Homework2

September 11, 2019

This notebook uses the packages **pandas**(loads datasets and output tables), **scikit-learn**(contains random forest classifiers), **numpy**(label formatting) and **matplotlib**(contains module for plotting graphs). In this project, the only dataset that will be used is the **madelon** dataset. The folder containing the **madelon** dataset must be in the same directory as this notebook.

In order to run the code for this project, the following packages must be imported first

[1]:
```
from sklearn.ensemble import RandomForestClassifier
import pandas as pd  # load datasets
import matplotlib.pyplot as plt
import numpy as np
from math import sqrt, log
```

The sizes for the graph and fonts were found in https://www.kdnuggets.com/2019/04/data-visualization-python-matplotlib-seaborn.html

[2]:
```
# style and size for graph fonts
fontdict_title = {'fontsize': 24, 'weight': 'bold', 'horizontalalignment':␣
 ↪'center'}
fontdict_xlabel = {'fontsize': 18, 'weight': 'bold', 'horizontalalignment':␣
 ↪'center'}
fontdict_ylabel = {'fontsize': 16, 'weight': 'bold', 'horizontalalignment':␣
 ↪'center', 'verticalalignment': 'baseline'}
```

The following line is used to show the plots inside the notebook

[3]:
```
%matplotlib inline
```

The tree number(k) for all the random forest models are 3,10,30,100,300

[4]:
```
tree_num = [3, 10, 30, 100, 300]
```

The following dictionary stores the training and test misclassification errors for the three problems. 'sqrt500', 'ln500' and 'all500' refer to the random forest models where the split attribute is chosen from a random subset of 500, ln(500) and all the 500 features at each node respectively.

[5]:
```
misclassification_errors = {
    "sqrt500": {"train": [], "test": []},
    "ln500": {"train": [], "test": []},
    "all500": {"train": [], "test": []}
}
```

Load training and test sets from the **madelon** dataset

[6]:
```
madelon_train_data = pd.read_csv("./MADELON/madelon_train.data", header=None,␣
 ↪sep=" ").dropna(axis=1).values
madelon_train_labels = np.ravel(
    pd.read_csv("./MADELON/madelon_train.labels", header=None, sep=" ").
 ↪dropna(axis=1).values)
madelon_test_data = pd.read_csv("./MADELON/madelon_valid.data", header=None,␣
 ↪sep=" ").dropna(axis=1).values
madelon_test_labels = np.ravel(
    pd.read_csv("./MADELON/madelon_valid.labels", header=None, sep=" ").
 ↪dropna(axis=1).values)
```

Create labels for the three Misclassification Errors tables

[7]:
```
rows_labels = tree_num
columns_labels = ["Number of Trees", "Train Misclassification Error", "Test␣
 ↪Misclassification Error"]
```

Problem 1: Random Forests with Split Attribute Chosen from a Random Subset of 500 Features at each Node

Create random forests with tree numbers(3,10,30,100,300) with split attribute chosen from a random subset of 500 features at each node.

[8]:
```
sqrt500_rfs_feature_num = int(sqrt(500))
sqrt500_rfs = [RandomForestClassifier(n_estimators=num,␣
 ↪max_features=sqrt500_rfs_feature_num) for num in tree_num]
```

Train and test random forests generated in previous step and store the misclassification errors for training and test sets of each random forest with its corresponding number of trees.

