Implement SGD Classifier with Logloss and L2 regularization Using SGD without using sklearn

There will be some functions that start with the word "grader" ex: grader_weights(), grader_sigmoid(), grader_logloss() etc, you should not change those function definition.

Every Grader function has to return True.

Importing packages

In [1]:
```
import numpy as np
import pandas as pd
from sklearn.datasets import make_classification
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn import linear_model
import math
```

Creating custom dataset

In [2]:
```
# please don't change random_state
X, y = make_classification(n_samples=50000, n_features=15, n_informative=10, n_redundant=5,
                           n_classes=2, weights=[0.7], class_sep=0.7, random_state=15)
# make_classification is used to create custom dataset
# Please check this link (https://scikit-learn.org/stable/modules/generated/sklearn.datasets.make_classification.h
```

In [3]:
```
X.shape, y.shape
```

Out[3]:
```
((50000, 15), (50000,))
```

Splitting data into train and test

In [4]:
```
#please don't change random state
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25, random_state=15)
```

In [5]:
```
# Standardizing the data.
scaler = StandardScaler()
X_train = scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)
```

In [6]:
```
X_train.shape, y_train.shape, X_test.shape, y_test.shape
```

Out[6]:
```
((37500, 15), (37500,), (12500, 15), (12500,))
```

SGD classifier

In [7]:
```
# alpha : float
# Constant that multiplies the regularization term.

# eta0 : double
# The initial learning rate for the ‘constant’, ‘invscaling’ or ‘adaptive’ schedules.

clf = linear_model.SGDClassifier(eta0=0.0001, alpha=0.0001, loss='log', random_state=15, penalty='l2', tol=1e-3, v
clf
# Please check this documentation (https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.SGDClass
```

Out[7]:
```
SGDClassifier(eta0=0.0001, learning_rate='constant', loss='log',
              random_state=15, verbose=2)
```

In [8]:
```
clf.fit(X=X_train, y=y_train) # fitting our model
```

```
-- Epoch 1
Norm: 0.70, NNZs: 15, Bias: -0.501317, T: 37500, Avg. loss: 0.552526
Total training time: 0.01 seconds.
-- Epoch 2
Norm: 1.04, NNZs: 15, Bias: -0.752393, T: 75000, Avg. loss: 0.448021
Total training time: 0.02 seconds.
```

```
-- Epoch 3
Norm: 1.26, NNZs: 15, Bias: -0.902742, T: 112500, Avg. loss: 0.415724
Total training time: 0.03 seconds.
-- Epoch 4
Norm: 1.43, NNZs: 15, Bias: -1.003816, T: 150000, Avg. loss: 0.400895
Total training time: 0.03 seconds.
-- Epoch 5
Norm: 1.55, NNZs: 15, Bias: -1.076296, T: 187500, Avg. loss: 0.392879
Total training time: 0.04 seconds.
-- Epoch 6
Norm: 1.65, NNZs: 15, Bias: -1.131077, T: 225000, Avg. loss: 0.388094
Total training time: 0.04 seconds.
-- Epoch 7
Norm: 1.73, NNZs: 15, Bias: -1.171791, T: 262500, Avg. loss: 0.385077
Total training time: 0.05 seconds.
-- Epoch 8
Norm: 1.80, NNZs: 15, Bias: -1.203840, T: 300000, Avg. loss: 0.383074
Total training time: 0.05 seconds.
-- Epoch 9
Norm: 1.86, NNZs: 15, Bias: -1.229563, T: 337500, Avg. loss: 0.381703
Total training time: 0.06 seconds.
-- Epoch 10
Norm: 1.90, NNZs: 15, Bias: -1.251245, T: 375000, Avg. loss: 0.380763
Total training time: 0.06 seconds.
-- Epoch 11
Norm: 1.94, NNZs: 15, Bias: -1.269044, T: 412500, Avg. loss: 0.380084
Total training time: 0.07 seconds.
-- Epoch 12
Norm: 1.98, NNZs: 15, Bias: -1.282485, T: 450000, Avg. loss: 0.379607
Total training time: 0.07 seconds.
-- Epoch 13
Norm: 2.01, NNZs: 15, Bias: -1.294386, T: 487500, Avg. loss: 0.379251
Total training time: 0.07 seconds.
-- Epoch 14
Norm: 2.03, NNZs: 15, Bias: -1.305805, T: 525000, Avg. loss: 0.378992
Total training time: 0.08 seconds.
Convergence after 14 epochs took 0.08 seconds
```

