```
#Grader function - 2
```

```
def grader_sigmoid(z):  
    val=sigmoid(z)  
    assert(val==0.8807970779778823)  
    return True  
grader_sigmoid(2)
```

True

```
#$log loss = -1*\frac{1}{n}\Sigma_{for each Yt,Y_{pred}}$  
(Ytlog10(Y_{pred})+(1-Yt)log10(1-Y_{pred}))$
```

```
#def logloss(y_true,y_pred):  
    # you have been given two arrays y_true and y_pred and you have to  
calculate the logloss  
    #while dealing with numpy arrays you can use vectorized operations  
for quicker calculations as compared to using loops
```

```
#https://www.pythonlikeyoumeanit.com/Module3_IntroducingNumpy/Vectoriz  
edOperations.html
```

```
    #https://www.geeksforgeeks.org/vectorized-operations-in-numpy/  
    #write your code here
```

```
#    n=len(y_true)  
#    loss =(-1)*(1/n)*np.sum((y_true*np.log10(y_pred)) + ((1-  
y_true)*np.log10(1-y_pred)))  
#    return loss
```

```
def sig(w,x,b):  
    return(1/(1+math.exp(-(np.dot(x,w)+b))))
```

```
def log_loss(w,b,X,Y):
```

```

N = len(X)
sum_log = 0
for i in range(N):
    sum_log += Y[i]*np.log10(sig(w,X[i],b))+ (1-Y[i])*np.log10(1-
sig(w,X[i],b))
return -1*sum_log/N

```

#Grader function - 3

```

#round off the value to 8 values
#def grader_logloss(true,pred):
def grader_logloss(w,b,X,Y):
    loss=logloss(w,b,X,Y)
    assert(np.round(loss,6)==0.076449)
    return True
#true=np.array([1,1,0,1,0])
#pred=np.array([0.9,0.8,0.1,0.8,0.2])
#grader_logloss(true,pred)

```

#Compute gradient w.r.to 'w'

\$\$\$dw^{\{t\}} = x_n(y_n - \sigma((w^{\{t\}})^{\{T\}} x_n+b^{\{t\}})) - \frac{\lambda}{N}w^{\{t\}}\$

#make sure that the sigmoid function returns a scalar value, you can use dot function operation

```

def gradient_dw(x,y,w,b,alpha,N):
    '''In this function, we will compute the gardient w.r.to w '''
    #print("w",w)
    #print("x",x)
    #print("b",b)
    #print(np.dot(w,x))
    #print(sigmoid(np.dot(w,x)+b))
    dw = (x*(y-sigmoid(np.dot(w,x)+b))) - ((alpha/N)*w)
    #print(dw)
    return dw

```

#Grader function - 4

```

def grader_dw(x,y,w,b,alpha,N):
    grad_dw=gradient_dw(x,y,w,b,alpha,N)
    assert(np.round(np.sum(grad_dw),5)==4.75684)
    return True
grad_x=np.array([-2.07864835, 3.31604252, -0.79104357, -3.87045546, -

```

```

1.14783286,
    -2.81434437, -0.86771071, -0.04073287,  0.84827878,
1.99451725,
    3.67152472,  0.01451875,  2.01062888,  0.07373904, -
5.54586092])
grad_y=0
grad_w=np.array([ 0.03364887,  0.03612727,  0.02786927,  0.08547455, -
0.12870234,
    -0.02555288,  0.11858013,  0.13305576,  0.07310204,
0.15149245,
    -0.05708987, -0.064768 ,  0.18012332, -0.16880843, -
0.27079877])
grad_b=0.5
alpha=0.0001
N=len(X_train)
grader_dw(grad_x,grad_y,grad_w,grad_b,alpha,N)

True

```

#Compute gradient w.r.to 'b'

#\$ db^{\{t\}} = y_n - \sigma((w^{\{t\}})^T x_n + b^{\{t\}})\$

#sb should be a scalar value

```

def gradient_db(x,y,w,b):
    '''In this function, we will compute gradient w.r.to b '''
    db = y-sigmoid(np.dot(w,x)+b)
    return db

```

#Grader function - 5

```

def grader_db(x,y,w,b):
    grad_db=gradient_db(x,y,w,b)
    assert(np.round(grad_db,4)==-0.3714)
    return True
grad_x=np.array([-2.07864835,  3.31604252, -0.79104357, -3.87045546, -
1.14783286,
    -2.81434437, -0.86771071, -0.04073287,  0.84827878,
1.99451725,
    3.67152472,  0.01451875,  2.01062888,  0.07373904, -
5.54586092])
grad_y=0.5
grad_b=0.1
grad_w=np.array([ 0.03364887,  0.03612727,  0.02786927,  0.08547455, -
0.12870234,
    -0.02555288,  0.11858013,  0.13305576,  0.07310204,
0.15149245,
    -0.05708987, -0.064768 ,  0.18012332, -0.16880843, -
0.27079877])

