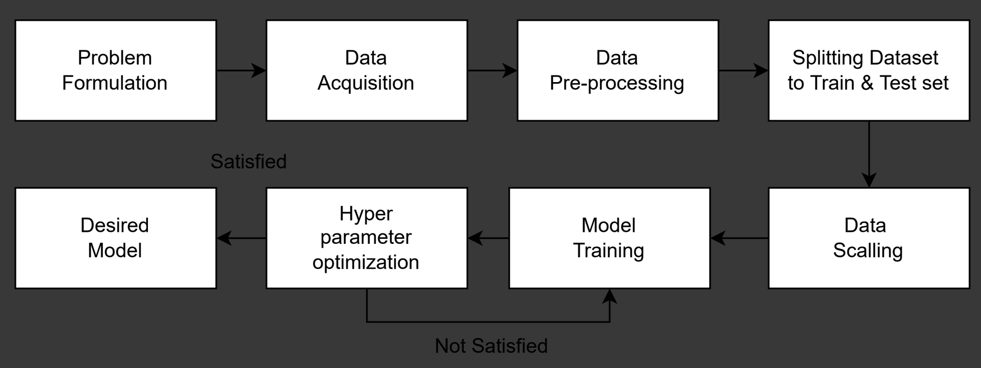
CSE445 Machine Learning

Online Class Preference Prediction Using Machine Learning Approach

We are proposing a machine-learning model to predict preference of online class among Bangladeshi students. Our goal is to create an efficient machine-learning model to predict if a student prefers online class or not by using some common available features such as age, gender, level of study, preferred device, results, knowledge and class performance development during online class, internet availability, location of joining, difficulties faced, etc.

Methodology

The major objective of this work is to develop a machine-learning model that will aid to predict if a student likes online classes or not. The approach adopted in this work is outlined in Fig. 1



The model to be developed to predict the response for the training data will be developed using the decision tree technique. It is one of the most popular and straightforward machine learning algorithms for categorization problems. Since supervised learning approach is to be used in this work and the model has to predict a target class that is categorized into "Yes" and "No", the decision tree algorithm will be useful to create a training model that can predict the target class by learning some decision rules inferred from training data.

Importing Libraries

```
# importing libraries
import pandas as pd # data processing
import numpy as np # linear algebra
import matplotlib.pyplot as plt # visualization
%matplotlib inline

import seaborn as sns
# increases the size of sns plots
sns.set(rc={'figure.figsize':(8,6)})

from sklearn.model_selection import train_test_split, KFold, cross_val_score
from sklearn import tree
from sklearn.tree import DecisionTreeClassifier, export_graphviz
from sklearn.metrics import accuracy_score, confusion_matrix, r2_score, roc_curve, auc, classification_report
import warnings
warnings.filterwarnings('ignore')
```

Data Acquisition

Dataset is collected from Kaggle. The dataset is created based on an online survey on Bangladeshi students and it contains 17 features such as age, level of study, devices used, result, knowledge and class performance in online class, have interest, internet availability, institute type, happy with online class etc.

```
# mount google drive
from google.colab import drive
drive.mount('/content/drive')
```

```
# raw data in panda dataframe
df = pd.read_csv('/content/drive/MyDrive/CSE 445 Project/Online Survey Data on Education Bd.csv')
print('Data Frame Shape: \n{}'.format(df.shape))
df.columns = df.columns.str.replace('Used smartphone/computer/laptop previously before online class?',
'Used Electronic Devices?')
# shows five instances of the dataframe
print('First few instances of the dataset: ')
df.head()
```

```
Data Frame Shape:
(8783, 17)
First few instances of the dataset:
```

