modelComparison

March 16, 2021

[1]:
```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import seaborn as sns; sns.set_style('white')  # plot formatting
import scipy
from IPython.display import display
```

1 Reading and Processing Data Sets

[2]:
```
HTRU2 = pd.read_csv('./Data/HTRU2/HTRU_2.csv', header=None)
```

[3]:
```
display(HTRU2)
HTRU2[8].value_counts()
```

```
                0          1         2         3           4          5  \
0      140.562500  55.683782 -0.234571 -0.699648    3.199833  19.110426
1      102.507812  58.882430  0.465318 -0.515088    1.677258  14.860146
2      103.015625  39.341649  0.323328  1.051164    3.121237  21.744669
3      136.750000  57.178449 -0.068415 -0.636238    3.642977  20.959280
4       88.726562  40.672225  0.600866  1.123492    1.178930  11.468720
...           ...        ...       ...       ...         ...        ...
17893  136.429688  59.847421 -0.187846 -0.738123    1.296823  12.166062
17894  122.554688  49.485605  0.127978  0.323061   16.409699  44.626893
17895  119.335938  59.935939  0.159363 -0.743025   21.430602  58.872000
17896  114.507812  53.902400  0.201161 -0.024789    1.946488  13.381731
17897   57.062500  85.797340  1.406391  0.089520  188.306020  64.712562

               6           7  8
0       7.975532   74.242225  0
1      10.576487  127.393580  0
2       7.735822   63.171909  0
3       6.896499   53.593661  0
4      14.269573  252.567306  0
...          ...         ... ..
17893  15.450260  285.931022  0
17894   2.945244    8.297092  0
17895   2.499517    4.595173  0
```

```
17896  10.007967  134.238910  0
17897  -1.597527    1.429475  0

[17898 rows x 9 columns]
```

```
[3]: 0    16259
     1     1639
     Name: 8, dtype: int64
```

```
[4]: # Drop date column as it has to relevance to the prediction task

     Occupancy1 = pd.read_csv('./Data/occupancy_data/datatest.txt', sep=",")
     Occupancy2 = pd.read_csv('./Data/occupancy_data/datatest2.txt', sep=",")
     Occupancy3 = pd.read_csv('./Data/occupancy_data/datatraining.txt', sep=",")
     OccupancyData = pd.concat([Occupancy1,Occupancy2,Occupancy3])
     OccupancyData = OccupancyData.drop(columns = ['date'])
```

```
[5]: display(OccupancyData)
     OccupancyData['Occupancy'].value_counts()
```

```
      Temperature  Humidity       Light         CO2  HumidityRatio  Occupancy
140       23.7000   26.2720  585.200000  749.200000       0.004764          1
141       23.7180   26.2900  578.400000  760.400000       0.004773          1
142       23.7300   26.2300  572.666667  769.666667       0.004765          1
143       23.7225   26.1250  493.750000  774.750000       0.004744          1
144       23.7540   26.2000  488.600000  779.000000       0.004767          1
...           ...       ...         ...         ...            ...        ...
8139      21.0500   36.0975  433.000000  787.250000       0.005579          1
8140      21.0500   35.9950  433.000000  789.500000       0.005563          1
8141      21.1000   36.0950  433.000000  798.500000       0.005596          1
8142      21.1000   36.2600  433.000000  820.333333       0.005621          1
8143      21.1000   36.2000  447.000000  821.000000       0.005612          1

[20560 rows x 6 columns]
```

```
[5]: 0    15810
     1     4750
     Name: Occupancy, dtype: int64
```

```
[6]: # convert string column to a binary column

     ElectricGridData = pd.read_csv('./Data/Data_for_UCI_named.csv')
     ElectricGridData['stability'] = (ElectricGridData['stabf'] == 'stable').
      ↪astype(int)
     ElectricGridData = ElectricGridData.drop(columns = ['stab', 'stabf'])
```

[7]:
```
display(ElectricGridData)
ElectricGridData['stability'].value_counts()
```

```
          tau1      tau2      tau3      tau4        p1        p2        p3  \
0     2.959060  3.079885  8.381025  9.780754  3.763085 -0.782604 -1.257395
1     9.304097  4.902524  3.047541  1.369357  5.067812 -1.940058 -1.872742
2     8.971707  8.848428  3.046479  1.214518  3.405158 -1.207456 -1.277210
3     0.716415  7.669600  4.486641  2.340563  3.963791 -1.027473 -1.938944
4     3.134112  7.608772  4.943759  9.857573  3.525811 -1.125531 -1.845975
...        ...       ...       ...       ...       ...       ...       ...
9995  2.930406  9.487627  2.376523  6.187797  3.343416 -0.658054 -1.449106
9996  3.392299  1.274827  2.954947  6.894759  4.349512 -1.663661 -0.952437
9997  2.364034  2.842030  8.776391  1.008906  4.299976 -1.380719 -0.943884
9998  9.631511  3.994398  2.757071  7.821347  2.514755 -0.966330 -0.649915
9999  6.530527  6.781790  4.349695  8.673138  3.492807 -1.390285 -1.532193

            p4        g1        g2        g3        g4  stability
0    -1.723086  0.650456  0.859578  0.887445  0.958034          0
1    -1.255012  0.413441  0.862414  0.562139  0.781760          1
2    -0.920492  0.163041  0.766689  0.839444  0.109853          0
3    -0.997374  0.446209  0.976744  0.929381  0.362718          0
4    -0.554305  0.797110  0.455450  0.656947  0.820923          0
...        ...       ...       ...       ...       ...        ...
9995 -1.236256  0.601709  0.779642  0.813512  0.608385          0
9996 -1.733414  0.502079  0.567242  0.285880  0.366120          1
9997 -1.975373  0.487838  0.986505  0.149286  0.145984          1
9998 -0.898510  0.365246  0.587558  0.889118  0.818391          0
9999 -0.570329  0.073056  0.505441  0.378761  0.942631          0

[10000 rows x 13 columns]
```

[7]:
```
0    6380
1    3620
Name: stability, dtype: int64
```

[8]:
```
CreditDefaultData = pd.read_excel('./Data/default of credit card clients.xls',␣
 ↪index_col = 0, header = 1)
```

[9]:
```
display(CreditDefaultData)
CreditDefaultData['default payment next month'].value_counts()
```

```
       LIMIT_BAL  SEX  EDUCATION  MARRIAGE  AGE  PAY_0  PAY_2  PAY_3  PAY_4  \
ID
1          20000    2          2         1   24      2      2     -1     -1
2         120000    2          2         2   26     -1      2      0      0
3          90000    2          2         2   34      0      0      0      0
4          50000    2          2         1   37      0      0      0      0
```

```
5          50000    1          2         1   57     -1      0     -1      0
...          ...  ...        ...       ...  ...    ...    ...    ...    ...
29996     220000    1          3         1   39      0      0      0      0
29997     150000    1          3         2   43     -1     -1     -1     -1
29998      30000    1          2         2   37      4      3      2     -1
29999      80000    1          3         1   41      1     -1      0      0
30000      50000    1          2         1   46      0      0      0      0

       PAY_5  ...  BILL_AMT4  BILL_AMT5  BILL_AMT6  PAY_AMT1  PAY_AMT2   \
ID            ...
1         -2  ...          0          0          0         0       689
2          0  ...       3272       3455       3261         0      1000
3          0  ...      14331      14948      15549      1518      1500
4          0  ...      28314      28959      29547      2000      2019
5          0  ...      20940      19146      19131      2000     36681
...      ...  ...        ...        ...        ...       ...       ...
29996      0  ...      88004      31237      15980      8500     20000
29997      0  ...       8979       5190          0      1837      3526
29998      0  ...      20878      20582      19357         0         0
29999      0  ...      52774      11855      48944     85900      3409
30000      0  ...      36535      32428      15313      2078      1800

       PAY_AMT3  PAY_AMT4  PAY_AMT5  PAY_AMT6  default payment next month
ID
1             0         0         0         0                           1
2          1000      1000         0      2000                           1
3          1000      1000      1000      5000                           0
4          1200      1100      1069      1000                           0
5         10000      9000       689       679                           0
...         ...       ...       ...       ...                         ...
29996      5003      3047      5000      1000                           0
29997      8998       129         0         0                           0
29998     22000      4200      2000      3100                           1
29999      1178      1926     52964      1804                           1
30000      1430      1000      1000      1000                           1

[30000 rows x 24 columns]
```

[9]:
```
0    23364
1     6636
Name: default payment next month, dtype: int64
```

[10]:
```python
DatasetList = [HTRU2, OccupancyData, ElectricGridData, CreditDefaultData]
DatasetNames = ["HTRU2","OccupancyData","ElectricGridData","CreditDefaultData"]
```

[11]:
```python
Algorithms = ['Logistic Regression', 'Decision trees','ANN']
```

[12]:

```
from sklearn.pipeline import Pipeline
from sklearn.pipeline import make_pipeline

from sklearn.ensemble import RandomForestClassifier


from sklearn.linear_model import LogisticRegression
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import GridSearchCV
from sklearn.model_selection import StratifiedKFold
from sklearn.model_selection import train_test_split

from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import roc_auc_score
from sklearn.metrics import roc_curve
from sklearn.metrics import precision_recall_curve

from sklearn.neural_network import MLPClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
```

