CS57300 Data Mining
Assignment 4

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Environment:
Experiment done on Apple Silicon M1.
Python version: **3.9.7**
Numpy version: **1.21.2**
Pandas version: **1.3.3**
Number of Extension Days used: 1

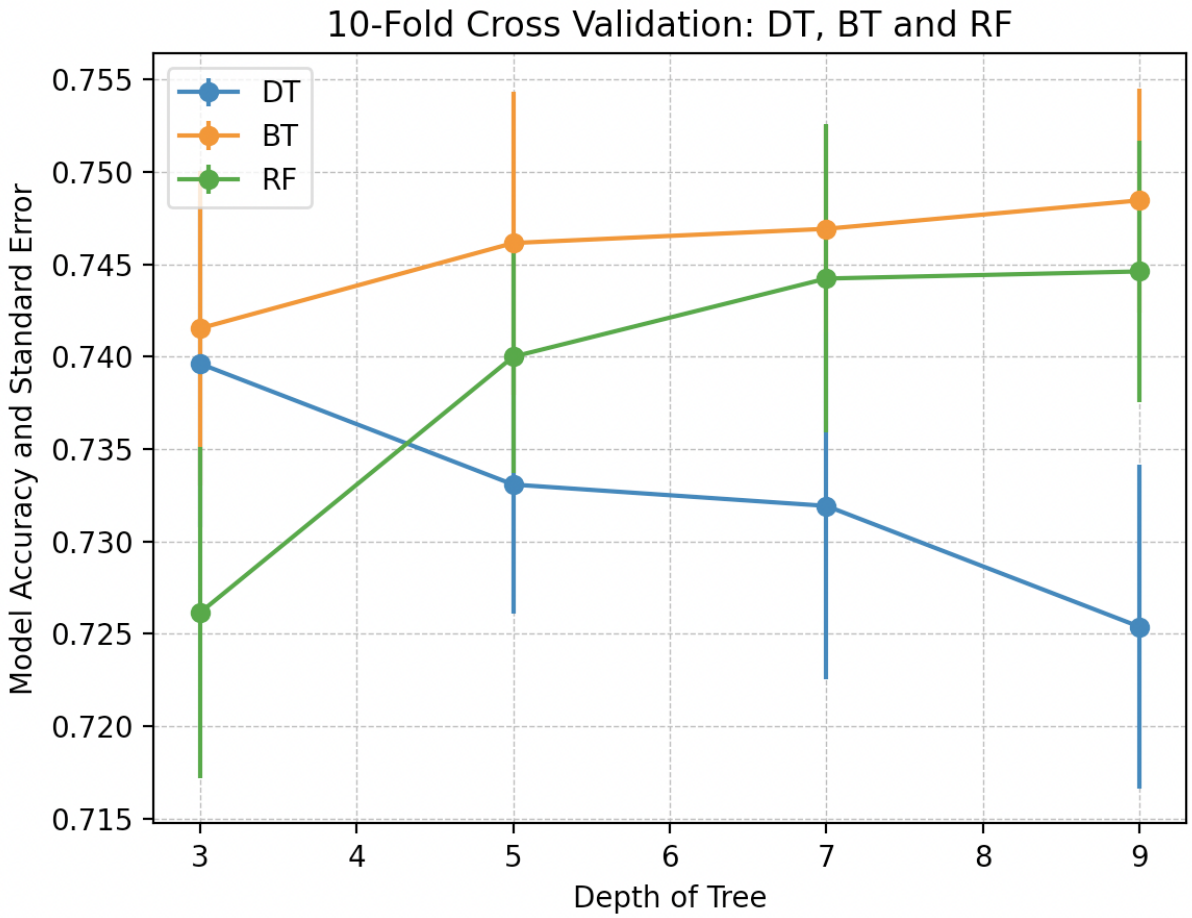
2. Implement Decision Trees, Bagging and Random Forests

```
(dm) ➜  assg4 git:(main) ✗ python trees.py trainingSet.csv testSet.csv 1
Training Accuracy DT: 0.77
Testing Accuracy DT: 0.72
Total Time Elapsed: 1.03 seconds
(dm) ➜  assg4 git:(main) ✗ python trees.py trainingSet.csv testSet.csv 2
Training Accuracy BT: 0.79
Testing Accuracy BT: 0.75
Total Time Elapsed: 7.99 seconds
(dm) ➜  assg4 git:(main) ✗ python trees.py trainingSet.csv testSet.csv 3
Training Accuracy RF: 0.76
Testing Accuracy RF: 0.72
Total Time Elapsed: 2.76 seconds
```