	Level of study?	Age?	Used Electronic Devices??	Result increased after online education (comparatively)?	Knowledge increased after online education (comparatively)?	Happy with online education?	Education Institute Area?	Have Internet availability?	Broadband / Mobile Internet?	Total hours of study before online education?	Total hours of study after online education?	Class performance increased in online education?	Institute Type	Current location (During Study) ?	Gender	Faced any issue with online class?	Preferred device for an online course
0	Upto HSC	20.0	Yes	No	Yes	No	Urban	No	Broadband	4	3	No	Public	Rural	Male	Yes	Mobile
1	Hons or Grater	25.0	No	No	No	No	Urban	No	Mobile Internet	4	4	No	Public	Rural	Male	Yes	Mobile
2	Hons or Grater	25.0	Yes	Yes	Yes	Yes	Rural	No	Mobile Internet	5	2	Yes	Public	Rural	Female	Yes	Computer
3	Upto HSC	21.0	Yes	Yes	No	Yes	Urban	Yes	Mobile Internet	5	3	No	Private	Urban	Male	Yes	Mobile
4	Hons or Grater	22.0	Yes	No	No	No	Rural	No	Mobile Internet	4	2	Yes	Public	Urban	Male	No	Mobile

```
# columns of the dataset
df.columns
```

```
Index(['Level of study?', 'Age?',
       'Used smartphone/computer/laptop previously before online class?',
       'Result increased after online education  (comparatively)?',
       'Knowledge increased after online education (comparatively)?',
       'Happy with online education?', 'Education Institute Area?',
       'Have Internet availability?', 'Broadband / Mobile Internet?',
       'Total hours of study before online education?',
       'Total hours of study after online education?',
       'Class performance increased in online education?', 'Institute Type',
       'Current location (During Study) ?', 'Gender',
       'Faced any issue with online class?',
       'Preferred device for an online course'],
      dtype='object')
```

```
# investigating all the elements whithin each Feature
for column in df:
  unique_vals = df[column].unique()
  nr_values = len(unique_vals)

  if nr_values < 10:
    print('The number of values for feature {} :{} -- {}'.format(column, nr_values,unique_vals))
  else:
    print('The number of values for feature {} :{}'.format(column, nr_values))
```

```
The number of values for feature Level of study? :2 -- ['Upto HSC' 'Hons or Grater']
The number of values for feature Age? :12
The number of values for feature Used smartphone/computer/laptop previously before online class? :3 -- ['Yes' 'No' nan]
The number of values for feature Result increased after online education  (comparatively)? :3 -- ['No' 'Yes' nan]
The number of values for feature Knowledge increased after online education (comparatively)? :2 -- ['Yes' 'No']
The number of values for feature Happy with online education? :2 -- ['No' 'Yes']
The number of values for feature Education Institute Area? :3 -- ['Urban' 'Rural' nan]
The number of values for feature Have Internet availability? :2 -- ['No' 'Yes']
The number of values for feature Broadband / Mobile Internet? :2 -- ['Broadband' 'Mobile Internet']
The number of values for feature Total hours of study before online education? :4 -- [4 5 3 6]
The number of values for feature Total hours of study after online education? :3 -- [3 4 2]
The number of values for feature Class performance increased in online education? :2 -- ['No' 'Yes']
The number of values for feature Institute Type :3 -- ['Public' 'Private' nan]
The number of values for feature Current location (During Study) ? :3 -- ['Rural' 'Urban' nan]
The number of values for feature Gender :3 -- ['Male' 'Female' nan]
The number of values for feature Faced any issue with online class? :3 -- ['Yes' 'No' nan]
The number of values for feature Preferred device for an online course :2 -- ['Mobile' 'Computer']
```

```
# checking for the null values
df.isnull().sum()
```

```
Level of study?                                                      0
Age?                                                               445
Used smartphone/computer/laptop previously before online class?    188
Result increased after online education  (comparatively)?          323
Knowledge increased after online education (comparatively)?          0
Happy with online education?                                         0
Education Institute Area?                                          529
```

```
Have Internet availability?                                    0
Broadband / Mobile Internet?                                   0
Total hours of study before online education?                  0
Total hours of study after online education?                   0
Class performance increased in online education?               0
Institute Type                                               726
Current location (During Study) ?                            726
Gender                                                       676
Faced any issue with online class?                           701
Preferred device for an online course                          0
dtype: int64
```

Data Preprocessing

For some entries in the collection, multiple columns have null values. The null values are removed. Correlation Matrix is also plotted to see the relationship among attributes.

Removing Null Values

Removing null values to make a clean dataset

```
# removing rows containing null values and creating a demo dataset
new_df = df.dropna()
print('New Data Frame Shape: ', new_df.shape)
```

```
New Data Frame Shape:  (5715, 17)
```

```
# checking null values in new data frame
new_df.isnull().sum()
```

```
Level of study?                                                  0
Age?                                                             0
Used smartphone/computer/laptop previously before online class?  0
Result increased after online education  (comparatively)?        0
Knowledge increased after online education (comparatively)?      0
Happy with online education?                                     0
Education Institute Area?                                        0
Have Internet availability?                                      0
Broadband / Mobile Internet?                                     0
Total hours of study before online education?                    0
Total hours of study after online education?                     0
Class performance increased in online education?                 0
Institute Type                                                   0
Current location (During Study) ?                                0
Gender                                                           0
Faced any issue with online class?                               0
Preferred device for an online course                            0
dtype: int64
```

```
# exporting new dataframe as csv
new_df.to_csv('/content/drive/MyDrive/CSE 445 Project/Online Education Filtered.csv')
```

```
# attributes of new dataframe
new_df.columns
```

```
Index(['Level of study?', 'Age?',
       'Used smartphone/computer/laptop previously before online class?',
       'Result increased after online education  (comparatively)?',
       'Knowledge increased after online education (comparatively)?',
       'Happy with online education?', 'Education Institute Area?',
       'Have Internet availability?', 'Broadband / Mobile Internet?',
       'Total hours of study before online education?',
       'Total hours of study after online education?',
       'Class performance increased in online education?', 'Institute Type',
       'Current location (During Study) ?', 'Gender',
       'Faced any issue with online class?',
       'Preferred device for an online course'],
      dtype='object')
```