1.1 Running Logistic Regression on DataSets

[13]:

```
%%time
pipe = Pipeline([('std', StandardScaler()),
                 ('classifier', LogisticRegression())])

search_space = [{'classifier': [LogisticRegression(max_iter=5000)],
                 'classifier__solver': ['saga'],
                 'classifier__penalty': ['l1', 'l2','none'],
                 'classifier__C': np.logspace(-8, 4, 13)}
                ]

# Function to pass in hyperparameters later
def logistic_create(self, **kwargs):
    return make_pipeline(StandardScaler(),
                         LogisticRegression(**kwargs))

all_trials_logisticReg = []
all_trials_train_logisticReg = []
all_gridsearch_trials_logisticReg = []

algorithm_results = np.zeros([4, 3])

algorithm_results_training = np.zeros([4, 3])
```

```
for idx, dataset in enumerate(DatasetList):
    print("Starting Dataset #" + str(idx))
    trial_results = np.zeros([5, 3])
    trial_results_training = np.zeros([5, 3])

    plt.figure(0, figsize=(10,5)).clf()
    plt.figure(1, figsize=(10,5)).clf()
    plt.figure(2, figsize=(10,5)).clf()
    plt.figure(3, figsize=(10,5)).clf()
    plt.figure(4, figsize=(10,5)).clf()

    gridsearch_trials_logisticReg = []

    for trial in range(5):

        #Creating new data split and grid searching for params

        X_train, X_test, y_train, y_test = train_test_split(
        dataset.iloc[:,:-1], dataset.iloc[:,-1:], train_size=5000)

        clf = GridSearchCV(pipe, search_space, cv=StratifiedKFold(n_splits=5),
                    scoring=['accuracy', 'f1', 'roc_auc'], refit=False,
                    verbose=0, n_jobs = -1)

        best_model = clf.fit(X_train, y_train)

        #Accuracy
        Accuracy_index = np.argmin(best_model.cv_results_['rank_test_accuracy'])
        Accuracy_param = clf.cv_results_['params'][Accuracy_index]
        Accuracy_model = logistic_create(Accuracy_param).fit(X_train, y_train)
        y_predict = Accuracy_model.predict(X_test)
        train_predict = Accuracy_model.predict(X_train)
        trial_results_training[trial][0] = accuracy_score(y_train,␣
 ↪train_predict)
        trial_results[trial][0] = accuracy_score(y_test, y_predict)

        #F1
        F1_index = np.argmin(best_model.cv_results_['rank_test_f1'])
        F1_param = clf.cv_results_['params'][F1_index]
        F1_model = logistic_create(F1_param).fit(X_train, y_train)
        y_predict = F1_model.predict(X_test)
        train_predict = F1_model.predict(X_train)
        trial_results_training[trial][1] = f1_score(y_train, train_predict)
        trial_results[trial][1] = f1_score(y_test, y_predict)

        #AUC
        AUC_index = np.argmin(best_model.cv_results_['rank_test_roc_auc'])
        AUC_param = clf.cv_results_['params'][AUC_index]
        AUC_model = logistic_create(AUC_param).fit(X_train, y_train)
        train_predict = AUC_model.predict(X_train)
        y_predict = AUC_model.predict(X_test)
        trial_results_training[trial][2] = roc_auc_score(y_train, train_predict)
        trial_results[trial][2] = roc_auc_score(y_test, y_predict)

        #Performances during hyperparameter search
        results = pd.DataFrame( best_model.cv_results_['params'] )
        results['accuracy'] = best_model.cv_results_['mean_test_accuracy']
        results['f1'] = best_model.cv_results_['mean_test_f1']
        results['roc_auc'] = best_model.cv_results_['mean_test_roc_auc']
        gridsearch_trials_logisticReg.append(results)

        #Plotting curves for each trial
        plt.figure(0)
        fpr, tpr, thresh = roc_curve(y_test, y_predict)
        plt.plot(fpr,tpr,label="Trial " + str(trial+1) + ",␣
↪auc="+str(round(trial_results[trial][2], 5)))

        plt.figure(1)
        precision, recall, thresholds = precision_recall_curve(y_test,␣
↪y_predict)
        plt.plot(recall,precision,label="Trial " + str(trial))

    print("DataSet " + DatasetNames[idx])
    print(trial_results)

    #Creating graphics and saving to file

    plt.figure(0)
    plt.title('ROC of Logistic Regression over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.legend(loc=0)
    plt.savefig('./ROC_Graphs/Logistic_Regression_ROC_Dataset:'+␣
↪DatasetNames[idx]+'.png')

    plt.figure(1)
    plt.title('Precision-Recall of Logistic Regression over 5 Trials, Dataset:␣
↪' + DatasetNames[idx])
    plt.xlabel('Recall')
    plt.ylabel('Precision')
    plt.legend(loc=0)
    plt.savefig('./PR_Graphs/Logistic_Regression_PR_Dataset:'+␣
↪DatasetNames[idx]+'.png')
```

```
    all_gridsearch_trials_logisticReg.append(gridsearch_trials_logisticReg)
    avg_gridsearch = pd.concat(gridsearch_trials_logisticReg).
↪groupby(['classifier'],level=0).agg(
        {'classifier__C':'first', 'classifier__penalty':'first', 'accuracy':
↪'mean', 'f1':'mean', 'roc_auc':'mean'})


    plt.figure(2)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('classifier__penalty','classifier__C','accuracy'),
             annot=True, fmt='.3f')
    plt.title('Accuracy Metric HeatMap of Logistic Regression over 5 Trials,␣
↪Dataset: ' + DatasetNames[idx])
    plt.savefig('./Accuracy_HeatMaps/Logistic_Regression_Dataset:'+␣
↪DatasetNames[idx]+'.png')

    plt.figure(3)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('classifier__penalty','classifier__C','f1'),
             annot=True, fmt='.3f')
    plt.title('F1 Metric HeatMap of Logistic Regression over 5 Trials, Dataset:␣
↪' + DatasetNames[idx])
    plt.savefig('./F1_HeatMaps/Logistic_Regression_Dataset:'+␣
↪DatasetNames[idx]+'.png')

    plt.figure(4)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('classifier__penalty','classifier__C','roc_auc'),
             annot=True, fmt='.3f')
    plt.title('ROC_AUC Metric HeatMap of Logistic Regression over 5 Trials,␣
↪Dataset: ' + DatasetNames[idx])
    plt.savefig('./ROC_HeatMaps/Logistic_Regression_Dataset:'+␣
↪DatasetNames[idx]+'.png')



    plt.show()

    #Adding results to data arrays for later analysis

    all_trials_logisticReg.append(trial_results)
    all_trials_train_logisticReg.append(trial_results_training)


    algorithm_results[idx] = np.mean(trial_results, axis = 0)
```

```python
    algorithm_results_training[idx] = np.mean(trial_results_training, axis = 0)


print("Avg Metric Results for Each Dataset")
print(algorithm_results)
```

```
Starting Dataset #0
```

```
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
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  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
```

```
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y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
```
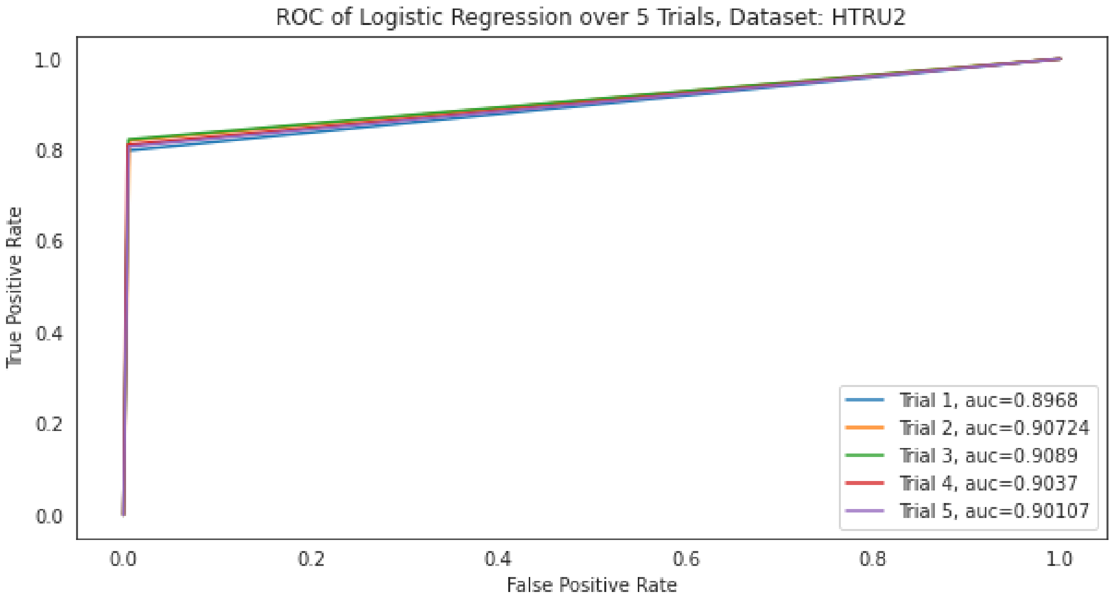
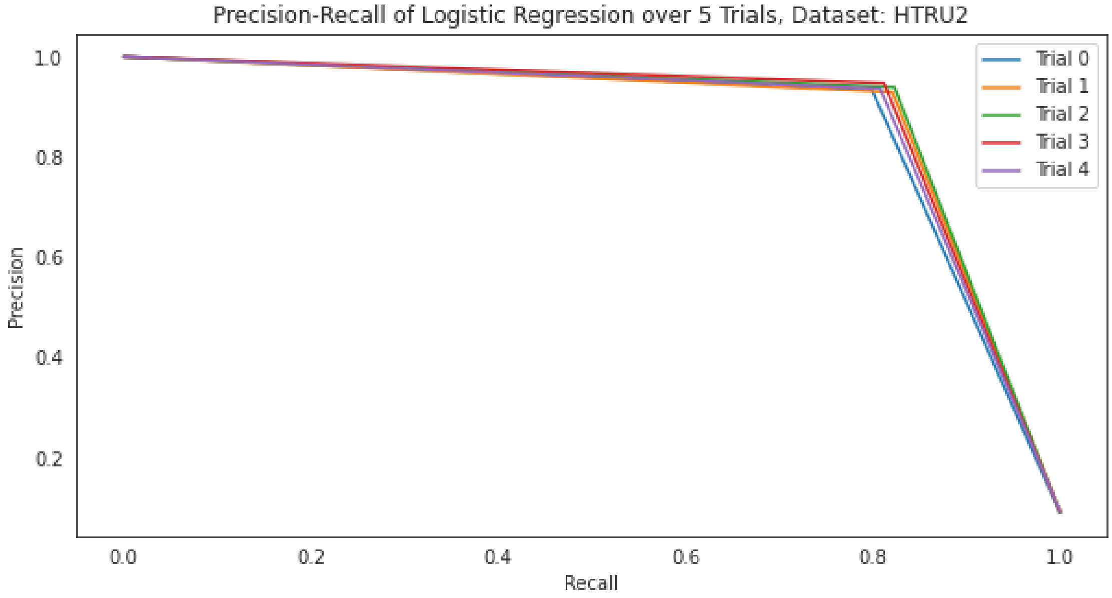
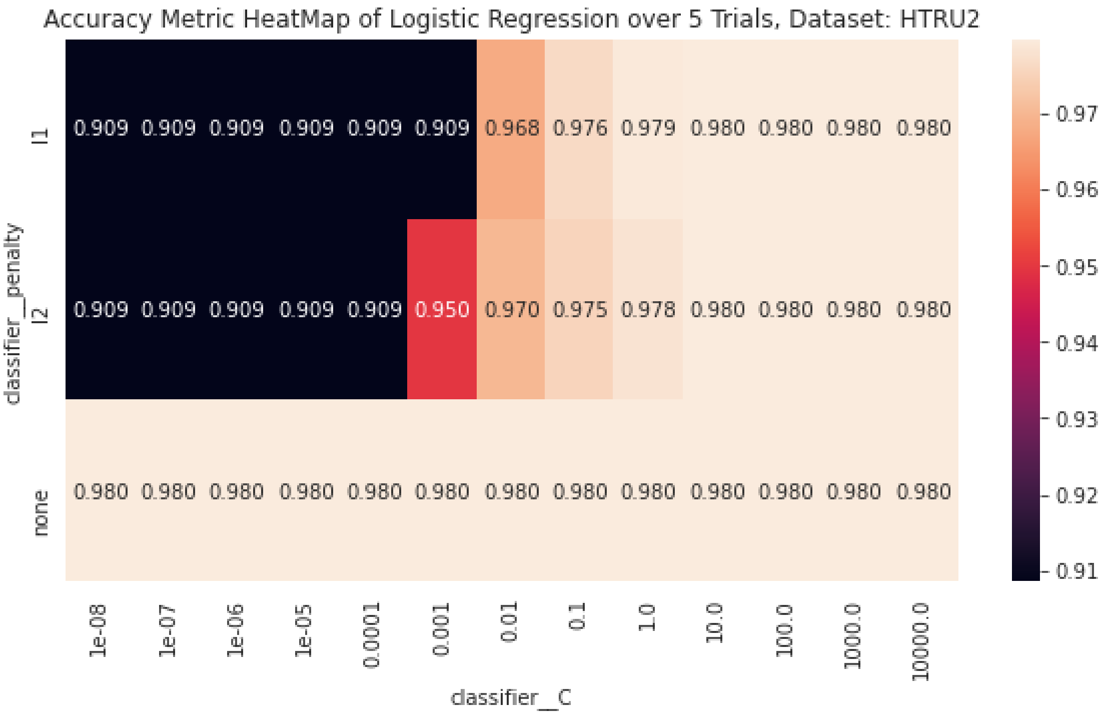
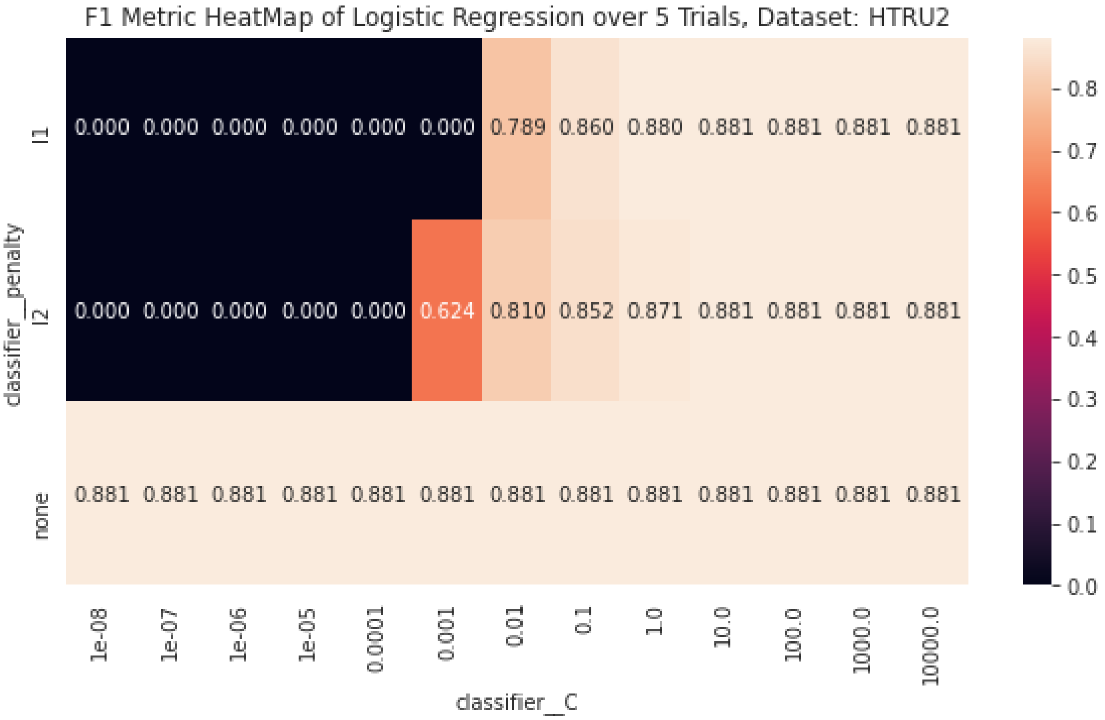

```
DataSet HTRU2
[[0.97705071 0.86129335 0.89679879]
 [0.97743836 0.87186262 0.90724044]
 [0.97914405 0.87744875 0.90889521]
 [0.9787564  0.87442713 0.90369693]
 [0.97689564 0.86743772 0.90107127]]
```


ROC of Logistic Regression over 5 Trials, Dataset: HTRU2
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
Trial 1, auc=0.8968
Trial 2, auc=0.90724
Trial 3, auc=0.9089
Trial 4, auc=0.9037
Trial 5, auc=0.90107

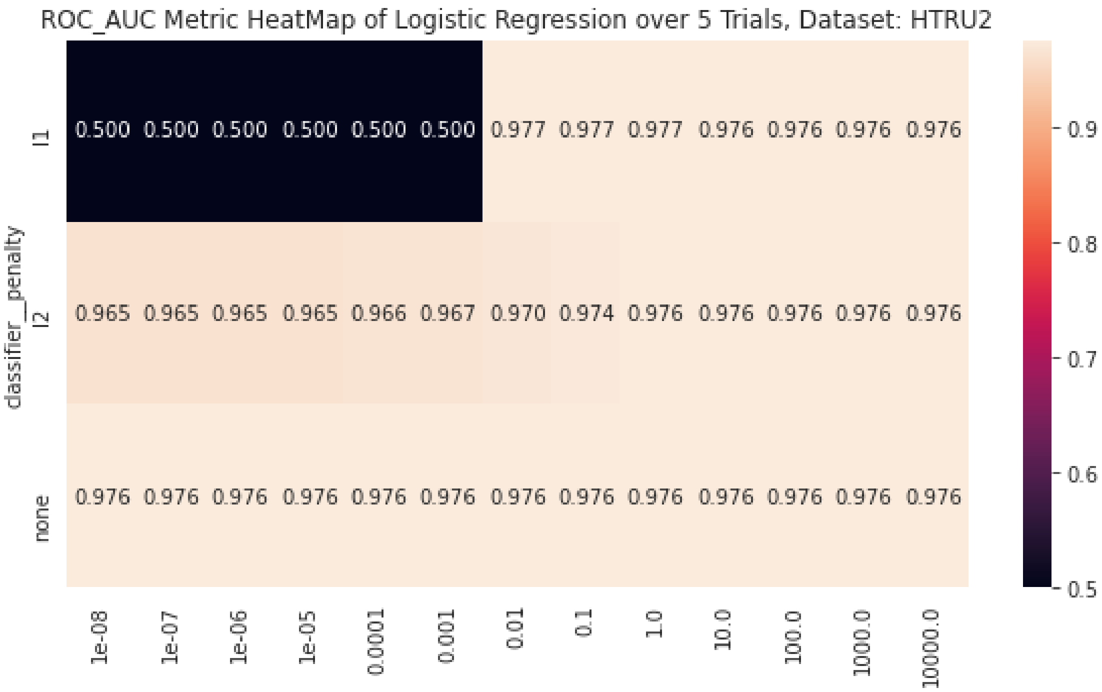

Precision-Recall of Logistic Regression over 5 Trials, Dataset: HTRU2
Precision
Recall
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4



Accuracy Metric HeatMap of Logistic Regression over 5 Trials, Dataset: HTRU2



F1 Metric HeatMap of Logistic Regression over 5 Trials, Dataset: HTRU2



```
Starting Dataset #1

/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
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packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
```

```
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  return f(**kwargs)
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```

