Exercise BCI

June 29, 2019

1 Exercise Brain-Computer Interfaces

In this assignment you will estimate cognitive states from electroencephalogram (EEG) data.

Electroencephalography (EEG) data was recorded during a copy-spelling BCI Experiment at the Berlin BCI group.

The data set consists preprocessed EEG data $X \in R^{5\times62\times5322}$ and stimulus labels $Y \in R^{2\times5322}$ during a copy-spelling paradigm with a P300 speller. The data matrix X contains 5 selected time windows of EEG activity at 62 electrodes after a visual stimulus was presented on the screen in front of the subject. If the first row of Y is 1, the stimulus was a target stimulus, if the second row of Y is 1, the stimulus was a non-target stimulus.

```
In [10]: import pylab as pl
         import scipy as sp
         from scipy.linalg import eig
         from scipy.io import loadmat
         from sklearn.model_selection import train_test_split

         def load_data(fname):
             # load the data
             data = loadmat(fname)
             # extract images and labels
             X = data['X']
             Y = data['Y']
             # collapse the time-electrode dimensions
             X = sp.reshape(X,(X.shape[0]*X.shape[1],X.shape[2])).T
             # transform the labels to (-1,1)
             Y = sp.sign((Y[0,:]>0) -.5)
             return X,Y

         X,Y = load_data(fname='bcidata.mat')
```

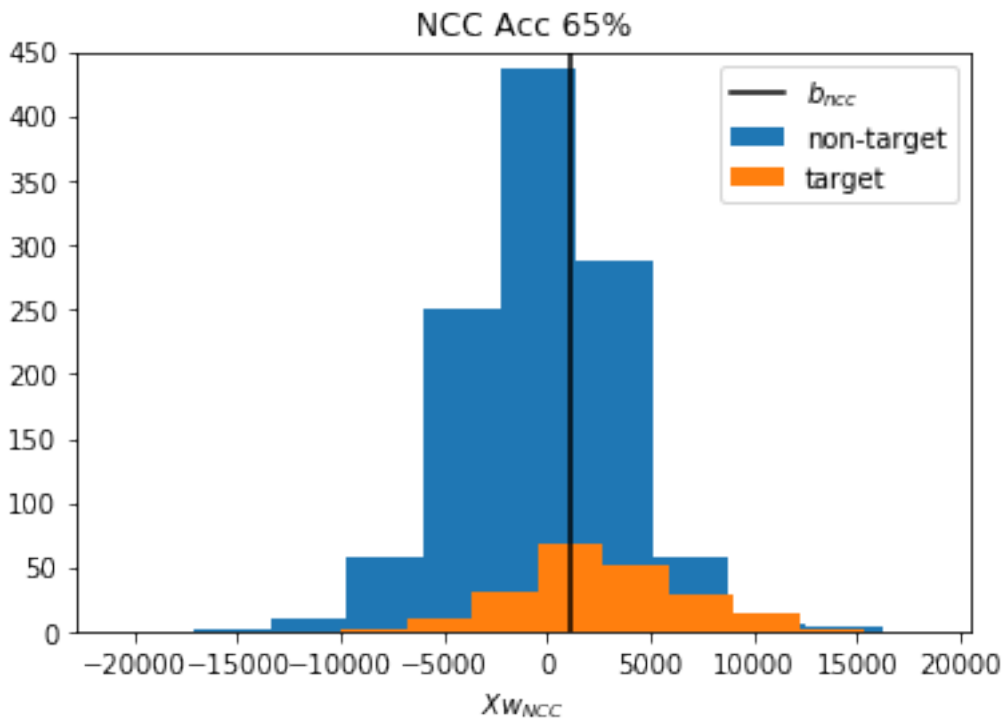
2 Assignment 1: Train a Nearest Centroid Classifier

```
In [11]: def ncc_fit(X, Y):
             '''
             Train a nearest centroid classifier for N data points in D dimensions
```

```
    Input:
    X N-by-D Data Matrix
    Y label vector of length N, labels are -1 or 1
    Output:
    w weight vector of length D
    b bias vector of length D
    '''
    # class means
    # IMPLEMENT CODE HERE
    mupos = X[Y==1,:].mean(axis=0).T
    muneg = X[Y==-1,:].mean(axis=0).T
    w = mupos - muneg
    b = (w.dot(mupos) + w.dot(muneg))/2.
    # return the weight vector
    return w,b

X_train, X_test, Y_train, Y_test = train_test_split(X,Y)

w_ncc, b_ncc = ncc_fit(X_train, Y_train)
pl.hist(X_test[Y_test<0, :] @ w_ncc)
pl.hist(X_test[Y_test>0, :] @ w_ncc)
pl.plot([b_ncc, b_ncc], [0, 500], color='k')
pl.xlabel('$Xw_{NCC}$')
pl.legend(('$b_{ncc}$','non-target','target'))
pl.ylim([0, 450])
acc = int((sp.sign(X_test @ w_ncc - b_ncc)==Y_test).mean()*100)
pl.title(f"NCC Acc {acc}%");
```