```



```

        -0.05708987, -0.064768 , 0.18012332, -0.16880843, -
0.27079877])
alpha=0.0001
N=len(X_train)
grader_db(grad_x,grad_y,grad_w,grad_b)

True

# prediction function used to compute predicted_y given the dataset X
def pred(w,b, X):
    N = len(X)
    predict = []
    for i in range(N):
        z=np.dot(w,X[i])+b
        predict.append(sigmoid(z))
    return np.array(predict)

#Implementing logistic regression

def train(X_train,y_train,X_test,y_test,epochs,alpha,eta0):
    ''' In this function, we will implement logistic regression'''

    loss = []
    w,b = initialize_weights(X_train[0]) # Initialize the weights
    N_train = len(X_train)
    for epoch in range(0,epochs):
        print("epoch ",epoch)
        for point_idx in range(0,N_train):

            grad_dw=gradient_dw(X_train[point_idx],y_train[point_idx],w,b,alpha,N_train)
                #print(grad_dw)

            grad_db=gradient_db(X_train[point_idx],y_train[point_idx],w,b)
                #print(grad_dw)
                #Updating weight vector w
                w = w +(alpha*grad_dw)
                b = b +(alpha*grad_db)
            print("updated w: ",w)
            print("updated b:",b)
            loss.append(log_loss(w,b,X_train,y_train))

    return w,b,loss

alpha=0.001
eta0=0.001
N=len(X_train)
epochs=20

```

```

w,b,loss=train(X_train,y_train,X_test,y_test,epochs,alpha,eta0)
print()
print("Updated final w vector:")
print(w)
w_mag=np.dot(w.T,w)
#print(w_mag)
#print()
#print(loss)

epoch 0
updated w: [ 0.02117625 -0.02837846 -0.24916815 -0.31360013
0.74242944]
updated b: -0.34338091950424815
epoch 1
updated w: [ 0.03135685 -0.06601553 -0.39986092 -0.5042512
1.1742522 ]
updated b: -0.4695941630682364
epoch 2
updated w: [ 0.03787557 -0.09657705 -0.50620721 -0.63899031
1.47563837]
updated b: -0.5325412211813059
epoch 3
updated w: [ 0.04277749 -0.1210008 -0.58764087 -0.74221493
1.70556446]
updated b: -0.5719027802871021
epoch 4
updated w: [ 0.04682098 -0.14101812 -0.65314439 -0.82526462
1.89020044]
updated b: -0.6006061881749659
epoch 5
updated w: [ 0.05034404 -0.15788235 -0.70760991 -0.89433026
2.04353872]
updated b: -0.6237050244054272
epoch 6
updated w: [ 0.0535158 -0.17243071 -0.75399258 -0.95315538
2.17396428]
updated b: -0.6434539818242859
epoch 7
updated w: [ 0.05642848 -0.1852249 -0.79421046 -1.00417065
2.28690414]
updated b: -0.6609688746829775
epoch 8
updated w: [ 0.05913615 -0.19665063 -0.82957683 -1.0490404
2.38607318]
updated b: -0.6768526762019881
epoch 9
updated w: [ 0.06167268 -0.20698008 -0.86102904 -1.08895233
2.47412548]
updated b: -0.6914581830845137
epoch 10

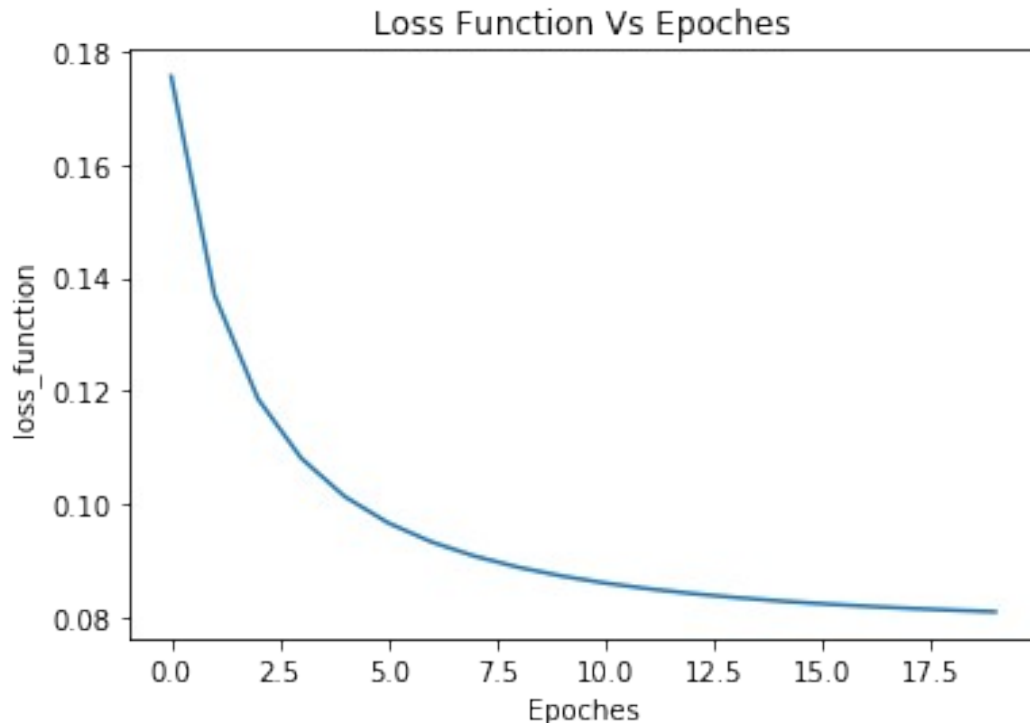
```

```
updated w: [ 0.06406071 -0.21641057 -0.8892588 -1.12478278
2.55302258]
updated b: -0.7050077573846306
epoch 11
updated w: [ 0.06631633 -0.2250888 -0.91479077 -1.15719628
2.62425477]
updated b: -0.7176516833137012
epoch 12
updated w: [ 0.06845167 -0.23312645 -0.93803211 -1.18670847
2.68898049]
updated b: -0.7294982285890527
epoch 13
updated w: [ 0.07047635 -0.24061031 -0.95930508 -1.21372732
2.74811785]
updated b: -0.7406298830628887
epoch 14
updated w: [ 0.07239832 -0.2476092 -0.97886901 -1.23858114
2.80240658]
updated b: -0.7511125076835554
epoch 15
updated w: [ 0.07422442 -0.2541786 -0.99693566 -1.26153797
2.85245134]
updated b: -0.7610006924301953
epoch 16
updated w: [ 0.07596067 -0.26036401 -1.01368019 -1.2828195
2.89875262]
updated b: -0.7703410119484414
epoch 17
updated w: [ 0.07761244 -0.26620322 -1.02924913 -1.30261117
2.94172927]
updated b: -0.7791740768281433
epoch 18
updated w: [ 0.07918466 -0.27172809 -1.04376628 -1.32106965
2.98173529]
updated b: -0.7875358740541664
epoch 19
updated w: [ 0.08068186 -0.27696573 -1.0573372 -1.33832854
3.01907254]
updated b: -0.7954586759581093
```

```
Updated final w vector:
[ 0.08068186 -0.27696573 -1.0573372 -1.33832854 3.01907254]
```

```
# Plot loss fuction vs epoches
epochs_list = [i for i in range(epochs)]
#print(epochs_list)
plt.plot(epochs_list,loss)
plt.xlabel("Epoches")
plt.ylabel("loss_function")
plt.title("Loss Function Vs Epoches")
```

