CS 529: Assignment #1

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Instructions

ℹ **Info:** This HW includes both theory and coding problems. Please read the course policy before starting your HW.

- Your code must work with Python 3.5+ (you may install the Anaconda distribution of Python).
- You need to submit a report including solutions of theory problems (in pdf format), and Jupyter notebooks that include your source code.
- You can always use course **Campuswire** page to ask your questions. I encourage you to answer questions to help each other.
- Failure to follow the instructions will lead to a deduction in points.

1 Problem 1: Background [25pt]

1. Define the terms in a couple of sentences with your own words (10pt):
   - Generalization
   - Overfitting
   - Underfitting
   - Regularization
   - No free lunch theorem
   - Occam's razor
   - Independent and identically distributed data points
   - Cross-validation
   - Degrees of freedom
2. Assume that you observe two different coins being tossed as follows (5pt):

   Coin$_1$=H,H,H,H,T,T,H,H,H,H,T,T,H,H,H,H,T

   Coin$_2$=H,H,T,T,T,T,H,H,T,T,T,T,H,H,T,T,T

   Assume the coin tosses are i.i.d. random variables. Each coin will be tossed one more time and you will be given $100 for each correct guess. What is your guess for Coin$_1$ and Coin$_2$'s next toss and why?

   NOTE: There is no one correct solution for this problem. You are free to interpret it in any way you wish. Please make sure to list all the assumptions that you make in the context of this question.

3. Find the closed form solution $\mathtt{w}^*$ to minimize the error function $\mathtt{E}(\mathtt{w})$ (10pt).

$$E(w) = \frac{1}{2}\sum_{n=1}^{N}\{y(x_n, w) - t_n\}^2, \text{ where}$$

$$y(x, w) = w_0 + w_1 x + w_2 x^2 + \ldots + w_M x^M = \sum_{j=0}^{M} w_j x^j$$

Then use the found $\mathtt{w}^*$ to illustrate the resulting polynomial $\mathtt{y}(\mathtt{x}, \mathtt{w}^*)$ (**Hint:** Use the matrix representation which is often simple and clean).

2 Problem 2: Exploratory Data Analysis with Pandas [25pt]

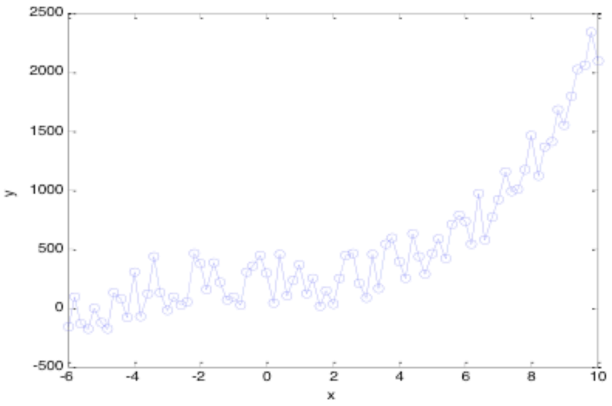
> **Info:** To answer this question, you need to create a Jupyter notebook named **HW1P2.ipynb**. Please complete the notebook with your code that answers the questions. You are encouraged to install Anaconda distribution of Python to run the Jupyter notebook to accomplish this task.

As it has been emphasized in the lectures, we need to have a good understanding of data before training a machine learning model. In this assignment, you are asked to analyze the UCI Adult data set, **adult.data.csv**. The Adult data set is a standard machine learning data set that contains demographic information about the US residents. The data set contains 32561 instances and 15 features (please check the notebook for possible values of each feature) with different types (categorical and continuous). The data is provided as a csv file and can be loaded into pandas' DataFrame object as `data = pd.read_csv('adult.data.csv')`.

1. How many men and women (sex feature) are represented in this data set?
2. What is the average age (age feature) of women?
3. What is the percentage of German citizens (native-country feature)?
4. What are the mean and standard deviation of age for those who earn more than 50K per year (salary feature) and those who earn less than 50K per year?
5. Is it true that people who earn more than 50K have at least high school education? (education –Bachelors, Prof-school, Assoc-acdm, Assoc-voc, Masters or Doctorate feature)
6. Display age statistics for each race (race feature) and each gender (sex feature).
7. What is the maximum number of hours a person works per week (hours-per-week feature)? How many people work such a number of hours, and what is the percentage of those who earn a lot (>50K) among them?
8. Count the average time of work (hours-per-week) for those who earn a little and a lot (salary) for each country (native-country). What will these be for Japan?

3 Problem 3: Linear Regression [50pt]

> **Info:** You are given a simple dataset, `data.txt`, which includes an input (`x`) and a continuous output (`y`). We can visualize the dataset below. You will create a Jupyter notebook named **HW1P3.ipynb**. You are required to complete this notebook and ensure that it runs without any errors to receive full credit.



1. Partition all data randomly into 10 folds and produce 10 different training-validation set pairs (3 pts). **Hint:** You can simply do as follows: For the first split, we randomly create a train/validation split using the entire data. Keeping the generated train/validation split (first fold) and saving it, and using the entire data again to create another train/validation split (this will form the second fold). We repeat the same process 10 times, and at the end, we will have 10 pairs of train/validation sets.

2. Normalize your training inputs and outputs by using training sample mean and std deviation (2 pts).

3. For each of the 10 training sets, compute (and print) the weights that minimize the training error:

$$E(w) = \frac{1}{N}\sum_{i=1}^{N}\left(y^t - g\left(x^t, w\right)\right)^2. \quad (1)$$

, for the following hypotheses classes (20 pts):

   (a) $g(x, w) = w_0 + xw_1$

   (b) $g(x, w) = w_0 + xw_1 + x^2w_2 + x^3w_3$

   (c) $g(x, w) = w_0 + x^1w_1 + x^2w_2 + x^3w_3 + x^4w_4 + x^5w_5$

   (d) $g(x, w) = w_0 + x^1w_1 + x^2w_2 + x^3w_3 + x^4w_4 + x^5w_5 + \ldots + x^{50}w_{50}$

4. For the hypothesis that minimizes the training error (20 pts),

   (a) Print the values of the mean training errors for all hypotheses, as well as the standard deviation of the training errors for all the hypotheses. Also. plot the errorbar (i.e., the mean and std/sqrt(10)) of training and validation errors in separate plots (you can use errorbar function, (**Hint:** x-axis = 1,. . . , 4 (hypothesis class), y-axis = mean error over 10 folds)).

   (b) Print the index of the validation fold for each hypothesis class that achieves the minimum training error. Also plot the training input and outputs and the minimum training error output (out of the 10 folds created) for each hypothesis class above (4 plots corresponding to the above hypotheses classes).

5. Which hypothesis class would you choose among (a),. . . , (d) and why (5 pts)?