EECS 349 (Machine Learning) Homework 3

How to submit your homework

1. Create a **PDF document** containing answers to the homework questions. Show your reasoning in your answers.
2. Include source code for the program you write.
3. Compress all of the files specified into a .zip file.
4. Name the file in the following manner, *firstname_lastname_hw3.zip*.
3. Submit this .zip file via Canvas by the date specified on Canvas.

1) Polynomial Regression (3 points)

Load the *linearreg.csv* file. This is the file you will use for this problem. There are two vectors in the file ***X*** and ***Y***. ***X*** consists of 30 instances of a univariate attribute vector, and ***Y*** is the response vector. The intent of this problem is to get hands on experience doing polynomial regression and to use cross-validation to get an idea of how model complexity relates to testing and training error.

A. (2 points) Using n-fold cross-validation (the value of n is your choice, but must be explained in your answer) with k^{th} polynomial regression, fit a function to the data for values of ***k*** between 0 and 9. In your homework, show the plot of the mean square error on the validation set(s), averaged over all of the folds, as a function of ***k***. Also, plot the best function overlaying a scatterplot of the data. The code for your work must be in a single file called *nfoldpolyfit.py*. The stub for this file has been provided to you as an example. Below is the function signature, as well as how it will be run from the command line.

```
def nfoldpolyfit(X,Y,maxK,n, verbose)
python nfoldpolyfit.py <csvfile> <maxdegree> <numberoffolds> <verbose>
```

B. (0.5 points) Which value of ***k*** yielded the best results, in terms of accuracy of the prediction on the testing data?

C. (0.5 point) Predict the response for a new query, ***x***=3. Given the performance during cross-validation, do you think this is an accurate prediction? Is there anything about the value 3 that should give you pause, given the training data? Explain your reasoning.

2) Classification with Regression (2 points)

A. (1 point) Explain how to do classification via regression. Be clear. Use a graph to illustrate.

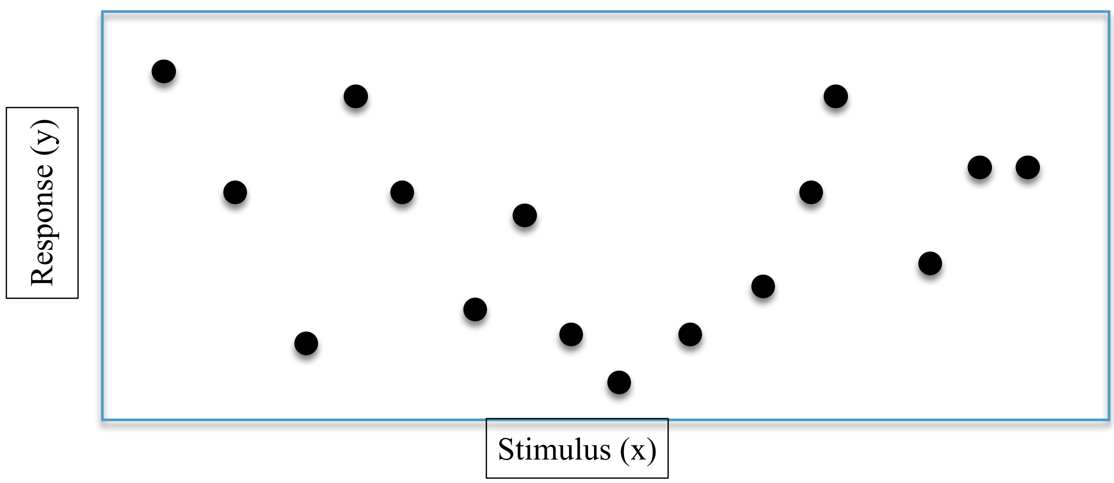
B. (1 point) Explain a weakness of classification via regression. Be clear. Use a graph and a concrete example to illustrate.

3) KNN Vs. Linear (2 points)

A. (0.5 points) For some arbitrary data set D, how can you set the parameters for polynomial regression (like you coded up in problem 1) and for KNN regression so that both approaches output the same value for f(x), regardless of the input value x?

B. (0.5 points) Give an illustration of where the output of KNN regression would be very similar to that of linear regression on the training data, but very different on a large range of testing data. Provide a graph and an explanation.

C. (0.5 points) Consider the data set in the image below. You want to learn a function that would be able to predict the response (y) given the stimulus (x). Assume the range of values for x is representative of the range you'll see when you actually apply the function. Assume measurement error is very small. Would you pick a KNN regression approach or a polynomial regression approach? Why?



D. (0.5 points) Now that you selected a regression approach, what parameters (e.g. value for K, degree of polynomial) would you pick for your approach? Why those values?

4) Perceptron Linear Discriminants (3 points)

Load the *linearclass.csv* file. There are four vectors in the file: ***X1***, ***Y1***, and ***X2***, ***Y2***. Vectors ***X1*** and ***X2*** both consist of 200 instances of a univariate attribute vector. ***Y1*** and ***Y2*** are the respective output labels {-1,1} for each input vector, e.g. the k^{th} labeled instance for ***X1*** is <X1(k),Y1(k)>.

begin **initialize** $\vec{w}, k \leftarrow 0$
  do $k \leftarrow k + 1 \bmod m$
    if $\vec{x}_k$ is misclassified using $\vec{w}$
    then $\vec{w} \leftarrow \vec{w} + \vec{x}_k y_k$
  until all examples are properly classified
 return $\vec{w}$
end

Figure 1. Pseudo code for Sequential Perceptron Algorithm

Figure 1 contains pseudo code for the Sequential Perceptron Algorithm. Here...
w is the parameter vector (weight vector and threshold value)
m is the number of training examples
$\boldsymbol{x_k}$ is the k^{th} training example
$\boldsymbol{y_k}$ is the k^{th} training example class label {-1,1}

A. (1 point) Implement the sequential perceptron algorithm to learn the parameters for a linear discriminant function that correctly assigns X1 to class -1 or 1. The algorithm should terminate when the classification error is 0. Output the number of iterations of that the algorithm performed before convergence and the learned parameters. Name your file *perceptrona.py* and include it with your homework submission. Comment this code to the level you saw in the provided stub for *nfoldpolyfit.py* Below is how the function will be run from the command line, as well as the function signature. We have provided some starter code for reading in the csv file in perceptrona.py

```
def perceptrona(w_init,X,Y):
      #return a tuple (w, e)
      return (w, e)
python perceptrona.py <csvfile>
```

where...
w is the parameter vector (weight vector and threshold value)
e is the number of epochs (one epoch is one iteration through all of X) the algorithm performed
w_init is the parameter vector (weight vector and threshold value)
X is the matrix of training examples (i.e. each row is an attribute vector with a prepended '1' for the threshold term)
Y is the column vector of class {-1,1} class labels for the training examples

B. (1 point) Using the same sequential perceptron algorithm from part A, learn the parameters for a linear discriminant function that correctly assigns ***X2*** to class -1 or 1. What happened and why?

C. (1 point) How can you transform the attributes of ***X2*** so that your algorithm can correctly classify the data? Add this transformation into your algorithm, and describe your changes. Name your function (and file) "perceptronc(.py)" and include with your homework submission. This function should have the exact same input and output parameters (in the same order) as *perceptrona*.