3. Influence of Tree Depth on Classifier Performance

(a) *Running Time* using python multiprocessing (6 processes): 3 mins 45 seconds

(a) DT - Decision Trees
(b) BT - Bagging Trees
(c) RF - Random Forests



The performance of Bagging trees increases with increase in the depth of the tree but doesn't increase by much after depth of 5. The performance of Random Forests also increases upto depth of 7 and then decreases. Decision Trees on the other hand always show a decrease in average validation accuracy as the depth limit increases. The standard errors for each of the models is also high which shows that the models tend to have tendency to output different prediction accuracies depending on the distribution of the data.

(b) **Formulating Hypothesis**:

Null Hypothesis: Bagging Trees doesn't perform any better than Decision Trees as the depth limit of the tree increases to 7.

Alternative Hypothesis: Bagging Trees performs better than Decision Tree as the depth limit of the tree increases to 7.

Alpha Level: Set threshold to 0.05.

Testing our formulated hypothesis:

We will use paired t-test for the paired samples we get from Bagging Trees and Decision Trees classifier.

t-statistic is calculated as:

$$t = \frac{\bar{X_D} - \mu_0}{s_D/\sqrt{n}}$$

where $\bar{X_D}$ and s_D are the average and standard deviation of the differences between all pairs at different depth of the tree. The pairs, here are accuracies of the two models DT and BT we want to compare trained using different sized samples.

Using the scipy package to compute the t-stastic and greater p-value at different depths of the trees taking the accuracies obtained at different folds, we observe p-values of 0.08, 0.06, 0.018 and 0.006 at depths 3, 5, 7 and 9 respectively. Since the p-value is less than the threshold value of 0.05 when the depth limit is 7 or 9, we REJECT the null hypothesis, and accept the alternative hypothesis to conclude that Bagging Trees model performs better than Decision Trees model as the depth of the tree changes(increases) to atleast 7 for the data in consideration. This is also evident from the graph shown above that the performance of bagging trees becomes better than decision trees in the case of dating classification as we increase the depth limit of the trees.

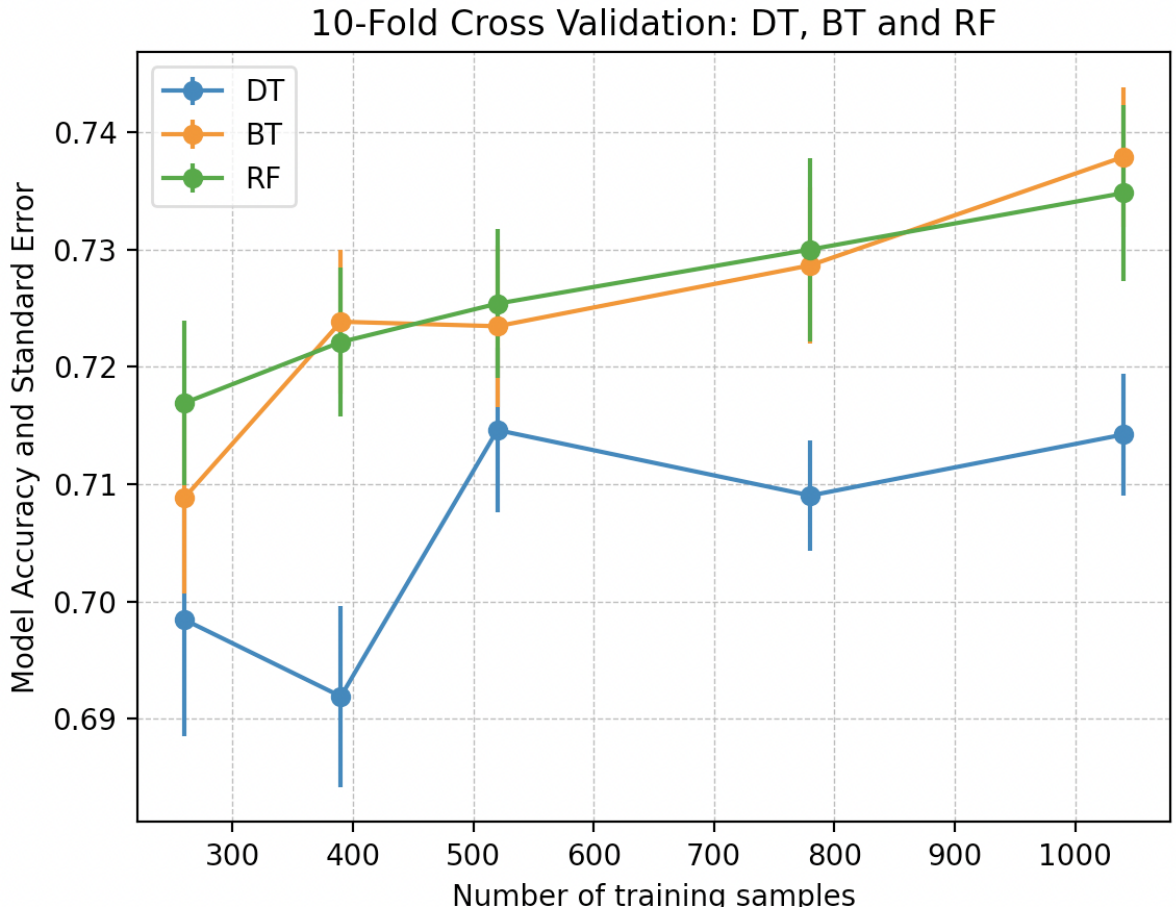
4. Compare Performance of Different Models

