Homework 5 **Name: _____**
ECE/CS 498 DS Spring 2020 **NetID: _____**
Issued: 04/27/20
Due: 05/04/20 23:59:59 (No late submission allowed)

What to submit:

- Jupyter notebook for coding part of problem 1
- A PDF report with the results from problem 1 and calculations of problem 2

Problem 1

Machine Learning has seen wide applications, one of which includes physics and astronomy. You might have heard about the recent achievement of imaging a black hole. The method used in that work involved machine learning. In this homework, you'll explore the use of SVM, Decision Trees and Random Forests classifiers in another problem based in astronomy.

Data: *HTRU_2.csv*

HTRU2 (High Time Resolution Universe Survey) Dataset. It describes a sample of pulsar candidates collected during the survey. Pulsar is a rate type of Neutron star. See the link for details about the study and description of the features in the dataset: https://archive.ics.uci.edu/ml/datasets/HTRU2

The data has 9 columns - 8 of which are features and 'Class' is the label. Class=0: Not a pulsar, Class=1: Is pulsar.

Problem:

Use sklearn package for SVM, decision trees, random forests, accuracy, precision and recall. Classify the samples based on the 8 features using the following methods:

- Linear SVM – regularization parameter C in {0.1, 1, 10}
- Decision Trees – maximum depth in {3, 4, 6}
- Random Forests – number of trees in {5, 11, 13}, maximum depth = 5

1. For each of the above perform 5-fold cross-validation of the data with 80%-20% train test split. Report the mean accuracy, precision and recall on the test

set. Report precision and recall for the positive class (pulsar). Also report the respective standard deviations. Provide the results in a table.

2. Explain the high value of accuracy compared to precision and recall.
3. Which classifier performs the best? Explain the reason why the picked classifier performed the best.
4. **(Optional)** Visualize a decision tree (depth=3) from one iteration of the cross-validation. You can visualize using the following code for ease. As a part of your submission, turn in an image of the generated tree.

```
Step 1:
from sklearn import tree

Y_Classes = ['0','1']
tree.export_graphviz(<variable of the decision tree>, out_file =
'htru_tree.dot',
                     feature_names = <insert the list of feature names here>,
                     class_names = Y_Classes,
                     filled=True, rounded=True)
Step 2:
Copy paste the text generated in htru_tree.dot on
http://www.webgraphviz.com/ to generate the decision tree.
```

Problem 2

Consider the neural network given below. Assume that all the neurons use the sigmoid activation function.

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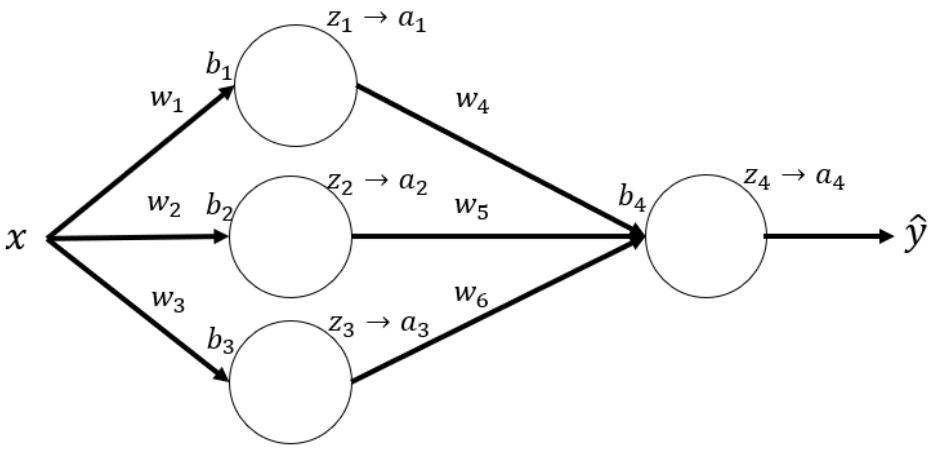

1. Write down the expressions for z_1, z_4, a_1 and a_4. Use them to express the output of the neural network given an input x_1, weights $w_1, w_2, w_3, w_4, w_5, w_6$ and biases b_1, b_2, b_3, b_4.

2. In the following questions, we use mean squared error as the loss function L. Consider a single sample x_i , with predicted label $\hat{y}_i$ and true label y_i. Write down the equation for L_i and for the gradients $\frac{\partial L_i}{\partial w_1}, \frac{\partial L_i}{\partial w_4}, \frac{\partial L_i}{\partial b_1}$, and $\frac{\partial L_i}{\partial b_4}$. (You may use $\hat{y}_i, y_i, z_{1i}, z_{2i}, z_{3i}, z_{4i}, w_1, w_2, w_3, w_4, w_5, w_6, b_1, b_2, b_3, b_4$ and x_i in your expressions.)

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3. Given a single training sample x_1, write the gradient descent equation for updating weight w_1. (The learning rate, which determines the step size at each iteration, is denoted as η.)

4. Given *n* training samples x_i for $i = 1,2,3, \ldots, n$, write the gradient descent equation for updating weight w_1. (The learning rate, which determines the step size at each iteration, is denoted as η.)

5. In the lecture we briefly mentioned two activation functions: 1) Sigmoid activation, and 2) ReLU activation. **List one advantage and one disadvantage for each of these two activation functions and briefly explain.** You may want to search online for this question. You can also conclude the advantages, disadvantages by explaining the properties of the functions itself or their first order derivatives.