Dataset Encoding

Encoding the dataset to make it suitable for machine learning algorithms

```
# data types
new_df.dtypes
```

```
Level of study?                                                   object
Age?                                                             float64
Used smartphone/computer/laptop previously before online class?   object
Result increased after online education  (comparatively)?         object
Knowledge increased after online education (comparatively)?       object
Happy with online education?                                      object
Education Institute Area?                                         object
Have Internet availability?                                       object
Broadband / Mobile Internet?                                      object
Total hours of study before online education?                      int64
Total hours of study after online education?                       int64
Class performance increased in online education?                  object
Institute Type                                                    object
Current location (During Study) ?                                 object
Gender                                                            object
Faced any issue with online class?                                object
Preferred device for an online course                             object
dtype: object
```

```
# Find out all the features with type object
objectList = new_df.select_dtypes(include = "object").columns
print (objectList)
```

```
Index(['Level of study?',
       'Used smartphone/computer/laptop previously before online class?',
       'Result increased after online education  (comparatively)?',
       'Knowledge increased after online education (comparatively)?',
       'Happy with online education?', 'Education Institute Area?',
       'Have Internet availability?', 'Broadband / Mobile Internet?',
       'Class performance increased in online education?', 'Institute Type',
       'Current location (During Study) ?', 'Gender',
       'Faced any issue with online class?',
       'Preferred device for an online course'],
      dtype='object')
```

```
#Label Encoding for object to numeric conversion
from sklearn.preprocessing import LabelEncoder
encoder = LabelEncoder()

for obj in objectList:
    new_df[obj] = encoder.fit_transform(new_df[obj].astype(str))

print (new_df.info())
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 5715 entries, 0 to 8781
Data columns (total 17 columns):
 #   Column                                                           Non-Null Count  Dtype
---  ------                                                           --------------  -----
 0   Level of study?                                                  5715 non-null   int64
 1   Age?                                                             5715 non-null   float64
 2   Used smartphone/computer/laptop previously before online class?  5715 non-null   int64
 3   Result increased after online education  (comparatively)?        5715 non-null   int64
 4   Knowledge increased after online education (comparatively)?      5715 non-null   int64
 5   Happy with online education?                                     5715 non-null   int64
 6   Education Institute Area?                                        5715 non-null   int64
 7   Have Internet availability?                                      5715 non-null   int64
 8   Broadband / Mobile Internet?                                     5715 non-null   int64
 9   Total hours of study before online education?                    5715 non-null   int64
 10  Total hours of study after online education?                     5715 non-null   int64
 11  Class performance increased in online education?                 5715 non-null   int64
 12  Institute Type                                                   5715 non-null   int64
 13  Current location (During Study) ?                                5715 non-null   int64
 14  Gender                                                           5715 non-null   int64
 15  Faced any issue with online class?                               5715 non-null   int64
 16  Preferred device for an online course                            5715 non-null   int64
dtypes: float64(1), int64(16)
memory usage: 803.7 KB
None
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:6: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
```

```
# exporting new dataframe as csv
new_df.to_csv('/content/drive/MyDrive/CSE 445 Project/Online Education Cleanded Dataset.csv')
```

Splitting Dataset

Splitting the dataset in a 80:20 ratio. 80% for training & 20% for testing

```
# separating attributes and target
attribute = new_df.drop(columns = ['Happy with online education?'])
target = new_df['Happy with online education?']
```

```
print('Attribute Shape: ', attribute.shape)
print('Target Shape: ', target.shape)
```

```
Attribute Shape:  (5715, 16)
Target Shape:  (5715,)
```

```
target.value_counts()
```

```
0    3677
1    2038
Name: Happy with online education?, dtype: int64
```

```
# first few instances of attribute
attribute.columns = attribute.columns.str.replace('Used smartphone/computer/laptop previously before online class?',
                                                  'Used Electronic Devices?')
attribute.head()
```