```
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packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
```
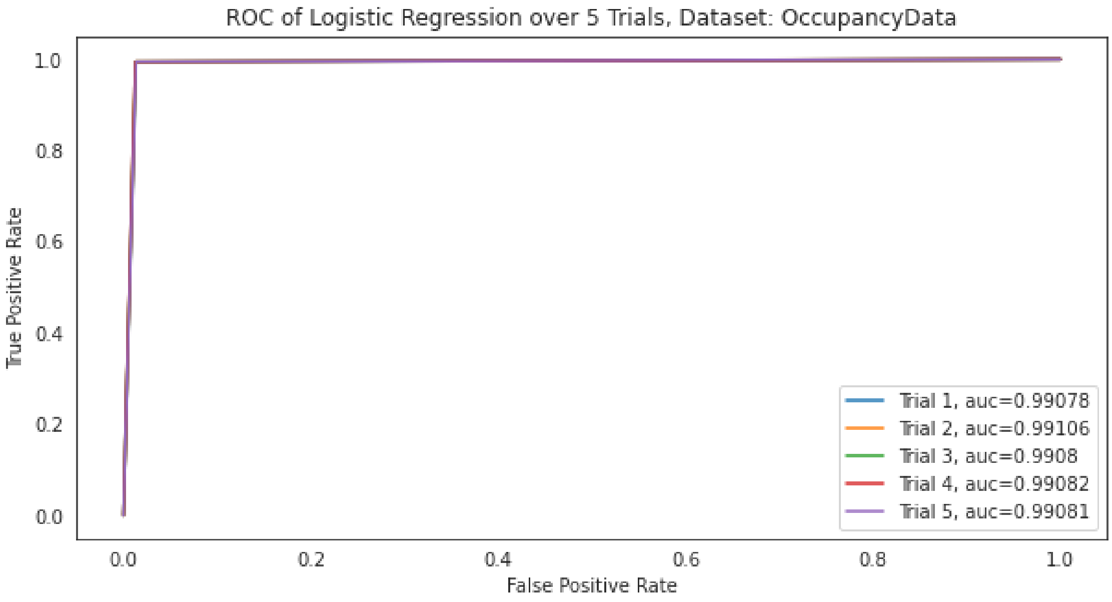
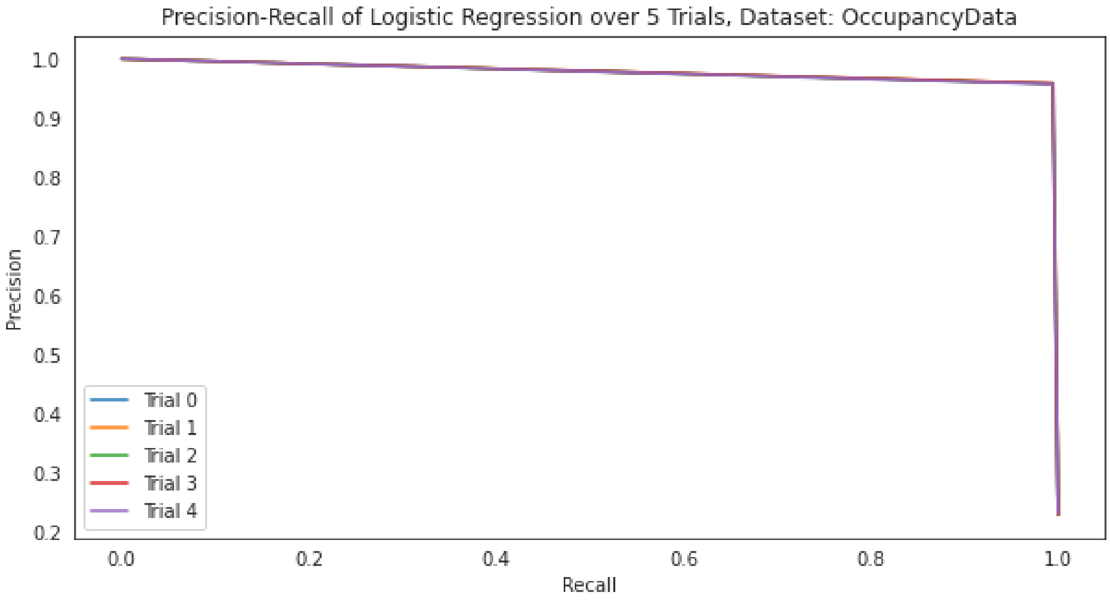
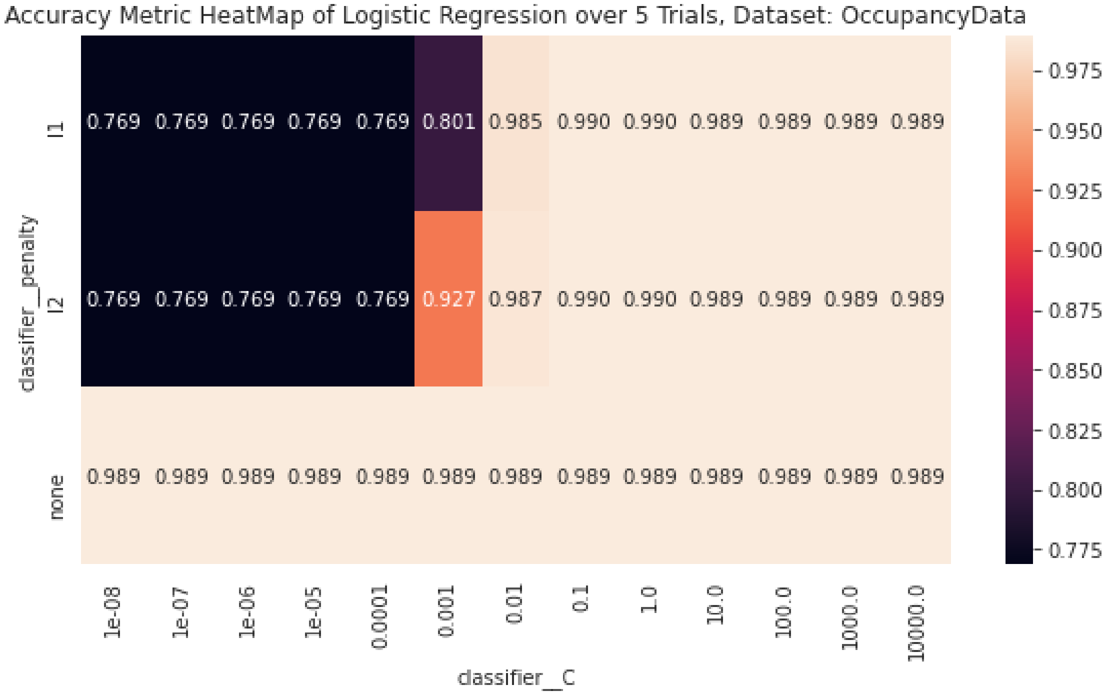
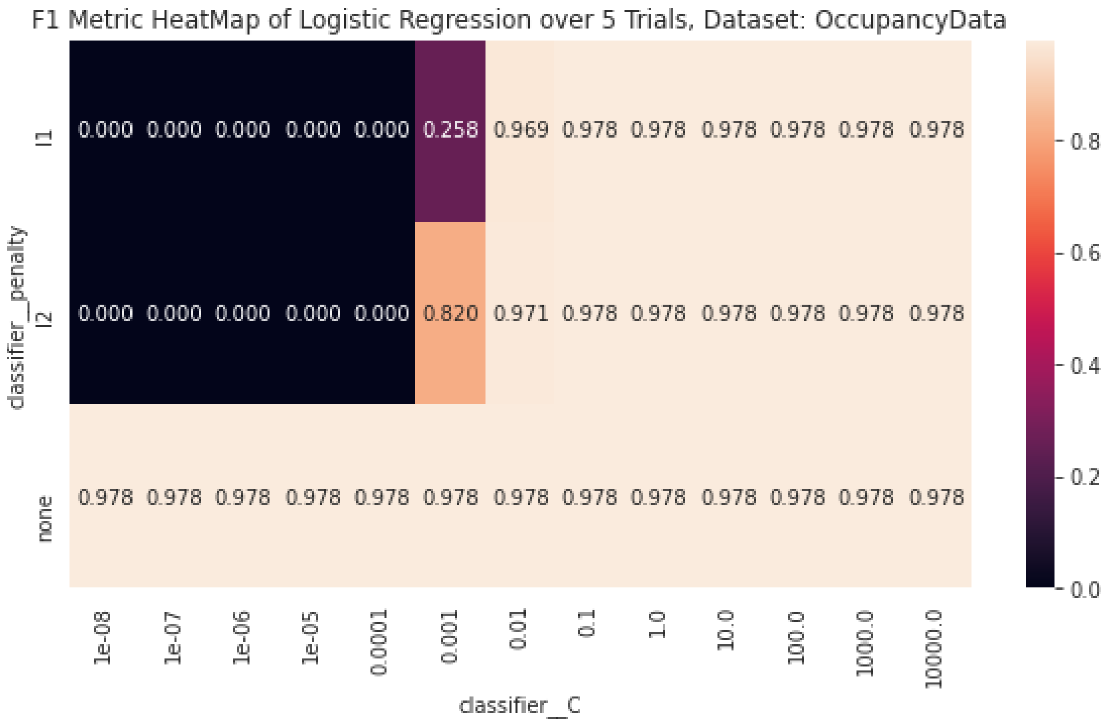
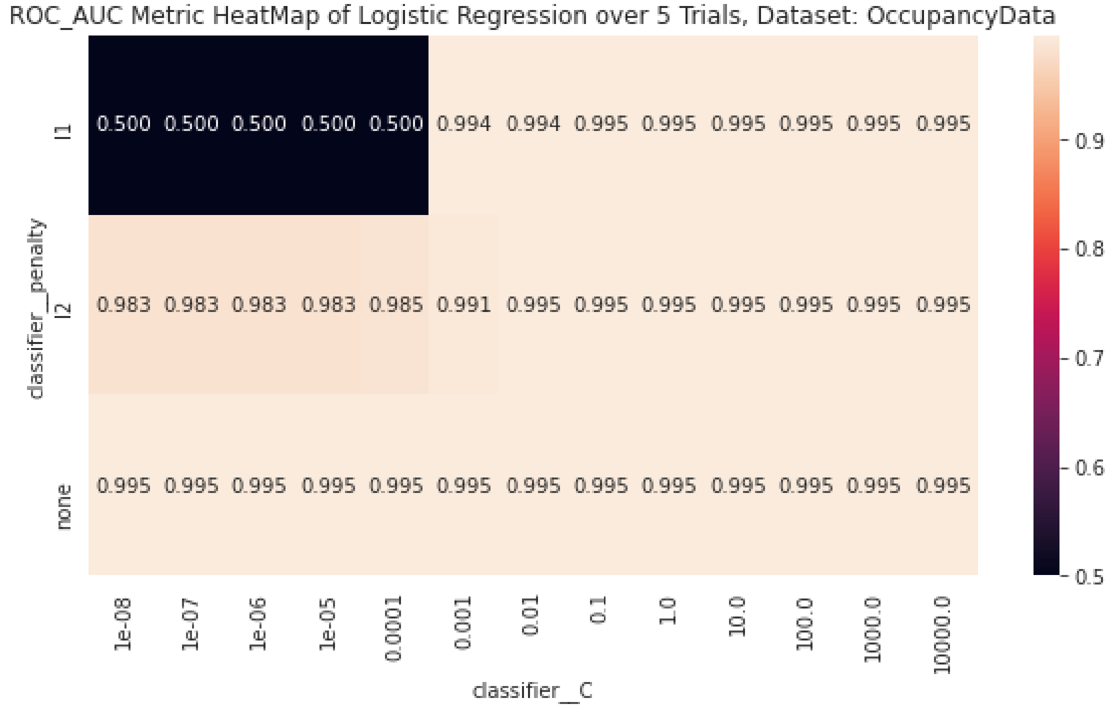

```
DataSet OccupancyData
[[0.98881748 0.9760989  0.99077761]
 [0.98894602 0.97647059 0.9910598 ]
 [0.98868895 0.97605442 0.99079866]
 [0.98888175 0.97628513 0.99082131]
 [0.98856041 0.97586768 0.99081327]]
```




Precision-Recall of Logistic Regression over 5 Trials, Dataset: OccupancyData


Accuracy Metric HeatMap of Logistic Regression over 5 Trials, Dataset: OccupancyData


F1 Metric HeatMap of Logistic Regression over 5 Trials, Dataset: OccupancyData


ROC_AUC Metric HeatMap of Logistic Regression over 5 Trials, Dataset: OccupancyData