3 Assignment 2: Train a Linear Discriminant Analysis Classifier

Train a linear discriminant classifier and compare it with the NCC one.

```
In [12]: def lda_fit(X,Y):
             '''
             Train a Linear Discriminant Analysis classifier

             Input:
             X N-by-D Data Matrix
             Y label vector of length N, labels are -1 or 1
             Output:
             w weight vector of length D
             b bias vector of length D
             '''
             # class means
             # IMPLEMENT CODE HERE
             mupos = X[Y==1,:].mean(axis=0).reshape((1,-1)).T
             muneg = X[Y==-1,:].mean(axis=0).reshape((1,-1)).T
             # D-by-D inter class covariance matrix (signal)
             Sinter = (mupos - muneg) @ (mupos - muneg).T
             # D-by-D intra class covariance matrices (noise)
             Sintra = sp.cov(X[Y==1,:].T) + sp.cov(X[Y==-1,:].T)
```

```
    # solve eigenproblem
    eigvals, eigvecs = sp.linalg.eig(Sinter,Sintra)
    w = eigvecs[:,eigvals.argmax()]
    # bias term
    b = (w.dot(mupos) + w.dot(muneg))/2.
    # return the weight vector
    return w,b
```

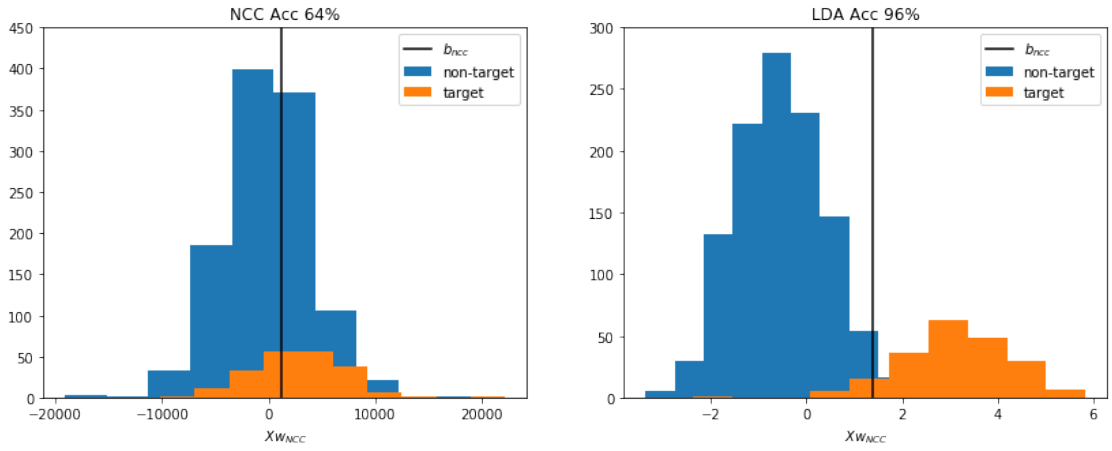
This Code plots the results, do not modify it

```
In [13]: X_train, X_test, Y_train, Y_test = train_test_split(X,Y)

    w_ncc, b_ncc = ncc_fit(X_train, Y_train)
    w_lda,b_lda = lda_fit(X_train,Y_train)

    pl.figure(figsize=[14,5])
    pl.subplot(1,2,1)
    pl.hist(X_test[Y_test<0, :] @ w_ncc)
    pl.hist(X_test[Y_test>0, :] @ w_ncc)
    pl.plot([b_ncc, b_ncc], [0, 500], color='k')
    pl.xlabel('$Xw_{NCC}$')
    pl.legend(('$b_{ncc}$','non-target','target'))
    pl.ylim([0, 450])
    acc = int((sp.sign(X_test @ w_ncc - b_ncc)==Y_test).mean()*100)
    pl.title(f"NCC Acc {acc}%");

    pl.subplot(1,2,2)
    pl.hist(X_test[Y_test<0, :] @ w_lda)
    pl.hist(X_test[Y_test>0, :] @ w_lda)
    pl.plot([b_lda, b_lda], [0, 500], color='k')
    pl.xlabel('$Xw_{NCC}$')
    pl.legend(('$b_{ncc}$','non-target','target'))
    pl.ylim([0, 300])
    acc = int((sp.sign(X_test @ w_lda - b_lda)==Y_test).mean()*100)
    pl.title(f"LDA Acc {acc}%");
```



```
In [14]: #pl.imshow(Sinter)
```