	Level of study?	Age?	Used Electronic Devices??	Result increased after online education (comparatively)?	Knowledge increased after online education (comparatively)?	Education Institute Area?	Have Internet availability?	Broadband / Mobile Internet?	Total hours of study before online education?	Total hours of study after online education?	Class performance increased in online education?	Institute Type	Current location (During Study) ?	Gender	Faced any issue with online class?	Preferred device for an online course
0	1	20.0	1	0	1	1	0	0	4	3	0	1	0	1	1	1
1	0	25.0	0	0	0	1	0	1	4	4	0	1	0	1	1	1
2	0	25.0	1	1	1	0	0	1	5	2	1	1	0	0	1	0
3	1	21.0	1	1	0	1	1	1	5	3	0	0	1	1	1	1
4	0	22.0	1	0	0	0	0	1	4	2	1	1	1	1	0	1

```
# first few instances of target
target.head()
```

```
0    0
1    0
2    1
3    1
4    0
Name: Happy with online education?, dtype: int64
```

```
# train test splitting
X_train, X_test, y_train, y_test = train_test_split(attribute, target, train_size = 0.7, test_size = 0.3, random_state = 0)
```

```
print('For training: ')
print('Attribute Shape: ', X_train.shape)
print('Target Shape: ', y_train.shape)

print('\nFor testing: ')
print('Attribute Shape: ', X_test.shape)
print('Target Shape: ', y_test.shape)
```

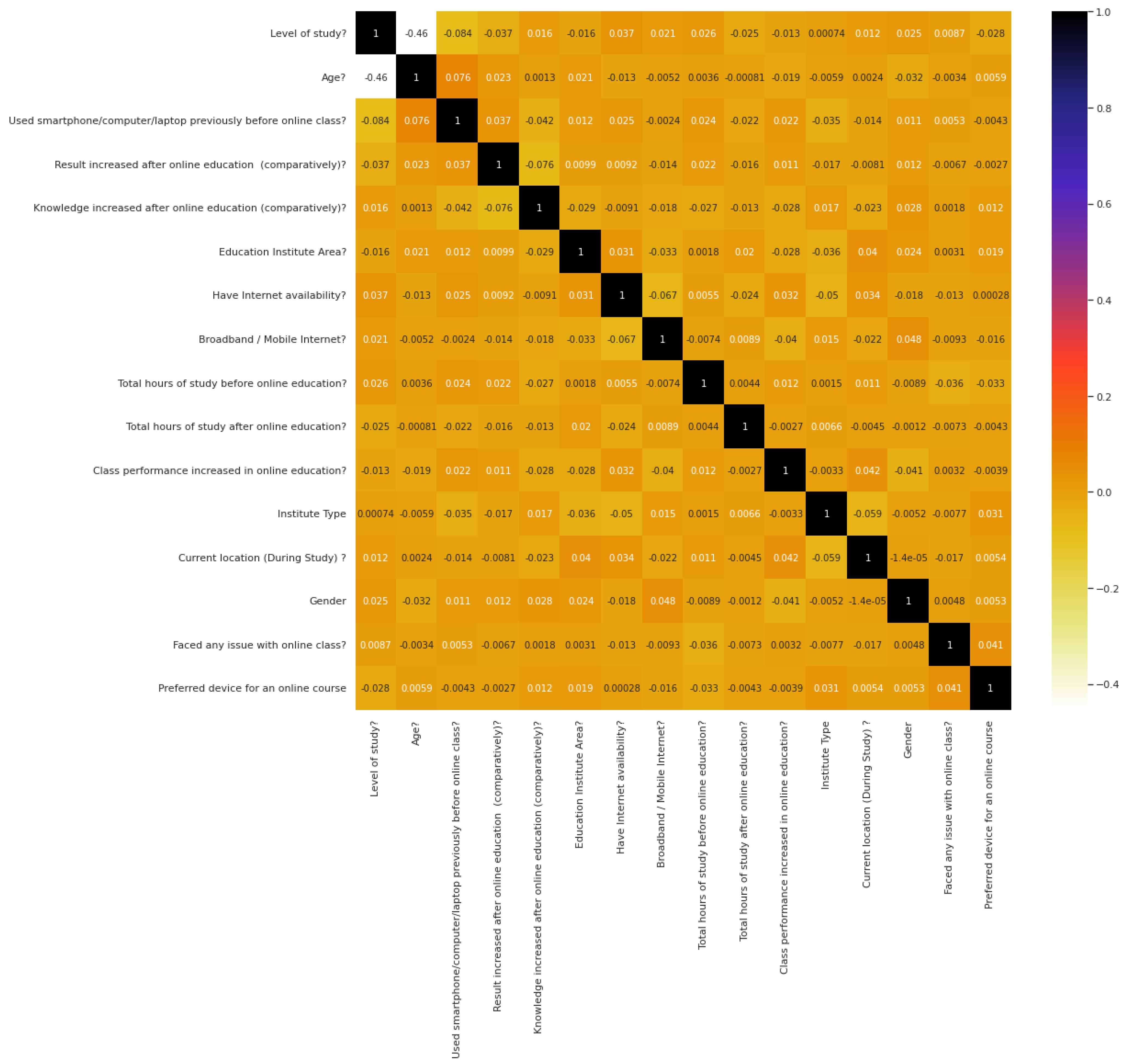
```
For training:
Attribute Shape:  (4000, 16)
Target Shape:  (4000,)

For testing:
Attribute Shape:  (1715, 16)
Target Shape:  (1715,)
```