```
Starting Dataset #2
```

```
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
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  return f(**kwargs)
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y was passed when a 1d array was expected. Please change the shape of y to
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  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
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```

```
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  return f(**kwargs)
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packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
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  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
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(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
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y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
```
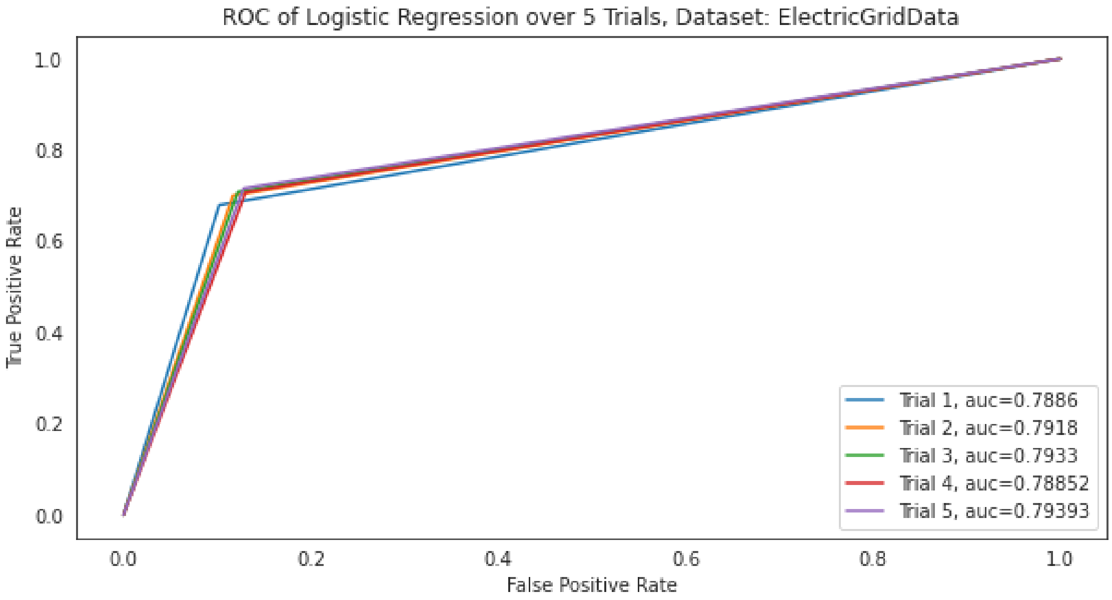
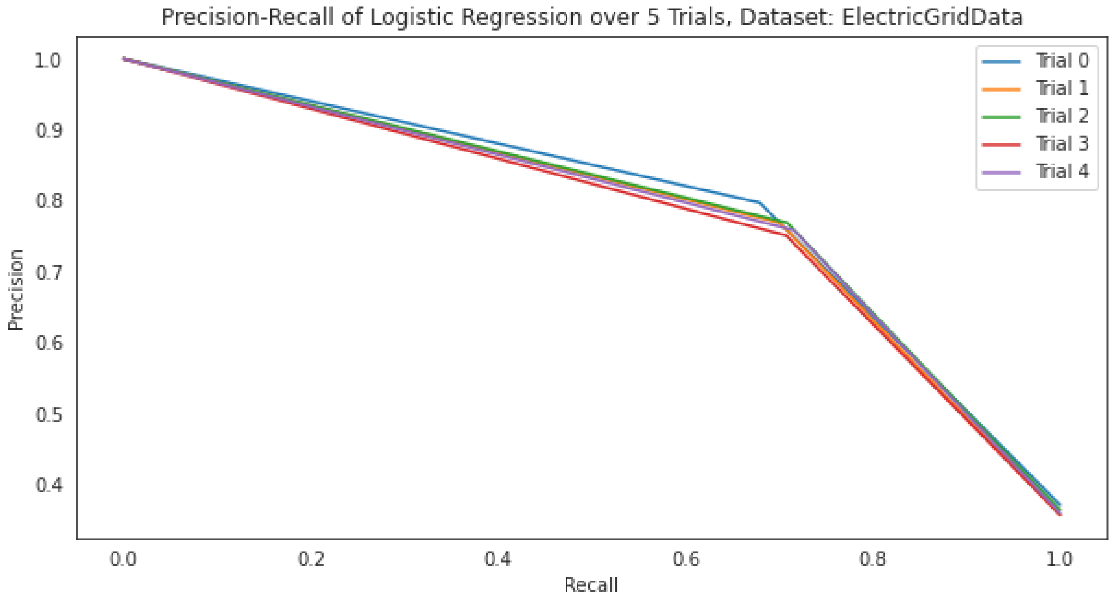
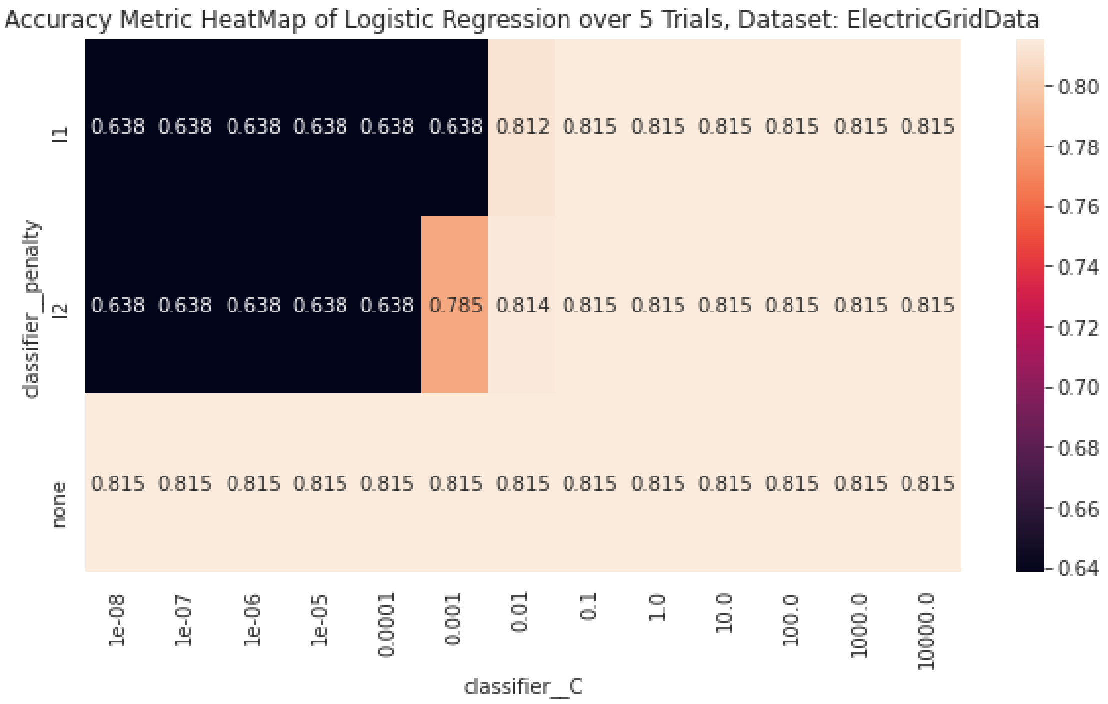
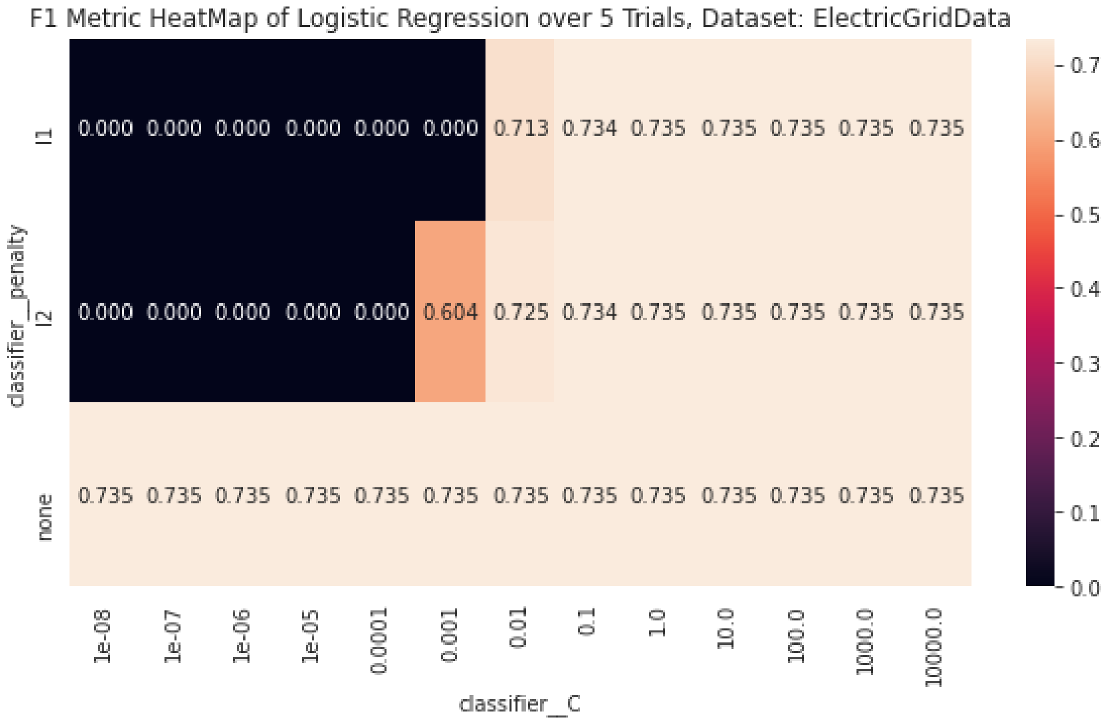
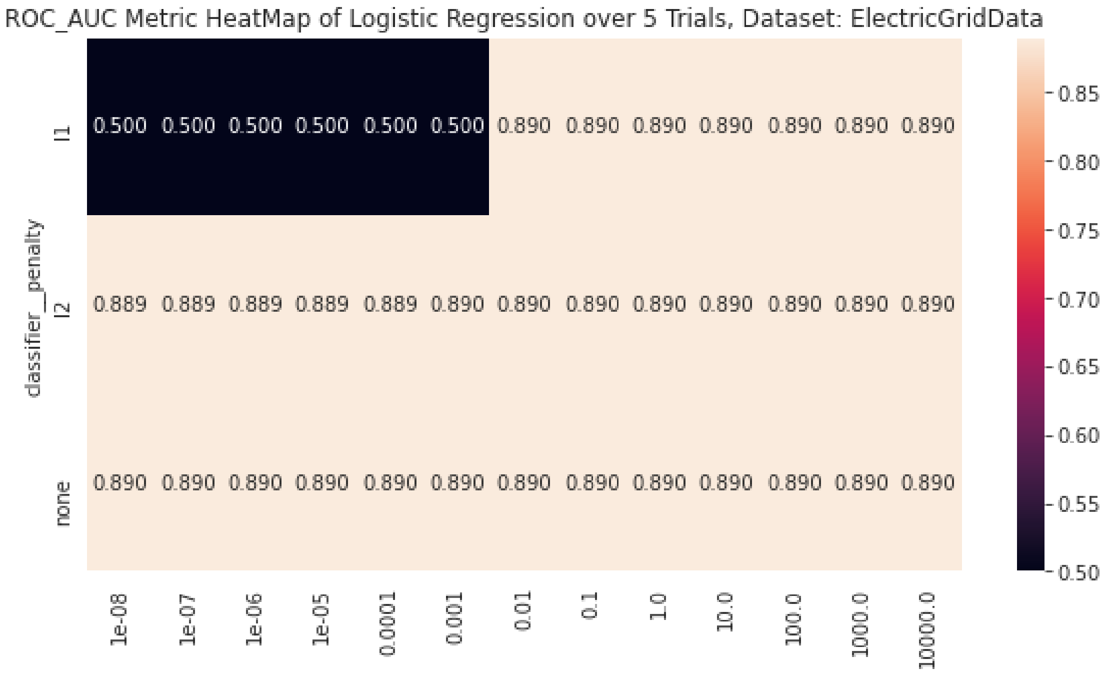

```
DataSet ElectricGridData
[[0.8166     0.7336625  0.78860039]
 [0.8178     0.73323572 0.79179548]
 [0.8162     0.73765344 0.79329705]
 [0.8116     0.72868664 0.78852304]
 [0.8158     0.7366314  0.79393417]]
```


ROC of Logistic Regression over 5 Trials, Dataset: ElectricGridData
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Trial 1, auc=0.7886
Trial 2, auc=0.7918
Trial 3, auc=0.7933
Trial 4, auc=0.78852
Trial 5, auc=0.79393


Precision-Recall of Logistic Regression over 5 Trials, Dataset: ElectricGridData
Precision
Recall
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of Logistic Regression over 5 Trials, Dataset: ElectricGridData