Text(0.5,1,'Loss Function Vs Epoches')



*#For a given data point from Xtest , $P(Y=1|X)=1/(1+\exp(-(W*f_{test}+b)))$
#where $f_{test} = \text{decision_function}(X_{test})$, W and b will be learned as mentioned in the above step*

```
for x in X_test:
    f =
    decision_function(clf.support_vectors_,clf.n_support_,clf.dual_coef_,c
    lf.intercept_,x)[0]
    #print(f)
    #print(w_mag)
    prob = (1/(math.exp(-(w_mag*f))))
    print("For ",x,"probability is",prob)
```

```
For [ 0.56205839  0.95914624  0.47392055  0.64027871 -0.65230023]
probability is 3.758523503664629e-15
For [-1.12868355  0.5259836  -0.11371356 -0.11703555  0.79121172]
probability is 830535.4615067666
For [ 0.77827558 -1.04397189  0.04636056  0.00756786 -1.0188899 ]
probability is 6.18884665408059e-14
For [-0.10445915 -1.35403628 -0.55372204 -0.7593877  0.56623399]
probability is 507368629.2360574
For [-1.28523571  0.04712579  0.15703589  0.19905871 -0.44336442]
probability is 6.130809612347924e-10
For [-1.47325101  1.7701801  0.43925358  0.63609024  0.13509864]
probability is 1.192941926321686e-07
```

For [1.20189375 -0.15709433 0.12650684 0.15091977 -0.52090478]
probability is 9.572770630202965e-10
For [1.49952363 -0.58600389 0.13007707 0.13463546 -0.89191499]
probability is 2.8263162283543374e-13
For [-1.07690686 -0.15079241 0.23152617 0.28282199 -0.83857399]
probability is 1.319945615617648e-14
For [-0.26724655 -1.15451929 0.07747155 0.04120209 -1.20735807]
probability is 2.0150023114350339e-16
For [0.66526567 -1.72732043 0.15647213 0.11247379 -1.93111833]
probability is 4.513179669515976e-24
For [0.49054689 1.36764199 -0.12216664 -0.08689388 1.52370326]
probability is 23807725028774.215
For [1.63069288 0.07452828 0.2477281 0.31402916 -0.69926232]
probability is 1.3073436337223092e-12
For [0.11604991 1.7762677 0.66176578 0.91520961 -0.54406865]
probability is 1.9956380191304e-16
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probability is 8.244574031043534e-05

For [0.15786322 0.24588685 0.17847529 0.23554342 -0.34245361]
probability is 5.978020033405516e-09