Correlation of Features

Finding the correlation among the features to see how they are connected. Main purpose is to find duplicate features

```
# using pearson correlation
plt.figure(figsize=(16, 14))
correlation = X_train.corr()
sns.heatmap(correlation, annot=True, cmap=plt.cm.CMRmap_r)
plt.show()
```



Decision Tree

Initially building a decision tree model with a max depth 5, later we will build a random forest classification model with hyper parameter tuing

```
# Decision Tree Model
dtree = DecisionTreeClassifier(max_depth = 5, random_state = 1)
dtree.fit(X_train, y_train)
```

```
DecisionTreeClassifier(max_depth=5, random_state=1)
```

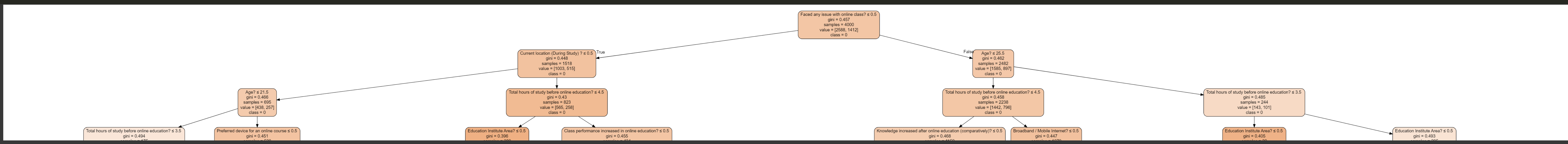
```
# Graph available in:  https://dreampuf.github.io/GraphvizOnline
import graphviz

dot_data = tree.export_graphviz(dtree, out_file='/content/drive/MyDrive/CSE 445 Project/Decision Tree.dot',
feature_names = new_df.drop('Happy with online education?', axis=1).columns,
class_names = new_df['Happy with online education?'].unique().astype(str),
filled=True, rounded=True,
special_characters=True)

graph = graphviz.Source(dot_data)
```

```
# Decision Tree generated from Graphviz
```

```
from IPython.display import Image
Image(filename='/content/drive/MyDrive/CSE 445 Project/Decision Tree.png')
```



Feature Importance

```
# Finding importance of each feature

for i, column in enumerate(new_df.drop('Happy with online education?', axis=1)):
  print('Importance of feature {}:, {:.3f}'.format(column, dtree.feature_importances_[i]))
  feature_imp = pd.DataFrame({'Variable': [column], 'Feature Importance Score': [dtree.feature_importances_[i]]})

  try:
    final_feature_imp = pd.concat([final_feature_imp, feature_imp], ignore_index = True)
  except:
    final_feature_imp = feature_imp

# Ordering the data
final_feature_imp = final_feature_imp.sort_values('Feature Importance Score', ascending = False).reset_index()
final_feature_imp
```

```
Importance of feature Level of study?:, 0.000
Importance of feature Age?:, 0.108
Importance of feature Used smartphone/computer/laptop previously before online class?:, 0.000
Importance of feature Result increased after online education  (comparatively)?:, 0.142
Importance of feature Knowledge increased after online education (comparatively)?:, 0.104
Importance of feature Education Institute Area?:, 0.151
Importance of feature Have Internet availability?:, 0.043
Importance of feature Broadband / Mobile Internet?:, 0.037
Importance of feature Total hours of study before online education?:, 0.142
Importance of feature Total hours of study after online education?:, 0.013
Importance of feature Class performance increased in online education?:, 0.008
Importance of feature Institute Type:, 0.015
Importance of feature Current location (During Study) ?:, 0.114
Importance of feature Gender:, 0.000
Importance of feature Faced any issue with online class?:, 0.018
Importance of feature Preferred device for an online course:, 0.103
```

	index	Variable	Feature Importance Score
0	5	Education Institute Area?	0.151486
1	8	Total hours of study before online education?	0.142285
2	3	Result increased after online education (comp...	0.142143
3	12	Current location (During Study) ?	0.114371
4	1	Age?	0.107682
5	4	Knowledge increased after online education (co...	0.104196
6	15	Preferred device for an online course	0.102895
7	6	Have Internet availability?	0.043115
8	7	Broadband / Mobile Internet?	0.037344
9	14	Faced any issue with online class?	0.018224
10	11	Institute Type	0.015106
11	9	Total hours of study after online education?	0.013115
12	10	Class performance increased in online education?	0.008038
13	0	Level of study?	0.000000
14	2	Used smartphone/computer/laptop previously bef...	0.000000
15	13	Gender	0.000000