F1 Metric HeatMap of Logistic Regression over 5 Trials, Dataset: ElectricGridData



```
Starting Dataset #3

/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
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  return f(**kwargs)
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packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
```

```
(n_samples, ), for example using ravel().
  return f(**kwargs)
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packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
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  return f(**kwargs)
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y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
```
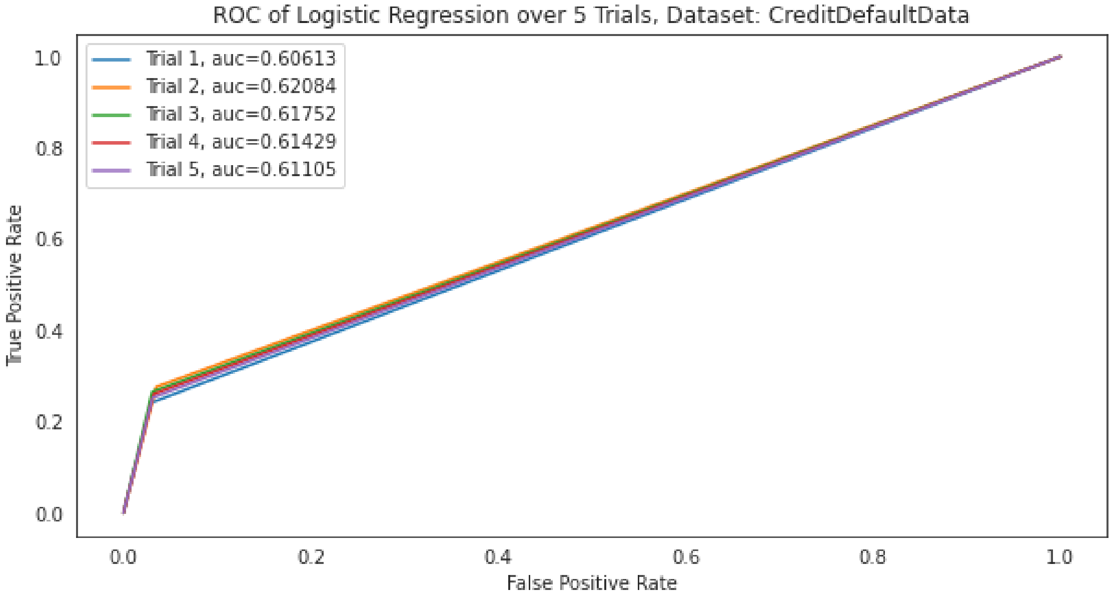
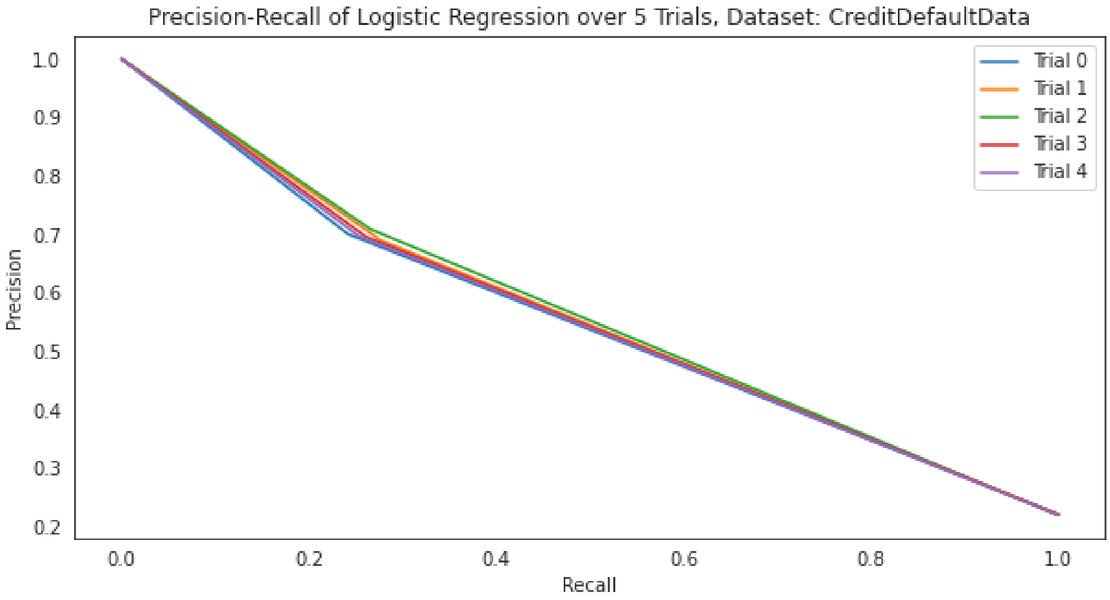
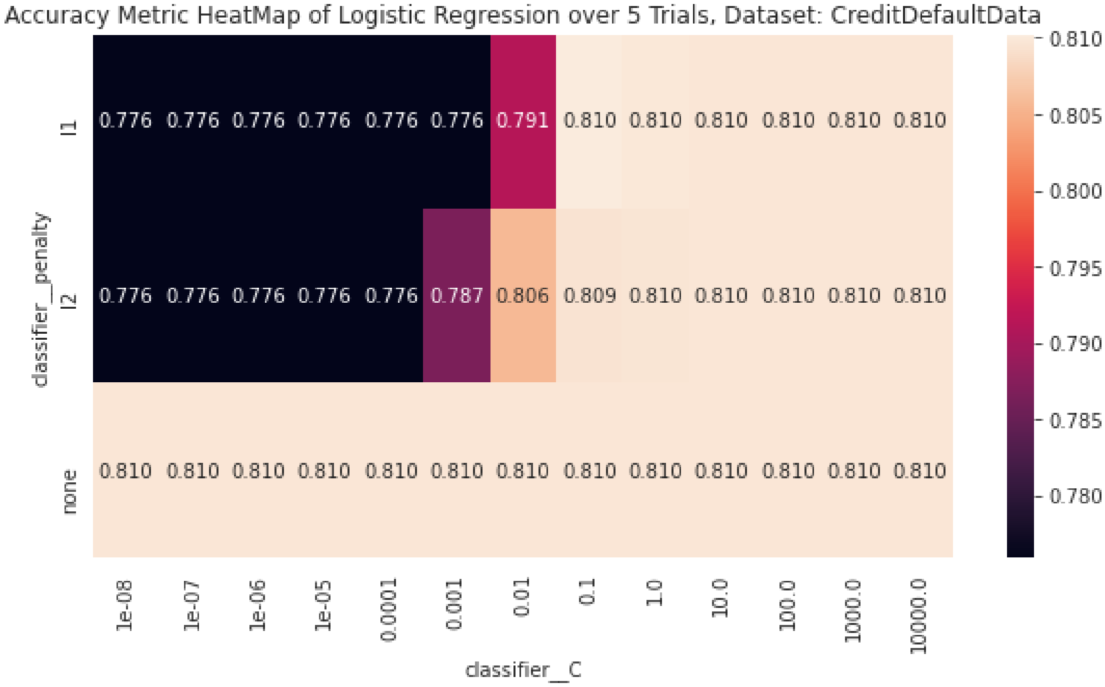
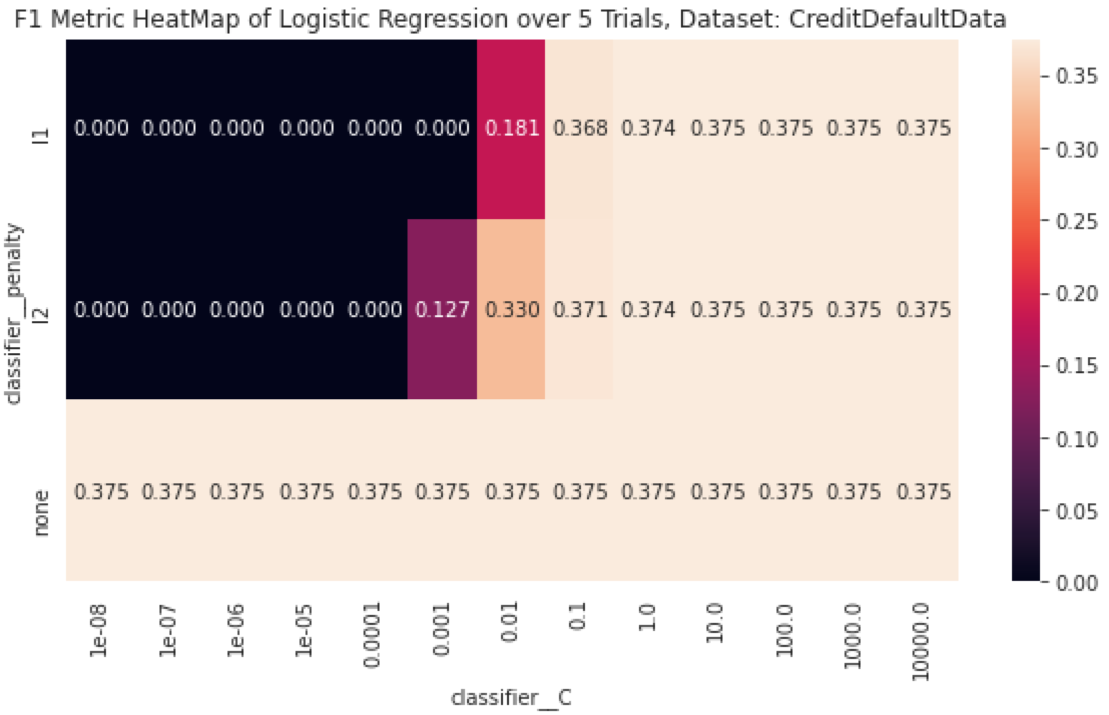

```
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
```

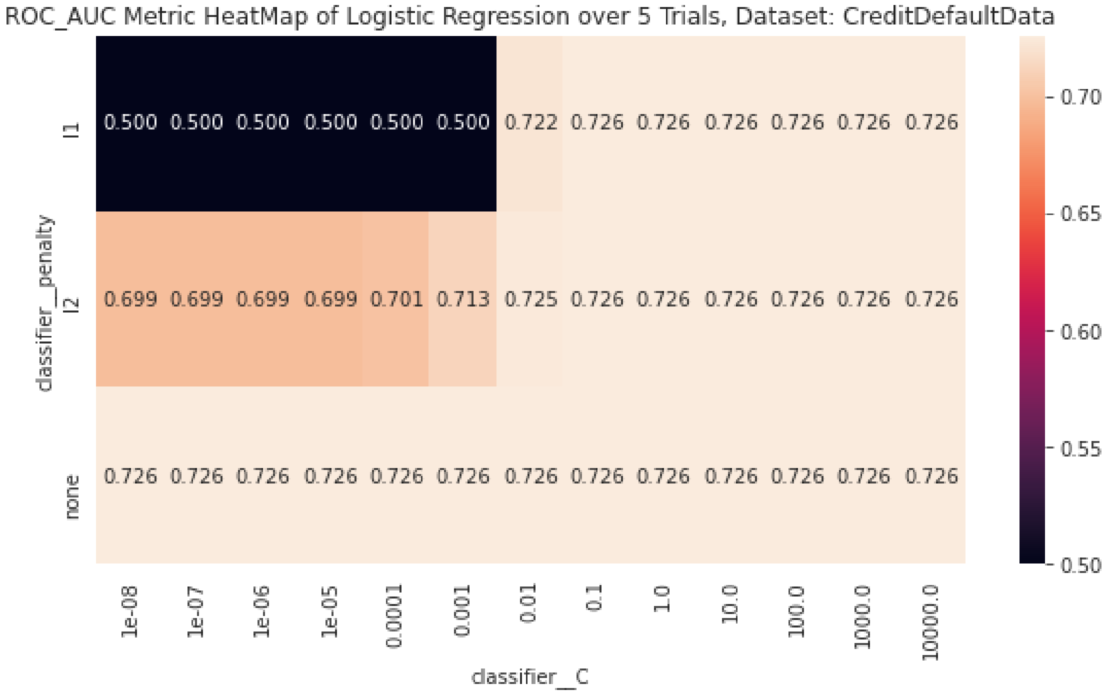
```
DataSet CreditDefaultData
[[0.8094     0.35928466 0.60613208]
 [0.81324    0.3951289  0.62083804]
 [0.81468    0.38660135 0.61751732]
 [0.81132    0.37958701 0.61429018]
 [0.81096    0.37154255 0.61105473]]
```




Precision-Recall of Logistic Regression over 5 Trials, Dataset: CreditDefaultData
Precision
Recall
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of Logistic Regression over 5 Trials, Dataset: CreditDefaultData
classifier__penalty
l1
l2
none
classifier__C
1e-08
1e-07
1e-06
1e-05
0.0001
0.001
0.01
0.1
1.0
10.0
100.0
1000.0
10000.0
0.776 0.776 0.776 0.776 0.776 0.776 0.791 0.810 0.810 0.810 0.810 0.810 0.810
0.776 0.776 0.776 0.776 0.776 0.787 0.806 0.809 0.810 0.810 0.810 0.810 0.810
0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810 0.810
0.810
0.805
0.800
0.795
0.790
0.785
0.780


F1 Metric HeatMap of Logistic Regression over 5 Trials, Dataset: CreditDefaultData


ROC_AUC Metric HeatMap of Logistic Regression over 5 Trials, Dataset: CreditDefaultData

Avg Metric Results for Each Dataset

```
[[0.97785703 0.87049391 0.90354053]
 [0.98877892 0.97615534 0.99085413]
 [0.8156     0.73397394 0.79123003]
 [0.81192    0.37842889 0.61396647]]
CPU times: user 12 s, sys: 801 ms, total: 12.8 s
Wall time: 2min 17s
```

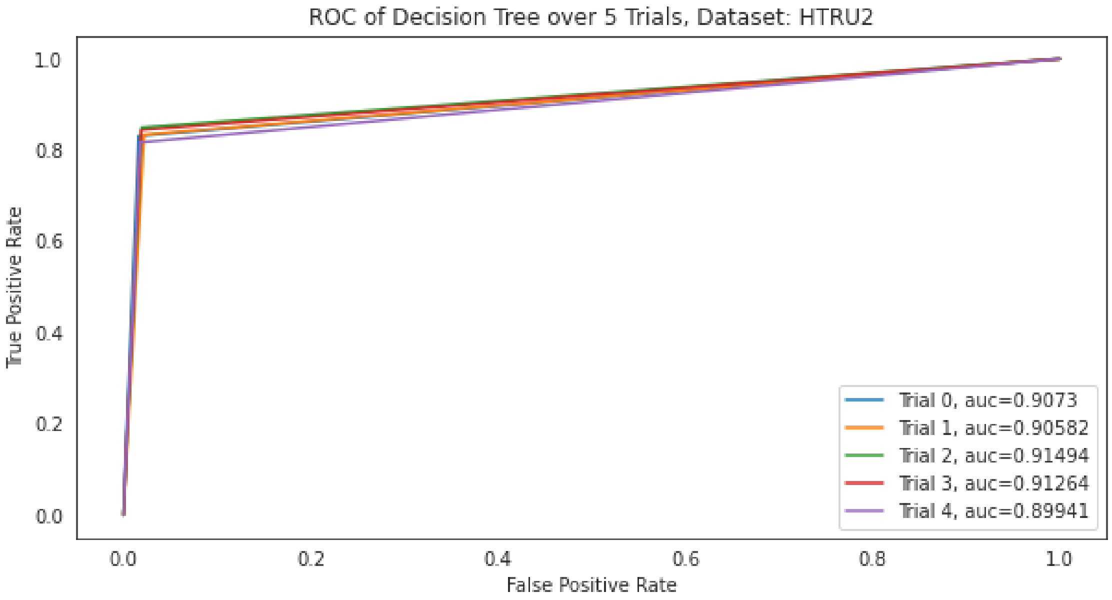
1.2 Running DecisionTree on DataSets

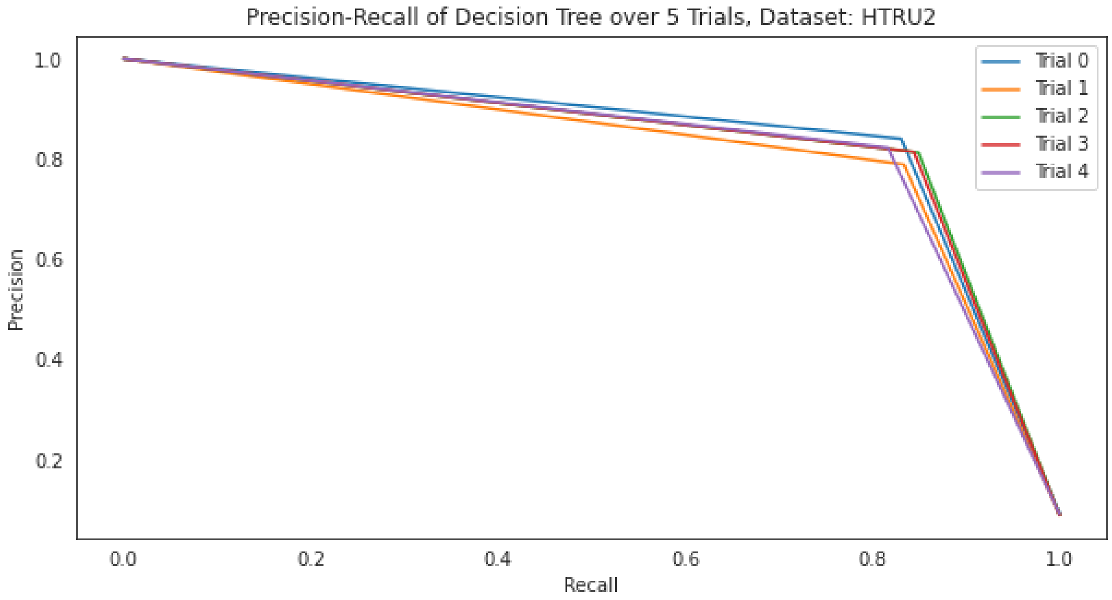
[14]:

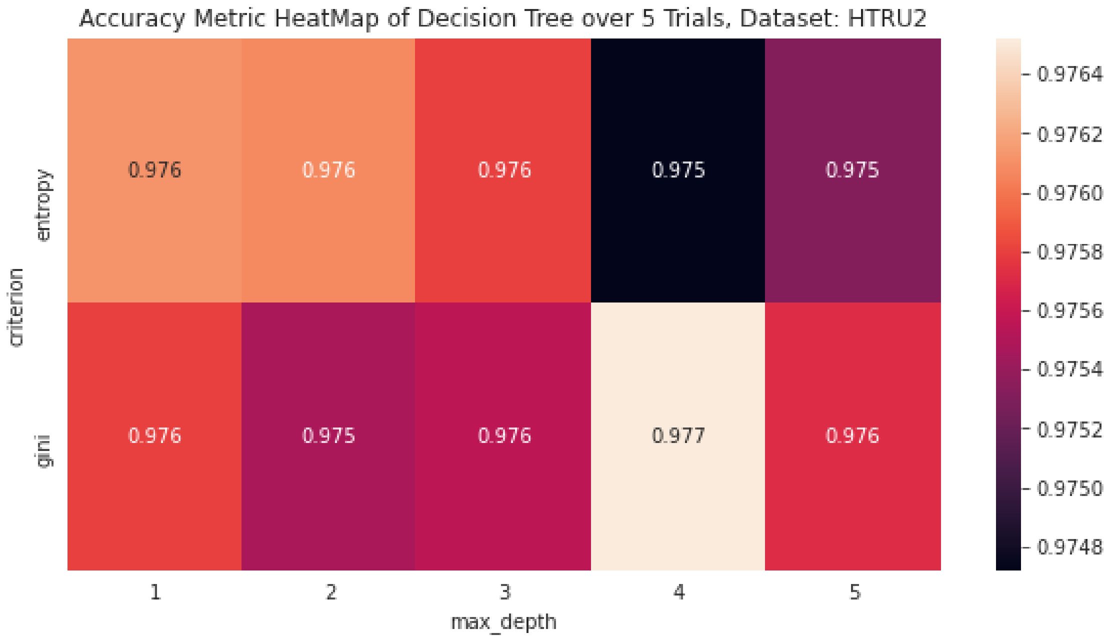
```
%%time

search_space = [{
                 'criterion': ['gini','entropy'],
                 'max_depth': [1,2,3,4,5],
                }]

# Function to pass in hyperparameters later
def Tree_create(self, **kwargs):
    return DecisionTreeClassifier(**kwargs)

all_trials_Tree_algorithm = []
all_trials_train_Tree_algorithm = []
all_gridsearch_trials_Tree_algorithm = []

Tree_algorithm_results = np.zeros([4, 3])

Tree_algorithm_results_training = np.zeros([4, 3])

for idx, dataset in enumerate(DatasetList):
    print("Starting Dataset #" + str(idx))
    trial_results = np.zeros([5, 3])
    trial_results_training = np.zeros([5, 3])

    plt.figure(0, figsize=(10,5)).clf()
    plt.figure(1, figsize=(10,5)).clf()
    plt.figure(2, figsize=(10,5)).clf()
    plt.figure(3, figsize=(10,5)).clf()
    plt.figure(4, figsize=(10,5)).clf()

    gridsearch_trials_Tree_algorithm = []


    for trial in range(5):

        #Creating new data split and grid searching for params

        X_train, X_test, y_train, y_test = train_test_split(
        dataset.iloc[:,:-1], dataset.iloc[:,-1:], train_size=5000)

        clf = GridSearchCV(estimator = DecisionTreeClassifier(), param_grid =␣
↪search_space, cv=StratifiedKFold(n_splits=5),
                   scoring=['accuracy', 'f1', 'roc_auc'], refit=False,
                   verbose=0, n_jobs = -1)

        best_model = clf.fit(X_train, y_train)

        #Accuracy
        Accuracy_index = np.argmin(best_model.cv_results_['rank_test_accuracy'])
        Accuracy_param = clf.cv_results_['params'][Accuracy_index]
        Accuracy_model = Tree_create(Accuracy_param).fit(X_train, y_train)
        y_predict = Accuracy_model.predict(X_test)
        train_predict = Accuracy_model.predict(X_train)
        trial_results_training[trial][0] = accuracy_score(y_train,␣
↪train_predict)
        trial_results[trial][0] = accuracy_score(y_test, y_predict)

        #F1
        F1_index = np.argmin(best_model.cv_results_['rank_test_f1'])
        F1_param = clf.cv_results_['params'][F1_index]
        F1_model = Tree_create(F1_param).fit(X_train, y_train)
        y_predict = F1_model.predict(X_test)
        train_predict = F1_model.predict(X_train)
        trial_results_training[trial][1] = f1_score(y_train, train_predict)
        trial_results[trial][1] = f1_score(y_test, y_predict)

        #AUC
        AUC_index = np.argmin(best_model.cv_results_['rank_test_roc_auc'])
        AUC_param = clf.cv_results_['params'][AUC_index]
        AUC_model = Tree_create(AUC_param).fit(X_train, y_train)
        train_predict = AUC_model.predict(X_train)
        y_predict = AUC_model.predict(X_test)
        trial_results_training[trial][2] = roc_auc_score(y_train, train_predict)
        trial_results[trial][2] = roc_auc_score(y_test, y_predict)

        #Performances during hyperparameter search
        results = pd.DataFrame( best_model.cv_results_['params'] )
        results['accuracy'] = best_model.cv_results_['mean_test_accuracy']
        results['f1'] = best_model.cv_results_['mean_test_f1']
        results['roc_auc'] = best_model.cv_results_['mean_test_roc_auc']
        gridsearch_trials_Tree_algorithm.append(results)

        #Plotting curves for each trial
        plt.figure(0)
        fpr, tpr, thresh = roc_curve(y_test, y_predict)
        plt.plot(fpr,tpr,label="Trial " + str(trial) + ",␣
↪auc="+str(round(trial_results[trial][2], 5)))

        plt.figure(1)
        precision, recall, thresholds = precision_recall_curve(y_test,␣
↪y_predict)
        plt.plot(recall,precision,label="Trial " + str(trial))

    print("DataSet " + DatasetNames[idx])
    print(trial_results)

    #Creating graphics and saving to file

    plt.figure(0)
    plt.title('ROC of Decision Tree over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.legend(loc=0)
    plt.savefig('./ROC_Graphs/Decision_Tree_ROC_Dataset:'+ DatasetNames[idx]+'.
↪png')


    plt.figure(1)
    plt.title('Precision-Recall of Decision Tree over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.xlabel('Recall')
    plt.ylabel('Precision')
    plt.legend(loc=0)
    plt.savefig('./PR_Graphs/Decision_Tree_PR_Dataset:'+ DatasetNames[idx]+'.
↪png')

    all_gridsearch_trials_Tree_algorithm.
↪append(gridsearch_trials_Tree_algorithm)
    avg_gridsearch = pd.concat(gridsearch_trials_Tree_algorithm).
↪groupby(['classifier'],level=0).agg(
        {'criterion':'first', 'max_depth':'first', 'accuracy':'mean', 'f1':
↪'mean', 'roc_auc':'mean'})

    plt.figure(2)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('criterion','max_depth','accuracy'),
             annot=True, fmt='.3f')
    plt.title('Accuracy Metric HeatMap of Decision Tree over 5 Trials, Dataset:␣
↪' + DatasetNames[idx])
```

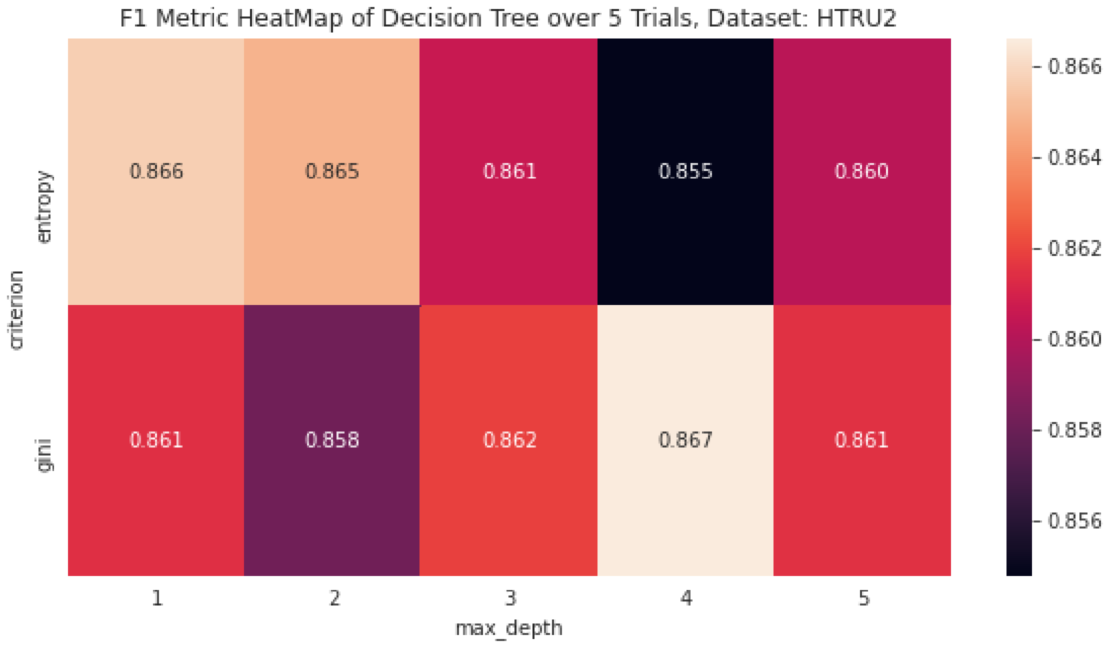
```
    plt.savefig('./Accuracy_HeatMaps/Decision_Tree_Dataset:'+␣
↪DatasetNames[idx]+'.png')

    plt.figure(3)
    sns.heatmap( avg_gridsearch.dropna().pivot('criterion','max_depth','f1'),
             annot=True, fmt='.3f')
    plt.title('F1 Metric HeatMap of Decision Tree over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.savefig('./F1_HeatMaps/Decision_Tree_Dataset:'+ DatasetNames[idx]+'.
↪png')

    plt.figure(4)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('criterion','max_depth','roc_auc'),
             annot=True, fmt='.3f')
    plt.title('ROC_AUC Metric HeatMap of Decision Tree over 5 Trials, Dataset:␣
↪' + DatasetNames[idx])
    plt.savefig('./ROC_HeatMaps/Decision_Tree_Dataset:'+ DatasetNames[idx]+'.
↪png')

    plt.show()

    #Adding results to data arrays for later analysis

    all_trials_Tree_algorithm.append(trial_results)
    all_trials_train_Tree_algorithm.append(trial_results_training)

    Tree_algorithm_results[idx] = np.mean(trial_results, axis = 0)
    Tree_algorithm_results_training[idx] = np.mean(trial_results_training, axis␣
↪= 0)


print(Tree_algorithm_results)
```

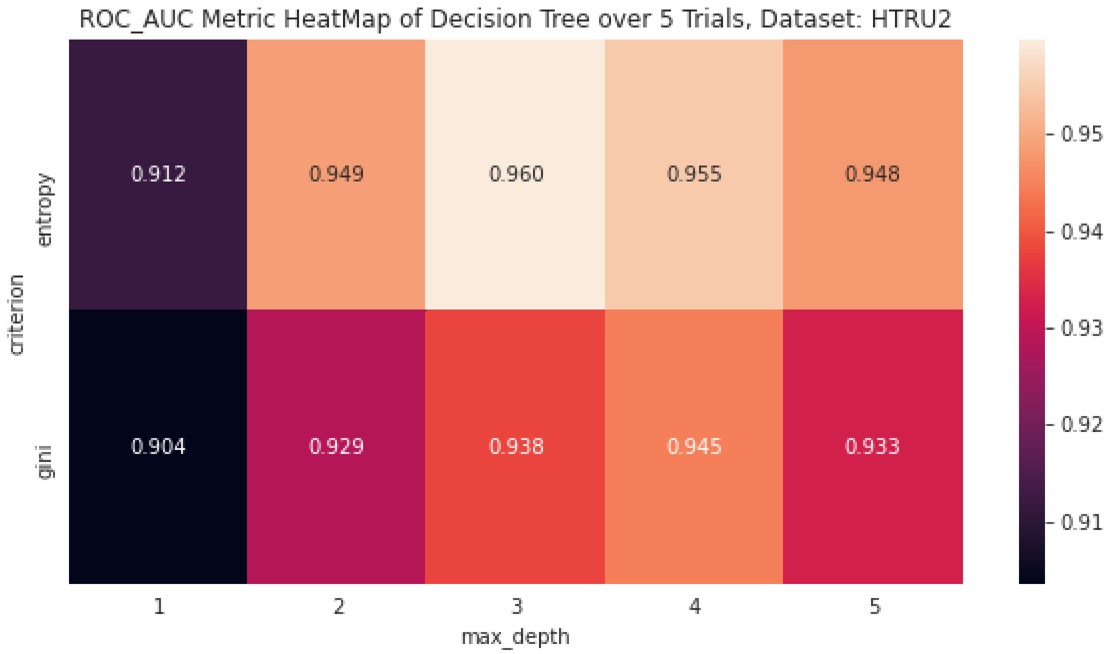
```
Starting Dataset #0
DataSet HTRU2
[[0.96929757 0.83381924 0.90729767]
 [0.96611878 0.81112985 0.9058204 ]
 [0.96883238 0.8211047  0.91493886]
 [0.96712669 0.82372739 0.91263991]
 [0.96852225 0.81860862 0.89940652]]
```


ROC of Decision Tree over 5 Trials, Dataset: HTRU2
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0, auc=0.9073
Trial 1, auc=0.90582
Trial 2, auc=0.91494
Trial 3, auc=0.91264
Trial 4, auc=0.89941