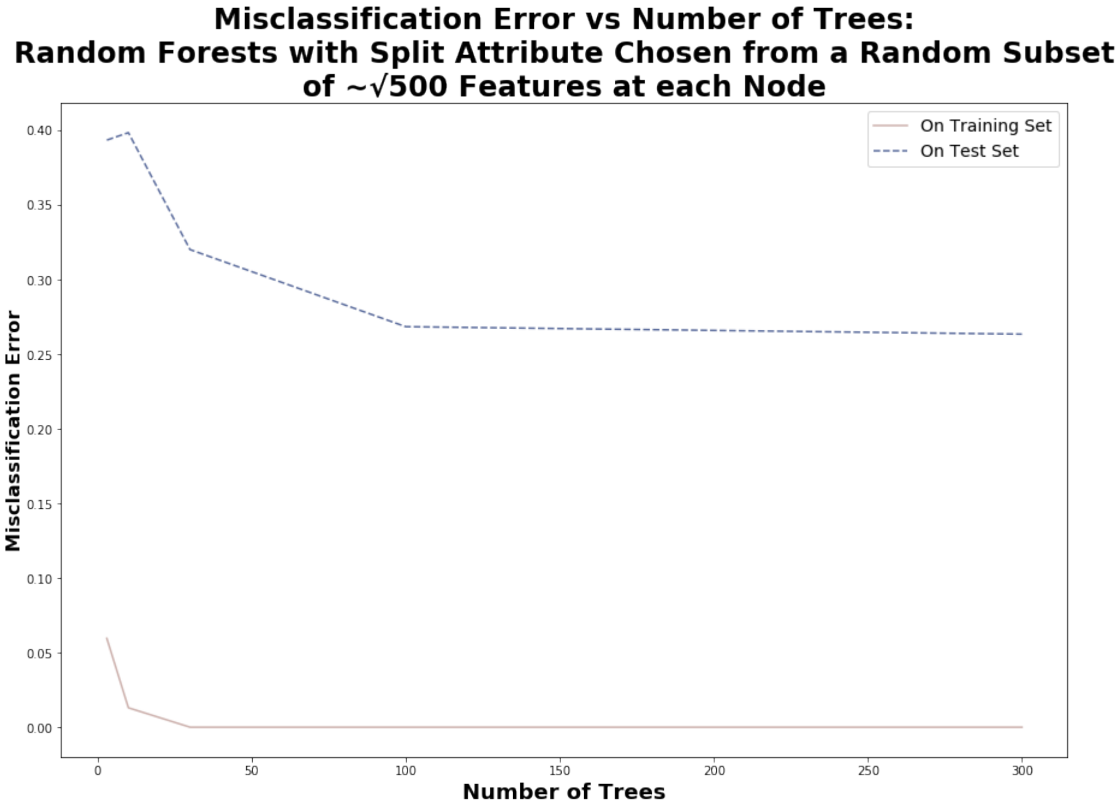
[9]:
```
for rf in sqrt500_rfs:
    rf = rf.fit(madelon_train_data, madelon_train_labels)
    misclassification_errors["sqrt500"]["train"].append([1 - rf.
 ↪score(madelon_train_data,
                                                                             ␣
 ↪madelon_train_labels),
                                                         rf.n_estimators])
    misclassification_errors["sqrt500"]["test"].append([1 - rf.
 ↪score(madelon_test_data,
                                                                    ␣
 ↪madelon_test_labels),
                                                        rf.n_estimators])
```

Plot training and test misclassification errors vs number of trees in random forests graph

[10]:
```
# size of graph
plt.rcParams['figure.figsize'] = [15, 10]  # size=15x10 inches

# labels
plt.title("Misclassification Error vs Number of Trees:\nRandom Forests with␣
 ↪Split Attribute Chosen from a Random "
          "Subset\nof 500 Features at each Node", fontdict=fontdict_title)
plt.xlabel("Number of Trees", fontdict=fontdict_xlabel)
plt.ylabel("Misclassification Error", fontdict=fontdict_ylabel)

# plotting
sqrt500_train_misclassification_errors = [train_error[0] for train_error in
                                         ␣
 ↪misclassification_errors["sqrt500"]["train"]]
sqrt500_test_misclassification_errors = [test_error[0] for test_error in␣
 ↪misclassification_errors["sqrt500"]["test"]]
plt.plot(tree_num, sqrt500_train_misclassification_errors,
         color="#CDB1AD",
         linestyle="-",
         label="On Training Set")
plt.plot(tree_num, sqrt500_test_misclassification_errors,
         color="#5D6E9E",
         linestyle="--",
         label="On Test Set")
plt.legend(fontsize=14);
```



Training and Test Misclassification Error Table

Create tables for training and test misclassification errors with the respective number of trees for each random forest

[11]:
```
# Find the training and test misclassification errors for each random forest in␣
 ↪order of increasing number of trees
sqrt500_train_errors = [error[0] for error in␣
 ↪misclassification_errors["sqrt500"]["train"]]
sqrt500_test_errors = [error[0] for error in␣
 ↪misclassification_errors["sqrt500"]["test"]]
sqrt500_errors = {
    columns_labels[1]: sqrt500_train_errors,
    columns_labels[2]: sqrt500_test_errors
}

# Create dataframe to output table
sqrt500_tabledf = pd.DataFrame(sqrt500_errors, index=rows_labels)
sqrt500_tabledf.index.name = columns_labels[0]
```

```
sqrt500_tabledf
```