Result From Decision Tree

```
# Training Accuracy Of Decision Tree
print("Training Accuracy is: ", dtree.score(X_train, y_train))

# Test Accuracy Of Decision Tree
print("Testing Accuracy is: ", dtree.score(X_test, y_test))
```

```
Training Accuracy is:  0.65125
Testing Accuracy is:  0.6297376093294461
```

```
# after applying k fold cross validation
kfold_validation = KFold(n_splits = 10)
results = cross_val_score(dtree, attribute, target, cv = kfold_validation)
print(results)
print ('\nResults = ', np.mean(results), '+/-', np.std(results))
```

```
[0.6520979  0.62587413 0.63286713 0.63461538 0.64160839 0.6357268
 0.62521891 0.63397548 0.67250438 0.6234676 ]

Results =  0.6377956106940345 +/- 0.014080679908422033
```

```
# Confusion Matrix
# Confusion Matrix function
def plot_confusion_matrix(cm, classes=None, title='Confusion matrix'):
  if classes is not None:
    sns.heatmap(cm, xticklabels=classes, yticklabels=classes, vmin=0., vmax=1., annot=True, annot_kws={'size':30})
  else:
    sns.heatmap(cm, vmin=0., vmax=1.)

  plt.title(title)
  plt.ylabel('True label')
  plt.xlabel('Predicted label')
```

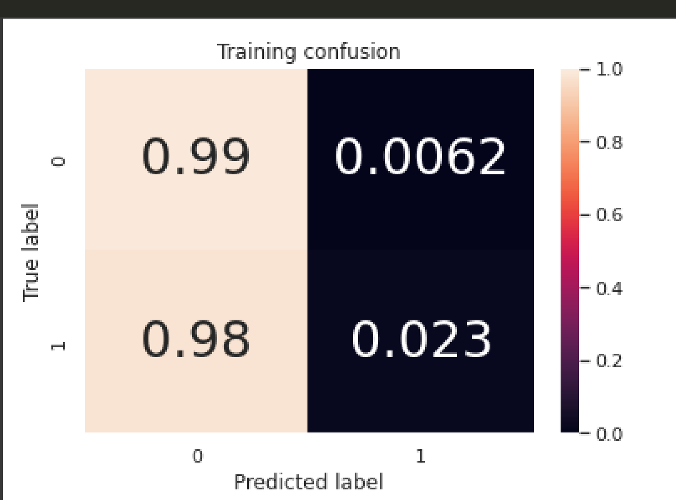
```
# prediction
y_pred = dtree.predict(X_train)

# Plotting Confusion Matrix for Training
cmatrix = confusion_matrix(y_train, y_pred)
```

```
cmatrix
```

```
array([[2572,   16],
       [1379,   33]])
```

```
cmatrix_norm = cmatrix/cmatrix.sum(axis=1)[:, np.newaxis]
plt.figure()
plot_confusion_matrix(cmatrix_norm, classes=dtree.classes_, title='Training confusion')
```




```
# Calculating False Positives (FP), False Negatives (FN), True Positives(TP), True Negatices (TN)
FP = cmatrix.sum(axis=0) - np.diag(cmatrix)
FN = cmatrix.sum(axis=1) - np.diag(cmatrix)
TP = np.diag(cmatrix)
TN = cmatrix.sum() - (FP + FN + TP)

# precision or positive predictive value
precision = TP / (TP + FP)
print('Precision per class: ', precision)

# sensitivity, recall or true predictive rate
recall = TP / (TP + FN)
print('Recall per class: ', recall)

# false positive rate
fpr = FP / (FP + TN)
print('False positive rate per class: ', fpr)
```

```
# false negative rate
fnr = FN / (TP + FN)
print('False negative rate per class: ', fnr)

# classification error
c_error = (FP + FN) / (TP + FP + FN + TN)
print('The classification error of each class: ' ,c_error)

# overall accuracy
accuracy = (TP + TN) / (TP + FP + FN + TN)
print('The accuracy of each class: ' ,accuracy)

# Averages
print('\nAverage Recall : ' ,recall.sum()/2)
print('Average Precision : ' ,precision.sum()/2)
print('Average Miss Rate : ' ,fnr.sum()/2)
print('Average Classification error : ' ,c_error.sum()/2)
print('Average accuracy : ' ,accuracy.sum()/2)
```

```
Precision per class:  [0.65097444 0.67346939]
Recall per class:  [0.99381762 0.0233711 ]
False positive rate per class:  [0.9766289  0.00618238]
False negative rate per class:  [0.00618238 0.9766289 ]
The classification error of each class:  [0.34875 0.34875]
The accuracy of each class:  [0.65125 0.65125]

Average Recall :  0.5085943622997404
Average Precision :  0.662221912303266
Average Miss Rate :  0.49140563770025963
Average Classification error :  0.34875
Average accuracy :  0.65125
```