Out[8]:
```
SGDClassifier(eta0=0.0001, learning_rate='constant', loss='log',
              random_state=15, verbose=2)
```

In [9]:
```
clf.coef_, clf.coef_.shape, clf.intercept_
#clf.coef_ will return the weights
#clf.coef_.shape will return the shape of weights
#clf.intercept_ will return the intercept term
```

Out[9]:
```
(array([[-0.89007184,  0.63162363, -0.07594145,  0.63107107, -0.38434375,
          0.93235243, -0.89573521, -0.07340522,  0.40591417,  0.4199991 ,
          0.24722143,  0.05046199, -0.08877987,  0.54081652,  0.06643888]]),
 (1, 15),
 array([-1.30580538]))
```

```
# This is formatted as code
```

Implement Logistic Regression with L2 regularization Using SGD: without using sklearn

1. We will be giving you some functions, please write code in that functions only.
2. After every function, we will be giving you expected output, please make sure that you get that output.

- Initialize the weight_vector and intercept term to zeros (Write your code in def initialize_weights())
- Create a loss function (Write your code in def logloss())

  $logloss = -1 * \frac{1}{n}\Sigma_{foreachYt,Y_{pred}}(Ytlog10(Y_{pred}) + (1-Yt)log10(1-Y_{pred}))$
- for each epoch:
  - for each batch of data points in train: (keep batch size=1)
    - calculate the gradient of loss function w.r.t each weight in weight vector (write your code in def gradient_dw())

      $dw^{(t)} = x_n(y_n - \sigma((w^{(t)})^T x_n + b^t)) - \frac{\lambda}{N}w^{(t)})$
    - Calculate the gradient of the intercept (write your code in def gradient_db()) check this

      $db^{(t)} = y_n - \sigma((w^{(t)})^T x_n + b^t))$
    - Update weights and intercept (check the equation number 32 in the above mentioned pdf):
      $w^{(t+1)} \leftarrow w^{(t)} + \alpha(dw^{(t)})$

      $b^{(t+1)} \leftarrow b^{(t)} + \alpha(db^{(t)})$
  - calculate the log loss for train and test with the updated weights (you can check the python assignment 10th question)
  - And if you wish, you can compare the previous loss and the current loss, if it is not updating, then you can stop the training
  - append this loss in the list (this will be used to see how loss is changing for each epoch after the training is over)

Initialize weights

In [10]:
```
def initialize_weights(dim):
    ''' In this function, we will initialize our weights and bias'''
    #initialize the weights to zeros array of (1,dim) dimensions
    #you use zeros_like function to initialize zero, check this link https://docs.scipy.org/doc/numpy/reference/ge
    #initialize bias to zero

    w = np.zeros_like(dim)
    b = 0
    return w,b
```

In [11]:
```
dim=X_train[0]
w,b = initialize_weights(dim)
print('w =',(w))
print('b =',str(b))
```

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

Grader function - 1

In [12]:
```
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)
```

Out[12]:
```
True
```

Compute sigmoid

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

In [13]:
```
def sigmoid(z):
    ''' In this function, we will return sigmoid of z'''
    # compute sigmoid(z) and return

    return 1 / ( 1 + np.exp(-z) )
```

Grader function - 2

In [14]:
```
def grader_sigmoid(z):
  val=sigmoid(z)
  assert(val==0.8807970779778823)
  return True
grader_sigmoid(2)
```

Out[14]:
```
True
```

Compute loss

$$logloss = -1 * \frac{1}{n}\Sigma_{foreachYt,Y_{pred}}(Ytlog10(Y_{pred}) + (1 - Yt)log10(1 - Y_{pred}))$$

In [15]:
```
def logloss(y_true,y_pred):
    '''In this function, we will compute log loss '''

    loss = 0
    n = len(y_true)
    for i in range(n):
        loss += ( y_true[i] * math.log10(y_pred[i]) ) + ( 1 - y_true[i] )* math.log10( 1 - y_pred[i] )

    loss = -1 * (1/n) * loss
    return loss
```

Grader function - 3

In [16]:
```
def grader_logloss(true,pred):
  loss=logloss(true,pred)
  print(loss)
  assert(loss==0.07644900402910389)
  return True
true=[1,1,0,1,0]
pred=[0.9,0.8,0.1,0.8,0.2]
grader_logloss(true,pred)
```

```
0.07644900402910389
```

Out[16]:
```
True
```

Compute gradient w.r.to 'w'

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

σ(x) = 1 / (1 + exp(-x))