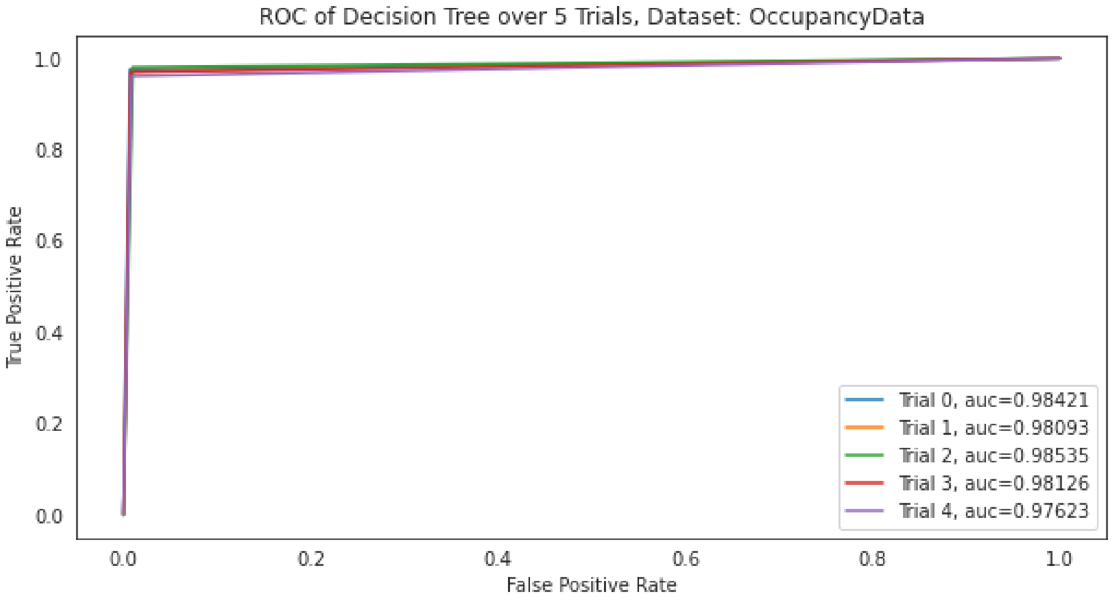

Precision-Recall of Decision Tree over 5 Trials, Dataset: HTRU2
Precision
Recall
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4

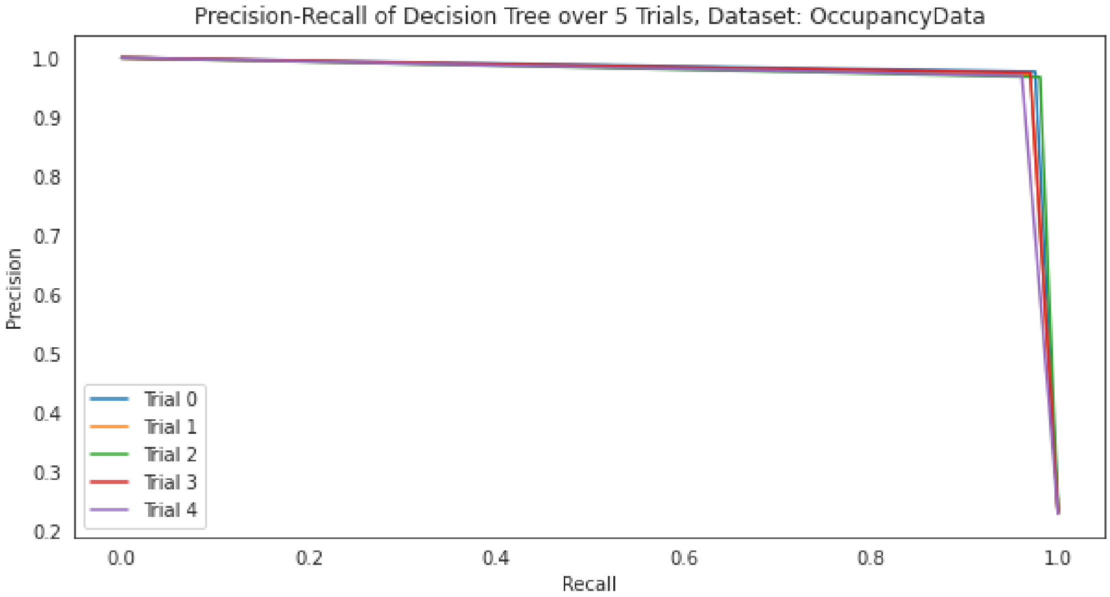

Accuracy Metric HeatMap of Decision Tree over 5 Trials, Dataset: HTRU2
criterion
entropy
gini
max_depth
1
2
3
4
5
0.976
0.976
0.976
0.975
0.975
0.976
0.975
0.976
0.977
0.976
0.9764
0.9762
0.9760
0.9758
0.9756
0.9754
0.9752
0.9750
0.9748

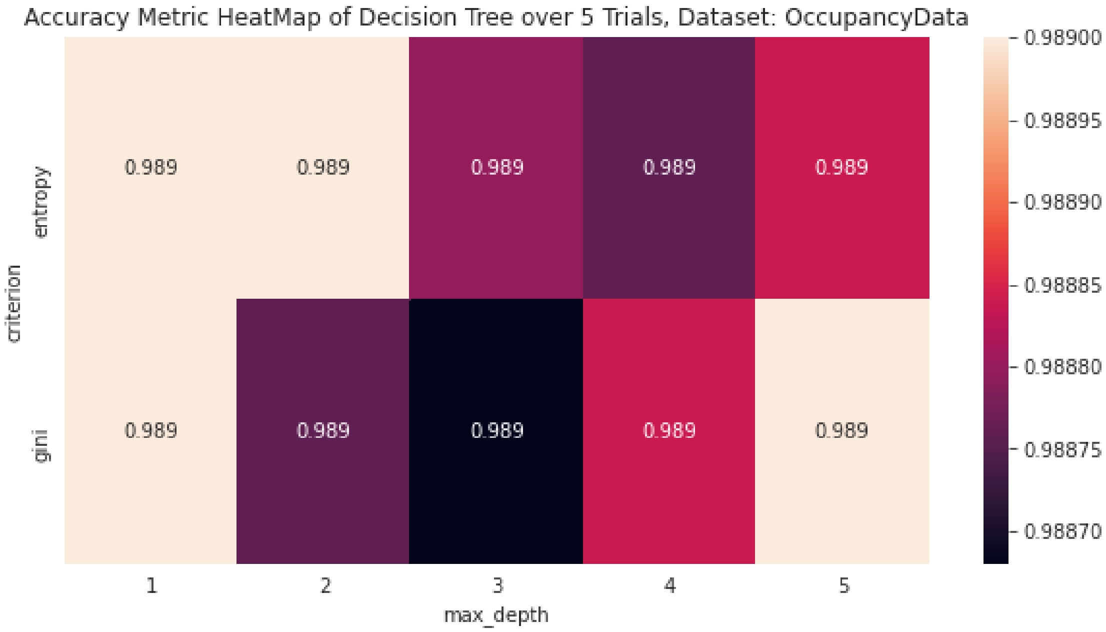

F1 Metric HeatMap of Decision Tree over 5 Trials, Dataset: HTRU2
criterion
entropy
gini
max_depth
1
2
3
4
5
0.866
0.865
0.861
0.855
0.860
0.861
0.858
0.862
0.867
0.861
0.866
0.864
0.862
0.860
0.858
0.856

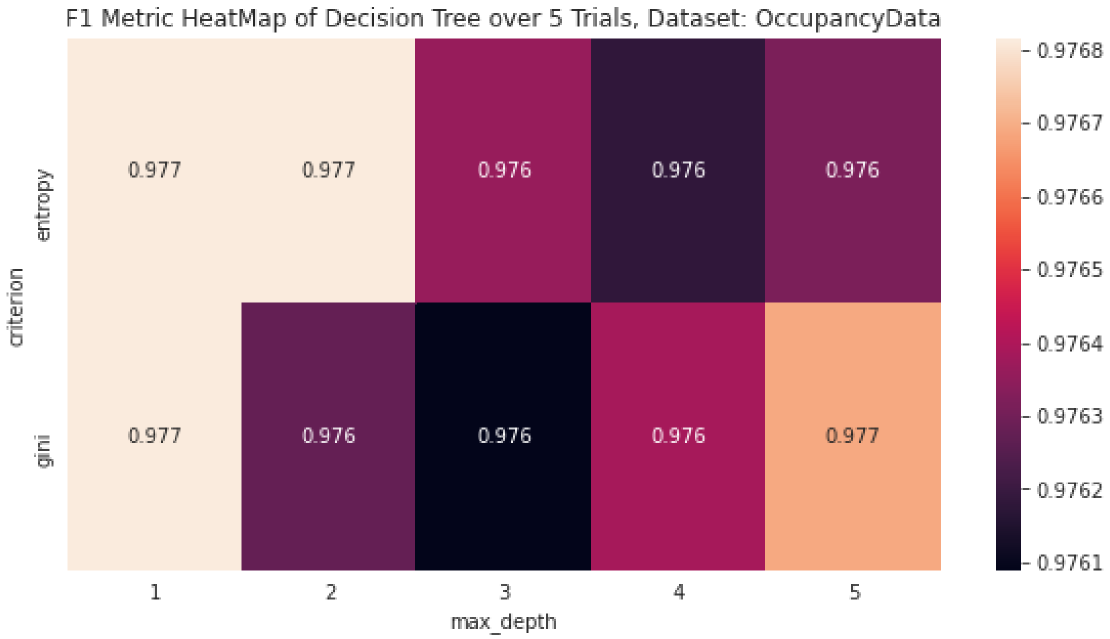


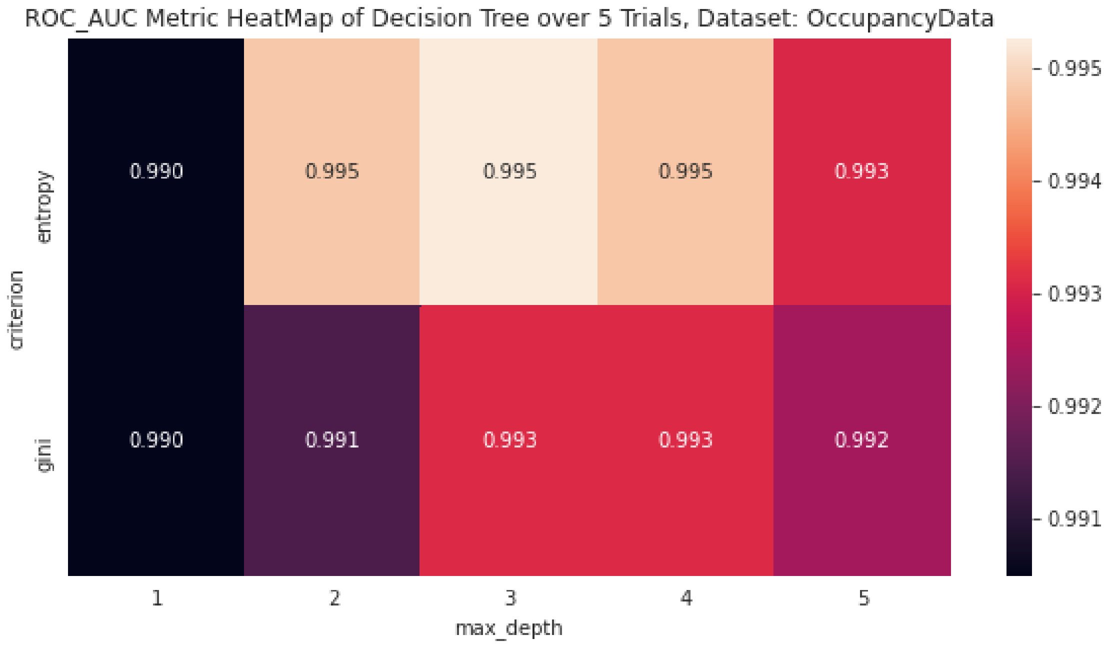
```
Starting Dataset #1
DataSet OccupancyData
[[0.98849614 0.97499651 0.98421307]
 [0.98663239 0.97029148 0.98093458]
 [0.98746787 0.97475302 0.98534599]
 [0.98701799 0.97356401 0.98126074]
 [0.98489717 0.96753247 0.97622932]]
```



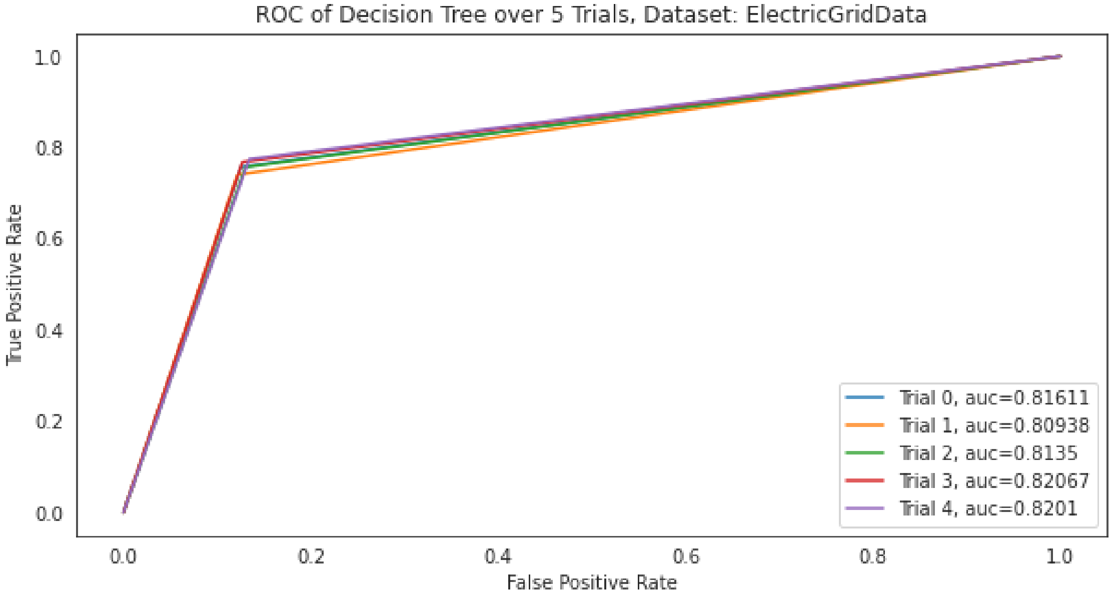

Precision-Recall of Decision Tree over 5 Trials, Dataset: OccupancyData
Precision
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Recall
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4