Tunning Decision Tree

Tunning the decision tree and applying cross validation technique to see if we can find a better result

```
from random import randint
from sklearn.model_selection import RandomizedSearchCV

parameters = {
    'max_depth' : [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15],
    'criterion': ['gini', 'entropy']
}

tunned_tree = DecisionTreeClassifier()
# applying cross validation technique
tunned_tree_cv = RandomizedSearchCV(tunned_tree, parameters, cv=10)
tunned_tree_cv.fit(X_train, y_train)
```

```
RandomizedSearchCV(cv=10, estimator=DecisionTreeClassifier(),
                   param_distributions={'criterion': ['gini', 'entropy'],
                                        'max_depth': [1, 2, 3, 4, 5, 6, 7, 8, 9,
                                                      10, 12, 14, 15]})
```

```
print('Tunned Decision Tree Parameters {}'.format(tunned_tree_cv.best_params_))
print('Best score: {}'.format(tunned_tree_cv.best_score_))
```

```
Tunned Decision Tree Parameters {'max_depth': 2, 'criterion': 'entropy'}
Best score: 0.6469999999999999
```

So far the model accuracy is not good. Lets try random forest algortihm to see if we can find a better model with better accuracy

We will also perform some hyper parameter tunning to get a better model

Random Forest

A random forest is a meta estimator that fits a number of decision tree classifiers on various sub-samples of the dataset and uses averaging to improve the predictive accuracy and control over-fitting. Takes the average of many Decision Trees via bagging.

n_estmators : number of trees in a forest

max_depth : the maximum depth of the tree

max_features : maximum number of features to consider when looking for the best split

min_samples_split : minimum number of samples required to split an internal node

min_samples_leaf : minimum number of samples required to be at a leaf node

```
from sklearn.ensemble import RandomForestClassifier
forest = RandomForestClassifier(n_estimators=300, criterion='entropy')
forest.fit(X_train, y_train)
prediction_test = forest.predict(X=X_test)

# Training Accuracy Of Random Forest
print("Training Accuracy : ", forest.score(X_train, y_train))

# Test Accuracy Of Random Forest
print("Testing Accuracy : ", forest.score(X_test, y_test))
```

```
Training Accuracy :  0.98975
Testing Accuracy :  0.59533527696793
```

```
print(confusion_matrix(y_test,prediction_test))
print(accuracy_score(y_test,prediction_test))
print(classification_report(y_test,prediction_test))
```

```
[[1037   52]
 [ 592   34]]
0.6244897959183674
              precision    recall  f1-score   support

           0       0.64      0.95      0.76      1089
           1       0.40      0.05      0.10       626

    accuracy                           0.62      1715
   macro avg       0.52      0.50      0.43      1715
weighted avg       0.55      0.62      0.52      1715
```

The model overfitted since we did not define any max_depth

Randomized Search CV

Random Search. Define a search space as a bounded domain of hyperparameter values and randomly sample points in that domain

```
# Number of trees in random forest
n_estimators = [int(x) for x in np.linspace(start = 20, stop = 300, num = 10)]
# Number of features to consider at every split
max_features = ['auto', 'sqrt','log2']
# Maximum number of levels in tree
max_depth = [int(x) for x in np.linspace(5, 100,5)]
# Minimum number of samples required to split a node
min_samples_split = [2, 3, 5, 7, 9, 10, 11, 14]
# Minimum number of samples required at each leaf node
min_samples_leaf = [1, 2, 4, 6, 7, 8]
# Create the random grid
random_grid = {'n_estimators': n_estimators,
  'max_features': max_features,
  'max_depth': max_depth,
  'min_samples_split': min_samples_split,
  'min_samples_leaf': min_samples_leaf,
  'criterion':['entropy','gini']
}
print(random_grid)
```

```
rand_forest = RandomForestClassifier()
rand_forest_randomcv = RandomizedSearchCV(estimator=rand_forest,param_distributions=random_grid,
                                          n_iter=100,cv=3,verbose=2, random_state=100,n_jobs=-1)
# fit the randomized model
rand_forest_randomcv.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 100 candidates, totalling 300 fits
RandomizedSearchCV(cv=3, estimator=RandomForestClassifier(), n_iter=100,
                   n_jobs=-1,
                   param_distributions={'criterion': ['entropy', 'gini'],
                                        'max_depth': [5, 28, 52, 76, 100],
                                        'max_features': ['auto', 'sqrt',
                                                         'log2'],
                                        'min_samples_leaf': [1, 2, 4, 6, 7, 8],
                                        'min_samples_split': [2, 3, 5, 7, 9, 10,
                                                              11, 14],
                                        'n_estimators': [20, 51, 82, 113, 144,
                                                         175, 206, 237, 268,
                                                         300]},
                   random_state=100, verbose=2)
```

```
# best parameters
rand_forest_randomcv.best_params_
```

```
{'criterion': 'entropy',
 'max_depth': 5,
 'max_features': 'log2',
 'min_samples_leaf': 7,
 'min_samples_split': 11,
 'n_estimators': 20}
```

```
# best estimator
rand_forest_randomcv.best_estimator_
```

```
RandomForestClassifier(criterion='entropy', max_depth=5, max_features='log2',
                       min_samples_leaf=7, min_samples_split=11,
                       n_estimators=20)
```

```
best_random_grid = rand_forest_randomcv.best_estimator_
```

```
y_pred=best_random_grid.predict(X_test)
print(confusion_matrix(y_test,y_pred))
print("Accuracy Score {}".format(accuracy_score(y_test,y_pred)))
print("Classification report: {}".format(classification_report(y_test,y_pred)))
```

```
[[1089    0]
 [ 626    0]]
Accuracy Score 0.6349854227405248
Classification report:               precision    recall  f1-score   support

           0       0.63      1.00      0.78      1089
           1       0.00      0.00      0.00       626

    accuracy                           0.63      1715
   macro avg       0.32      0.50      0.39      1715
weighted avg       0.40      0.63      0.49      1715
```