In [17]:
```
def gradient_dw(x,y,w,b,alpha,N):
    '''In this function, we will compute the gardient w.r.to w '''

    dw = x*( y - sigmoid(np.dot(w, x+b ) ) ) - ( ( alpha * w )/ N )

    return dw
```

Grader function - 4

In [18]:
```
def grader_dw(x,y,w,b,alpha,N):
  grad_dw=gradient_dw(x,y,w,b,alpha,N)
  print(grad_dw)
  assert(np.sum(grad_dw)==2.613689585)
  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,grad_b=initialize_weights(grad_x)
alpha=0.0001
N=len(X_train)
print(grader_dw(grad_x,grad_y,grad_w,grad_b,alpha,N))
```

```
[ 1.03932417 -1.65802126  0.39552179  1.93522773  0.57391643  1.40717219
  0.43385535  0.02036643 -0.42413939 -0.99725862 -1.83576236 -0.00725938
 -1.00531444 -0.03686952  2.77293046]
True
```

Compute gradient w.r.to 'b'

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

In [19]:
```
 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

In [20]:
```
def grader_db(x,y,w,b):
  grad_db=gradient_db(x,y,w,b)
  print(grad_db)
  assert(grad_db==-0.5)
  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,grad_b=initialize_weights(grad_x)
alpha=0.0001
N=len(X_train)
grader_db(grad_x,grad_y,grad_w,grad_b)
```

```
-0.5
```

Out[20]:
```
True
```

Implementing logistic regression

In [21]:
```
def train(X_train,y_train,X_test,y_test,epochs,alpha,eta0):
    ''' In this function, we will implement logistic regression'''
    #Here eta0 is learning rate
    #implement the code as follows
    # initalize the weights (call the initialize_weights(X_train[0]) function)
    # for every epoch
        # for every data point(X_train,y_train)
           #compute gradient w.r.to w (call the gradient_dw() function)
           #compute gradient w.r.to b (call the gradient_db() function)
           #update w, b
        # predict the output of x_train[for all data points in X_train] using w,b
        #compute the loss between predicted and actual values (call the loss function)
        # store all the train loss values in a list
        # predict the output of x_test[for all data points in X_test] using w,b
        #compute the loss between predicted and actual values (call the loss function)
        # store all the test loss values in a list
        # you can also compare previous loss and current loss, if loss is not updating then stop the process and r
```

```
    w,b = initialize_weights(X_train[0])
    loss_train = []
    loss_test = []
    N = len(X_train)
    for i in range(epochs):
        for j in range(N):
            ## batch size of 1
            x = X_train[j]
            y = y_train[j]

            dw = gradient_dw(x,y,w,b,alpha,N)
            db = gradient_db(x,y,w,b)

            w += (eta0 * dw)
            b += (eta0 * db)
        y_pred_train = sigmoid(np.dot(w.T, X_train.T) + b )
        loss_train.append(logloss(y_train,y_pred_train))
        y_pred_test = sigmoid(np.dot(w.T, X_test.T) + b )
        loss_test.append(logloss(y_test,y_pred_test))

    return w,b, loss_train, loss_test
```

In [43]:

```
alpha=0.0001
eta0=0.0001
N=len(X_train)
epochs=13
w,b, loss_train, loss_test=train(X_train,y_train,X_test,y_test,epochs,alpha,eta0)
print(w)
print(b)


##(array([[-0.89007184,  0.63162363, -0.07594145,  0.63107107, -0.38434375,
#           0.93235243, -0.89573521, -0.07340522,  0.40591417,  0.4199991 ,
#           0.24722143,  0.05046199, -0.08877987,  0.54081652,  0.06643888]]),
#  (1, 15),
#  array([-1.30580538]))
```