(a) *Running Time* using python multiprocessing (6 processes): 3 mins 5 seconds

(a) DT - Decision Trees

(b) BT - Bagging Trees

(c) RF - Random Forests



As is evident from the graph, the performance of the models increases as we increase the number of samples to train. Bagging Trees and Random Forests show better performance than decision trees even in limited data settings.

(b) **Formulating Hypothesis**:

Null Hypothesis: Bagging Trees doesn't perform any better than Decision Trees.

Alternative Hypothesis: Bagging Trees performs better than Decision Trees.

Alpha Level: Set threshold to 0.05.

Testing our formulated hypothesis:

We will use paired t-test for the paired samples we get from DT and BT classifier.

t-statistic is calculated as:

$$t = \frac{\bar{X_D} - \mu_0}{s_D/\sqrt{n}}$$

where $\bar{X_D}$ and s_D are the average and standard deviation of the differences between all pairs. The pairs, here are accuracies of the two models DT and BT we want to compare trained using different sized samples.

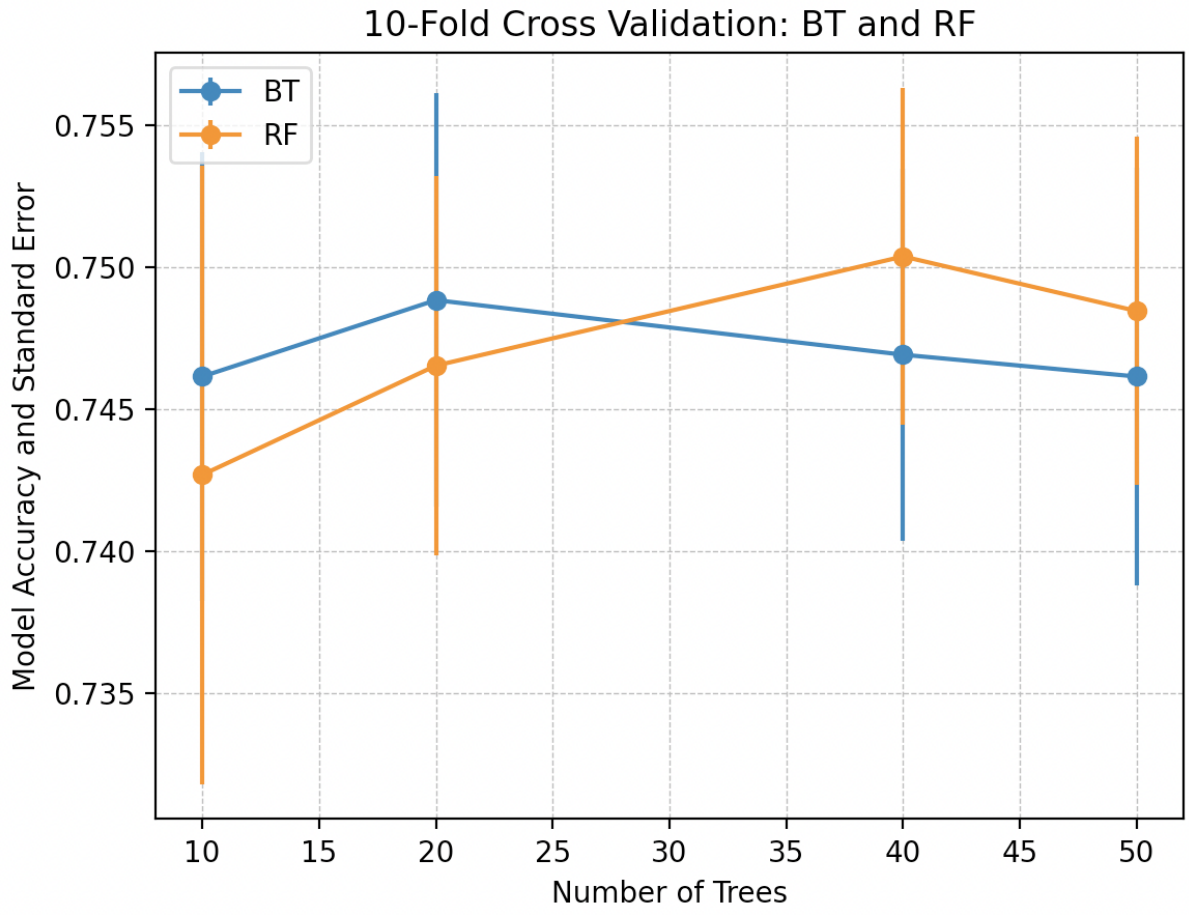
Using the scipy package to compute the t-stastic and greater p-value, we observe a p-value of less than 0.05 ($p \approx 0.002$). Since the p-value is less than the threshold value of 0.05, we REJECT the null hypothesis, and accept the alternative hypothesis to conclude that Bagging Trees model performs better than Decision Trees model for the data in consideration. This is also evident from the graph shown above that the performance of bagging trees is better than decision trees in the case of dating classification.

