MIDTERM EXAM

ELECTRONIC SUBMISSION (WITH CODE) DUE NOV 2, 2022, 4 PM

This is an exam. **Please make sure that your submitted work is only attributed to you.**

(1) (5pts) Assume you are given a data set. Based on the class lectures and discussions, please write down the steps you will take from getting that data, to providing a final learned hypothesis. After writing down the steps, create a visual flowchart of the various steps which essentially is what we have referred to as the machine learning pipeline in the lectures.

(2) (5pts) Exercise 1.12 (page 26)

(3) (10 pts) Use the data uploaded on ELMS for the exam as a training and test set. Each line of the files corresponds to a two-dimensional input $x = (x_1, x_2)$, so that $\mathcal{X} = R^2$, followed by the corresponding label from Y = {-1, 1}. Use Linear Regression with a non-linear transformation for classification. The nonlinear transformation is given by $\phi(x_1, x_2) = (1, x_1, x_2, x_1^2, x_2^2, x_1x_2, |x_1 - x_2|, |x_1 + x_2|)$. Report the classification error which is defined as the fraction of misclassified points.
   (a) Run Linear Regression on the training set after performing the nonlinear transformation. Report the in-sample and out-of-sample classification errors, respectively.
   (b) Now add weight decay to Linear Regression, namely, add the regularization term $\frac{\lambda}{N}\sum_{i=0}^{7} w_i^2$ to the squared in-sample error, using $\lambda = 10^k$. What are the values to the in-sample and out-of-sample classification errors, respectively, for k = -3?
   (c) Using k = 3, report the new in-sample and out-of-sample classification errors.
   (d) Using k=2,1,0,-1,-2, report which value gives the smallest out-of-sample classification errors and also provide the smallest out-of-sample classification errors.

(4) (5pts) In each of the following cases, please state what can you conclude about the VC dimension and the break point
   (a) There is a set of N points that can be shattered by H.
   (b) Any set of N points can be shattered by H.
   (c) There is a set of N points that cannot be shattered by H.

(d) No set of N points can be shattered by H.

(5) (6pts) Consider the function

$$f(x_1, x_2) = e^{x_1+3x_2-0.1} + e^{x_1-3x_2-0.1} + e^{-x_1-0.1}$$

(a) Plot the level sets of $f(x_1, x_2) = k$ for different positive values of k.
(b) Compute the gradient of the function.
(c) Utilize the gradient descent algorithm to optimize the function, report the minimum, and plot the progression towards the minimum. The plot should be submitted. You have to write your own function for solving this problem and not utilize standard existing libraries for gradient descent.