```
[-0.90191345  0.64173883 -0.06928284  0.63715603 -0.37650335  0.9437959
 -0.91172705 -0.07454269  0.41345094  0.41527597  0.24908629  0.05305991
 -0.08507288  0.54769202  0.06929096]
-0.8692705174174877
```

Goal of assignment

Compare your implementation and SGDClassifier's the weights and intercept, make sure they are as close as possible

In [44]:
```
# these are the results we got after we implemented sgd and found the optimal weights and intercept
w-clf.coef_, b-clf.intercept_
```

Out[44]:
```
(array([[-0.01184162,  0.0101152 ,  0.0066586 ,  0.00608496,  0.0078404 ,
          0.01144346, -0.01599184, -0.00113747,  0.00753677, -0.00472313,
          0.00186487,  0.00259792,  0.00370699,  0.00687549,  0.00285207]]),
 array([0.43653486]))
```

Plot epoch number vs train , test loss

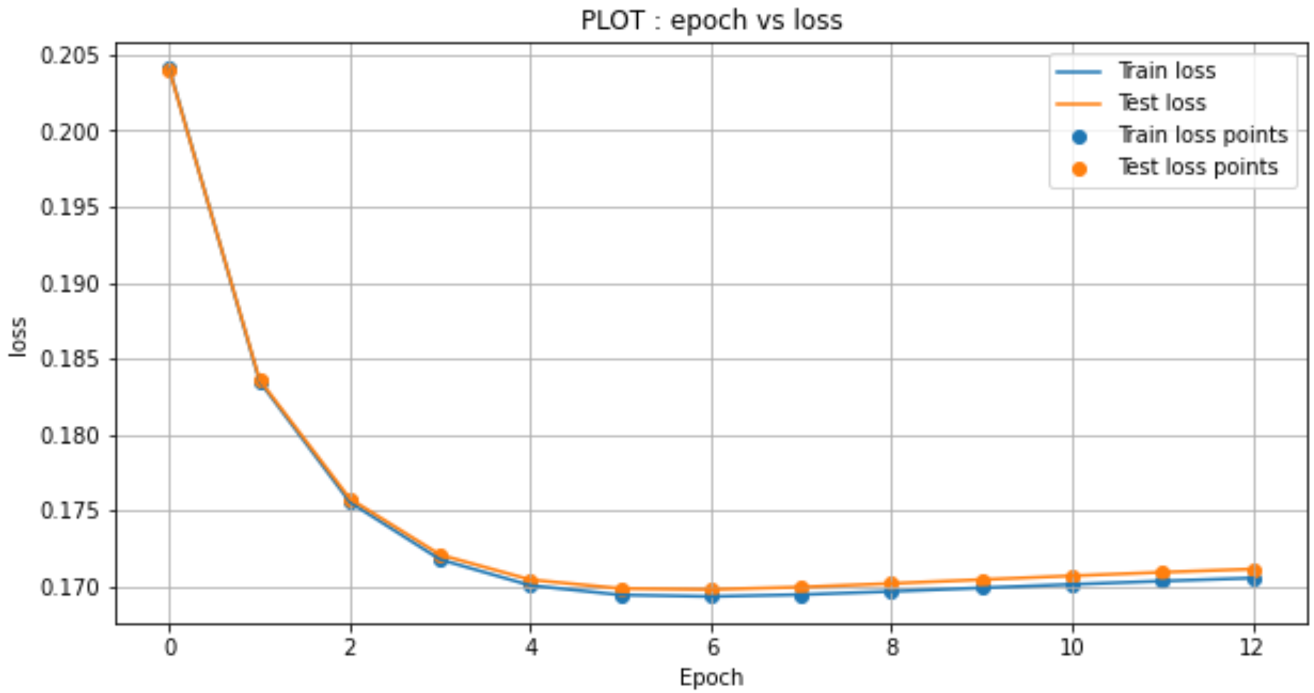
- epoch number on X-axis
- loss on Y-axis

In [46]:
```
import matplotlib.pyplot as plt
epoch = list(range(0, epochs))

plt.figure(figsize=(10,5))
plt.plot(epoch, loss_train, label='Train loss')
plt.plot(epoch, loss_test, label='Test loss')

plt.scatter(epoch, loss_train, label='Train loss points')
plt.scatter(epoch, loss_test, label='Test loss points')

plt.legend()
plt.xlabel("Epoch")
plt.ylabel("loss")
plt.title("PLOT : epoch vs loss")
plt.grid()
plt.show()
```



In [47]:

```
def pred(w,b, X):
    N = len(X)
    predict = []
    for i in range(N):
        z=np.dot(w,X[i])+b
        if sigmoid(z) >= 0.5: # sigmoid(w,x,b) returns 1/(1+exp(-(dot(x,w)+b)))
            predict.append(1)
        else:
            predict.append(0)
    return np.array(predict)
print(1-np.sum(y_train - pred(w,b,X_train))/len(X_train))
print(1-np.sum(y_test  - pred(w,b,X_test))/len(X_test))
```

```
1.01456
1.01168
```

Summary

- According to the plot epoch vs loss, the loss on both train and test dataset is seen to be decreasing drastically, it increases slightly, but remains constant for more number of epochs.
- It can be said from the difference calculated, that there is much less difference in weights but there is ~ 0.5 difference in the intercepts.