[11]:

```
                 Train Misclassification Error  Test Misclassification Error
Number of Trees
3                                       0.0595                      0.393333
10                                      0.0130                      0.398333
30                                      0.0000                      0.320000
100                                     0.0000                      0.268333
300                                     0.0000                      0.263333
```

Problem 2: Random Forests with Split Attribute Chosen from a Random Subset of ln(500) Features at each Node

Create random forests with tree numbers(3,10,30,100,300) with every split attribute chosen from a random subset of ln(500) features at each node.

[12]:

```
ln500_rfs_feature_num = int(log(500))
ln500_rfs = [RandomForestClassifier(n_estimators=num,␣
 ↪max_features=ln500_rfs_feature_num) for num in tree_num]
```

Train and test random forests generated in previous step and store the misclassification errors for training and test sets of each random forest with its corresponding number of trees.

[13]:

```
for rf in ln500_rfs:
    rf = rf.fit(madelon_train_data, madelon_train_labels)
    misclassification_errors["ln500"]["train"].append([1 - rf.
 ↪score(madelon_train_data,
                                                                   ␣
 ↪madelon_train_labels),
                                                      rf.n_estimators])
    misclassification_errors["ln500"]["test"].append([1 - rf.
 ↪score(madelon_test_data,
                                                                 ␣
 ↪madelon_test_labels),
                                                    rf.n_estimators])
```

Plot training and test errors vs number of trees in random forests graph

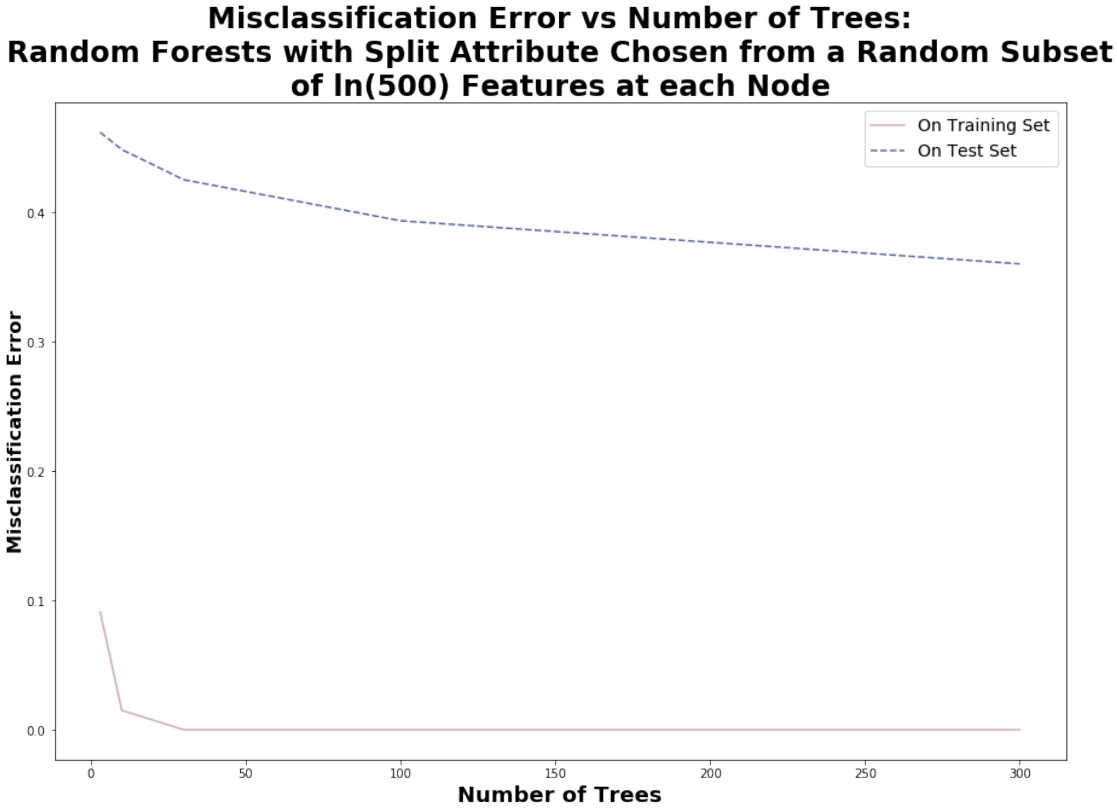
[14]:

```
# size of graph
plt.rcParams['figure.figsize'] = [15, 10]  # size=15x10 inches

# labels
plt.title("Misclassification Error vs Number of Trees:\nRandom Forests with␣
 ↪Split Attribute Chosen from a Random "
```

```
          "Subset\nof ln(500) Features at each Node", fontdict=fontdict_title)
plt.xlabel("Number of Trees", fontdict=fontdict_xlabel)
plt.ylabel("Misclassification Error", fontdict=fontdict_ylabel)

# plotting
ln500_train_misclassification_errors = [train_error[0] for train_error in
                                       ␣
 ↪misclassification_errors["ln500"]["train"]]
ln500_test_misclassification_errors = [test_error[0] for test_error in␣
 ↪misclassification_errors["ln500"]["test"]]
plt.plot(tree_num, ln500_train_misclassification_errors,
         color="#CDB1AD",
         linestyle="-",
         label="On Training Set")
plt.plot(tree_num, ln500_test_misclassification_errors,
         color="#5D6E9E",
         linestyle="--",
         label="On Test Set")
plt.legend(fontsize=14);
```