5. The Influence of Number of Trees on Classifier Performance

(a) *Running Time* using python multiprocessing (6 processes): 4 mins 50 seconds

(a) BT - Bagging Trees

(b) RF - Random Forests



As is evident from the graph, the performance of both the models increases as we increase the number of trees at the start, the models tend to generalize well on the training data. However, as we start to use more trees, the performance drops as the model overfits the training data and thus fails to perform better on the unseen data.

(b) **Formulating Hypothesis**:

Null Hypothesis: Bagging Trees doesn't perform any better than Random Forests.

Alternative Hypothesis: Bagging Trees performs better than Random Forests.

Alpha Level: Set threshold to 0.05.

Testing our formulated hypothesis:

We will use paired t-test for the paired samples we get from BT and RF classifier.

t-statistic is calculated as:

$$t = \frac{\bar{X_D} - \mu_0}{s_D/\sqrt{n}}$$

where $\bar{X_D}$ and s_D are the average and standard deviation of the differences between all pairs. The pairs, here are accuracies of the two models BT and RF we want to compare trained using different sized samples.

Using the scipy package to compute the t-stastic and greater p-value, we observe a p-value of greater than 0.05 ($p \approx 0.5$). Since the p-value is greater than the threshold value of 0.05, we CANNOT REJECT the null hypothesis and conclude that the Bagging Trees model doesn't perform any better than Random Forests for the data in consideration. This is also evident from the graph shown above that the performance of bagging trees is atpar with random forests in the case of dating classification.

Bonus Question

Implemented Neural Networks with two hidden layers of size 10 and 5 respectively. Code can be found inside *neural_net.py* file and can be executed using simple *python neural_net.py trainingSet.csv testSet.csv* script. 3000 epochs were used for training. Hyperparameter tuning was done by keeping aside some part of training set to be used as validation set. A grid search approach was used to select the best learning rate, batch size and number of epochs. Learning rate was set to 0.3. Loss was seen converging on both train and test dataset. Data was processed in batch size of 64. A random seed of 0 for numpy random has been set to initialize the weights for reproducibility purpose. The training accuracy rounded to two decimal places is 0.81 and test accuracy is 0.76.

```
(dm) ➜  assg4 python neural_net.py trainingSet.csv testSet.csv
Training Accuracy NN: 0.8094230769230769
Testing Accuracy NN: 0.7576923076923077
Total Time Elapsed: 18.2378408908844 seconds
(dm) ➜  assg4
```