Hyperparameter Tunning

```
from itertools import product

n_estimators = [1, 2, 4, 8, 16, 32, 64, 100, 200, 300]
max_features = ['auto', 'sqrt', 'log2']
max_depths = [None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]

train_results = []
test_results = []

# to iterate through all possible combinations
for feature, depth in product(max_features, max_depths):
  for estimator in n_estimators:
    tunned_forest = RandomForestClassifier(n_estimators=estimator,
                                    criterion='entropy',
                                    max_features=feature,
                                    max_depth=depth,
                                    n_jobs=1,
                                    random_state=30)

    tunned_forest.fit(X_train, y_train)
    prediction_train = tunned_forest.predict(X=X_train)
    false_positive_rate, true_positive_rate, thresholds = roc_curve(y_train, prediction_train)
    roc_auc = auc(false_positive_rate, true_positive_rate)
    train_results.append(roc_auc)

    prediction_test = tunned_forest.predict(X=X_test)
    false_positive_rate, true_positive_rate, thresholds = roc_curve(y_test, prediction_test)
    roc_auc = auc(false_positive_rate, true_positive_rate)
    test_results.append(roc_auc)


    # Checking classification accuracy of each tree
    print('For n_estimators : ' ,estimator)
    print('Classification accuracy on Train set with max_features = {} and max_depth = {}: Accuracy: = {}'
        .format(feature, depth, accuracy_score(y_train, prediction_train)))

    print('Classification accuracy on test set with max_features = {} and max_depth = {}: Accuracy: = {}'
        .format(feature, depth, accuracy_score(y_test, prediction_test)))
    print()
    # Generating confusion matrix
    c_matrix = confusion_matrix(y_test, prediction_test)
    c_matrix_norm = c_matrix/c_matrix.sum(axis=1)[:, np.newaxis]

    #plt.figure()
    #plot_confusion_matrix(c_matrix_norm, classes=tunned_forest.classes_,
    #    title='Classification accuracy on test set with max_features = {} and max_depth = {}: Accuracy = {}'
    #                      .format(feature, depth, accuracy_score(y_test, prediction_test)))
```

```
For n_estimators :  1
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.83175
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5317784256559767

For n_estimators :  2
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.833
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5790087463556851

For n_estimators :  4
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.8965
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5865889212827988

For n_estimators :  8
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.95225
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5830903790087464

For n_estimators :  16
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.98
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5819241982507288

For n_estimators :  32
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.9885
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5906705539358601

For n_estimators :  64
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.98975
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5924198250728863

For n_estimators :  100
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.98975
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5935860058309038

For n_estimators :  200
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.98975
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.597667638483965

For n_estimators :  300
Classification accuracy on Train set with max_features = auto and max_depth = None: Accuracy: = 0.98975
Classification accuracy on test set with max_features = auto and max_depth = None: Accuracy: = 0.5930029154518951

For n_estimators :  1
Classification accuracy on Train set with max_features = auto and max_depth = 1: Accuracy: = 0.647
Classification accuracy on test set with max_features = auto and max_depth = 1: Accuracy: = 0.6349854227405248

For n_estimators :  2
Classification accuracy on Train set with max_features = auto and max_depth = 1: Accuracy: = 0.647
Classification accuracy on test set with max_features = auto and max_depth = 1: Accuracy: = 0.6349854227405248

For n_estimators :  4
Classification accuracy on Train set with max_features = auto and max_depth = 1: Accuracy: = 0.647
Classification accuracy on test set with max_features = auto and max_depth = 1: Accuracy: = 0.6349854227405248

For n_estimators :  8
Classification accuracy on Train set with max_features = auto and max_depth = 1: Accuracy: = 0.647
Classification accuracy on test set with max_features = auto and max_depth = 1: Accuracy: = 0.6349854227405248

For n_estimators :  16
Classification accuracy on Train set with max_features = auto and max_depth = 1: Accuracy: = 0.647
```