Training and Test Misclassification Error Table

Create tables for training and test misclassification errors with their respective number of trees for each random forest

```
[15]: # Find the training and test misclassification errors for each random forest in␣
       ↪order of increasing number of trees
      ln500_train_errors = [error[0] for error in␣
       ↪misclassification_errors["ln500"]["train"]]
      ln500_test_errors = [error[0] for error in␣
       ↪misclassification_errors["ln500"]["test"]]
      ln500_errors = {
          columns_labels[1]: ln500_train_errors,
          columns_labels[2]: ln500_test_errors
      }

      # Create dataframe to output table
      ln500_tabledf = pd.DataFrame(ln500_errors, index=rows_labels)
      ln500_tabledf.index.name = columns_labels[0]
      ln500_tabledf
```

```
[15]:                  Train Misclassification Error  Test Misclassification Error
      Number of Trees
      3                                        0.091                      0.461667
      10                                       0.015                      0.448333
      30                                       0.000                      0.425000
      100                                      0.000                      0.393333
      300                                      0.000                      0.360000
```

Problem 3: Random Forests with Split Attribute Chosen from all 500 Features at each Node

Create random forests with tree numbers=(3,10,30,100,300) with every split attribute chosen from all 500 features at each node.

```
[16]: all500_rfs_feature_num = 500
      all500_rfs = [RandomForestClassifier(n_estimators=num,␣
       ↪max_features=all500_rfs_feature_num) for num in tree_num]
```

Train and test random forests generated in previous step and store the misclassification errors for training and test sets of each random forest with its corresponding number of trees.

```
[17]: for rf in all500_rfs:
          rf = rf.fit(madelon_train_data, madelon_train_labels)
```

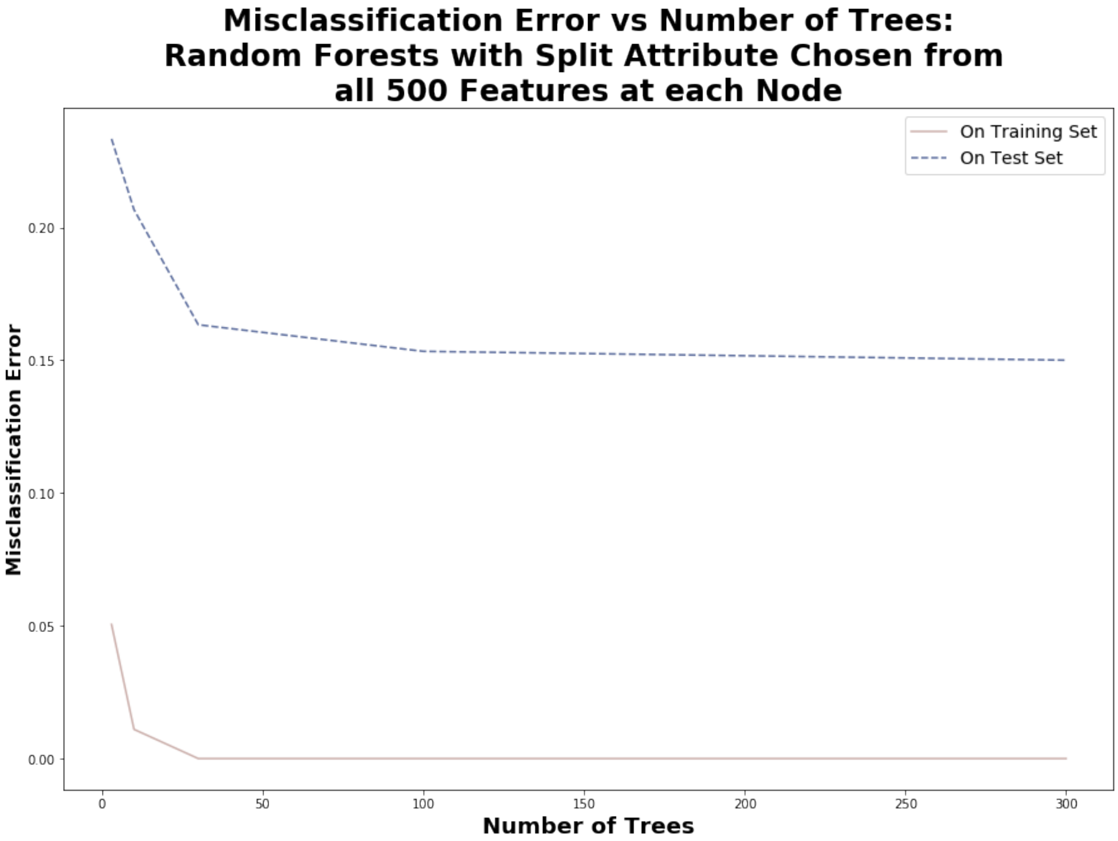
```
    misclassification_errors["all500"]["train"].append([1 - rf.
 ↪score(madelon_train_data,
                                                                                 ␣
 ↪madelon_train_labels),
                                                                          rf.n_estimators])
    misclassification_errors["all500"]["test"].append([1 - rf.
 ↪score(madelon_test_data,
                                                                                ␣
 ↪madelon_test_labels),
                                                                         rf.n_estimators])
```

Plot training and test errors vs number of trees in random forests graph

[18]:
```
# size of graph
plt.rcParams['figure.figsize'] = [15, 10]  # size=15x10 inches

# labels
plt.title("Misclassification Error vs Number of Trees:\nRandom Forests with␣
 ↪Split Attribute Chosen from \n"
          "all 500 Features at each Node", fontdict=fontdict_title)
plt.xlabel("Number of Trees", fontdict=fontdict_xlabel)
plt.ylabel("Misclassification Error", fontdict=fontdict_ylabel)

# plotting
all500_train_misclassification_errors = [train_error[0] for train_error in
                                         ␣
 ↪misclassification_errors["all500"]["train"]]
all500_test_misclassification_errors = [test_error[0] for test_error in␣
 ↪misclassification_errors["all500"]["test"]]
plt.plot(tree_num, all500_train_misclassification_errors,
         color="#CDB1AD",
         linestyle="-",
         label="On Training Set")
plt.plot(tree_num, all500_test_misclassification_errors,
         color="#5D6E9E",
         linestyle="--",
         label="On Test Set")
plt.legend(fontsize=14);
```



Training and Test Misclassification Error Table

Create table for training and test misclassification errors with their respective number of trees for each random forest

[19]:

```
all500_train_errors = [error[0] for error in␣
 ↪misclassification_errors["all500"]["train"]]
all500_test_errors = [error[0] for error in␣
 ↪misclassification_errors["all500"]["test"]]
all500_errors = {
    columns_labels[1]: all500_train_errors,
    columns_labels[2]: all500_test_errors
}

# Create dataframe to output table
all500_tabledf = pd.DataFrame(all500_errors, index=rows_labels)
all500_tabledf.index.name = columns_labels[0]
all500_tabledf
```

[19]:

```
                 Train Misclassification Error  Test Misclassification Error
Number of Trees
3                                       0.0505                      0.233333
10                                      0.0110                      0.206667
30                                      0.0000                      0.163333
100                                     0.0000                      0.153333
300                                     0.0000                      0.150000
```