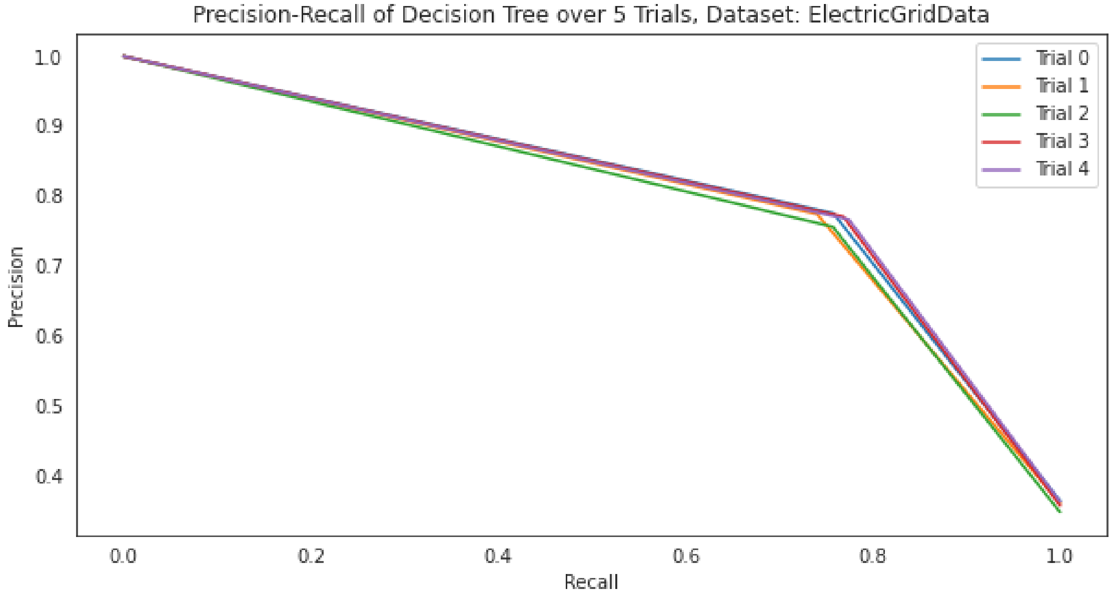

Accuracy Metric HeatMap of Decision Tree over 5 Trials, Dataset: OccupancyData
criterion
entropy
gini
0.989
0.989
0.989
0.989
0.989
0.989
0.989
0.989
0.989
0.989
max_depth
1
2
3
4
5
0.98900
0.98895
0.98890
0.98885
0.98880
0.98875
0.98870

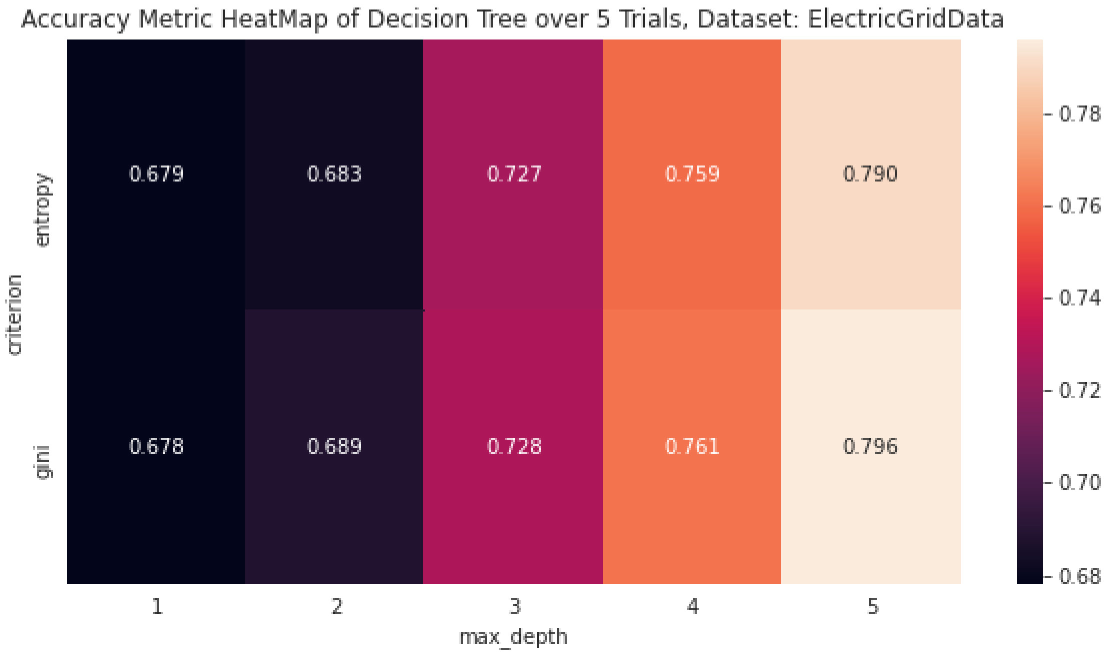


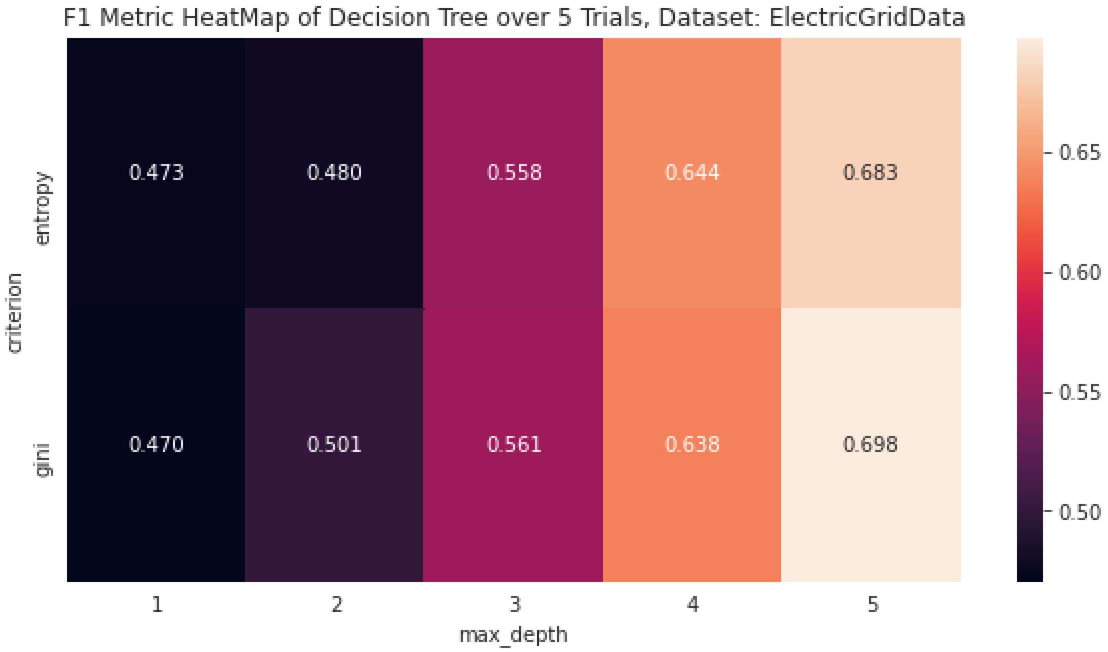


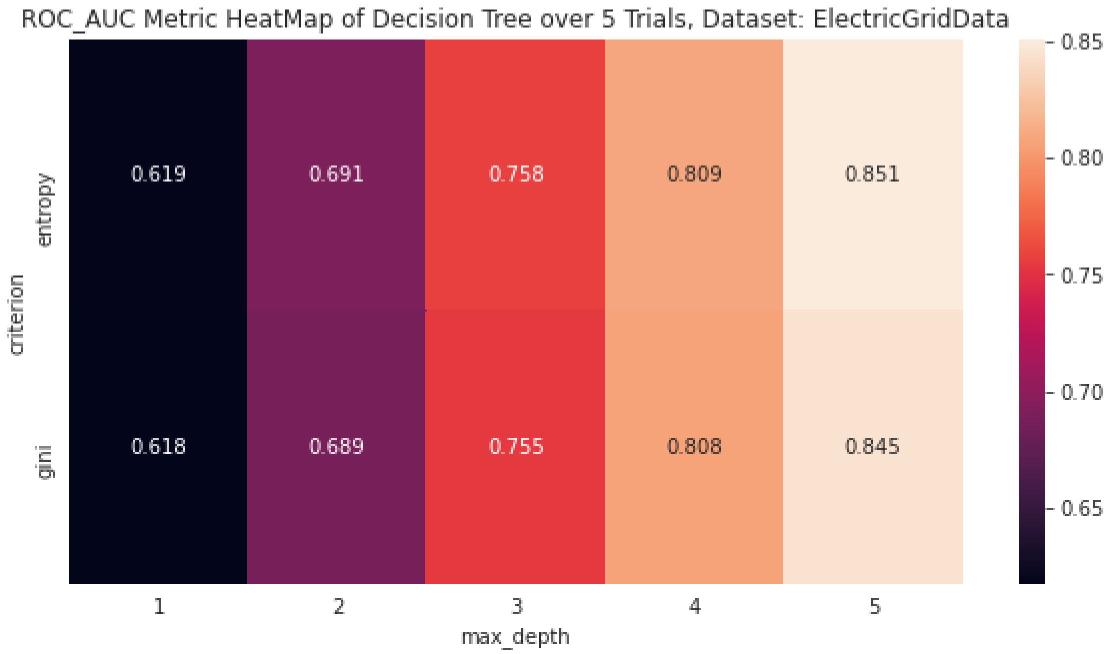
```
Starting Dataset #2
DataSet ElectricGridData
[[0.826      0.77188108 0.8161103 ]
 [0.8254     0.75912822 0.80937802]
 [0.8292     0.75476053 0.81350184]
 [0.8346     0.77529346 0.82067134]
 [0.8326     0.77348066 0.82009685]]
```



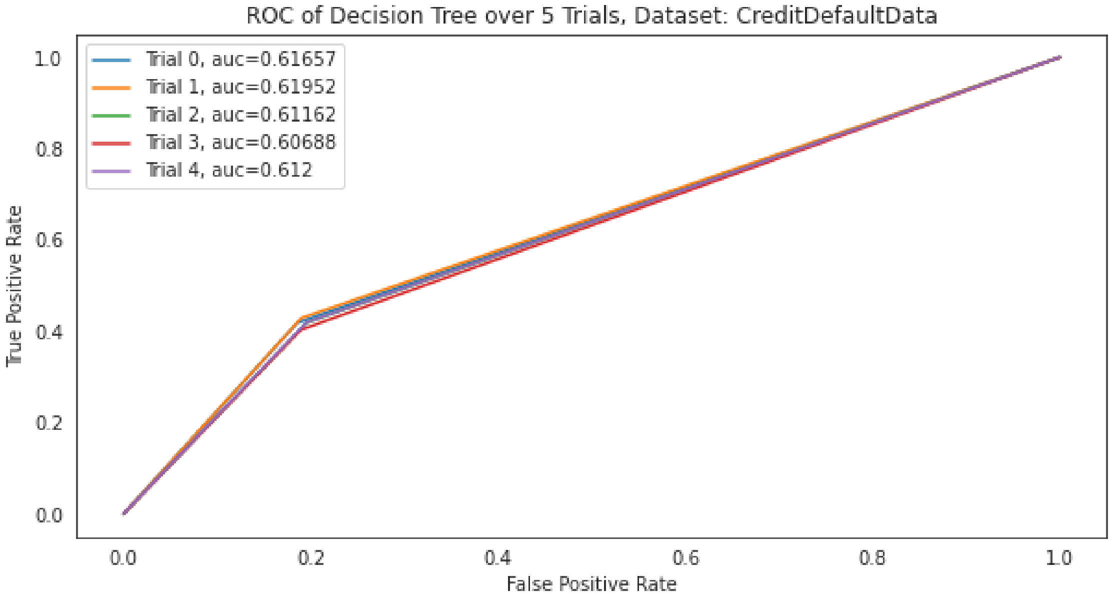


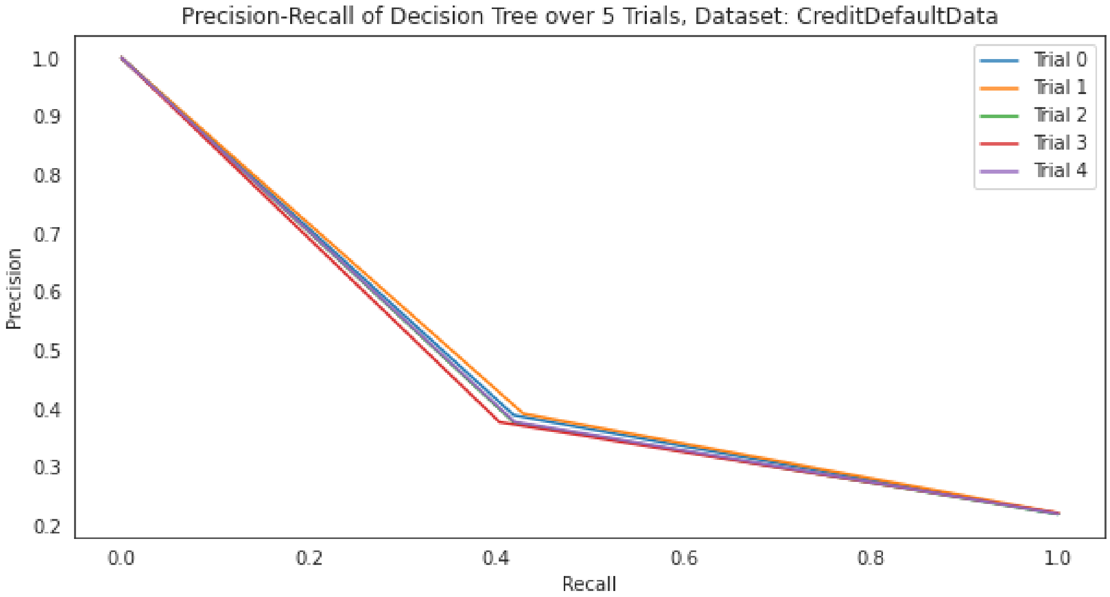

Accuracy Metric HeatMap of Decision Tree over 5 Trials, Dataset: ElectricGridData
criterion
entropy
gini
0.679
0.683
0.727
0.759
0.790
0.678
0.689
0.728
0.761
0.796
1
2
3
4
5
max_depth
0.78
0.76
0.74
0.72
0.70
0.68

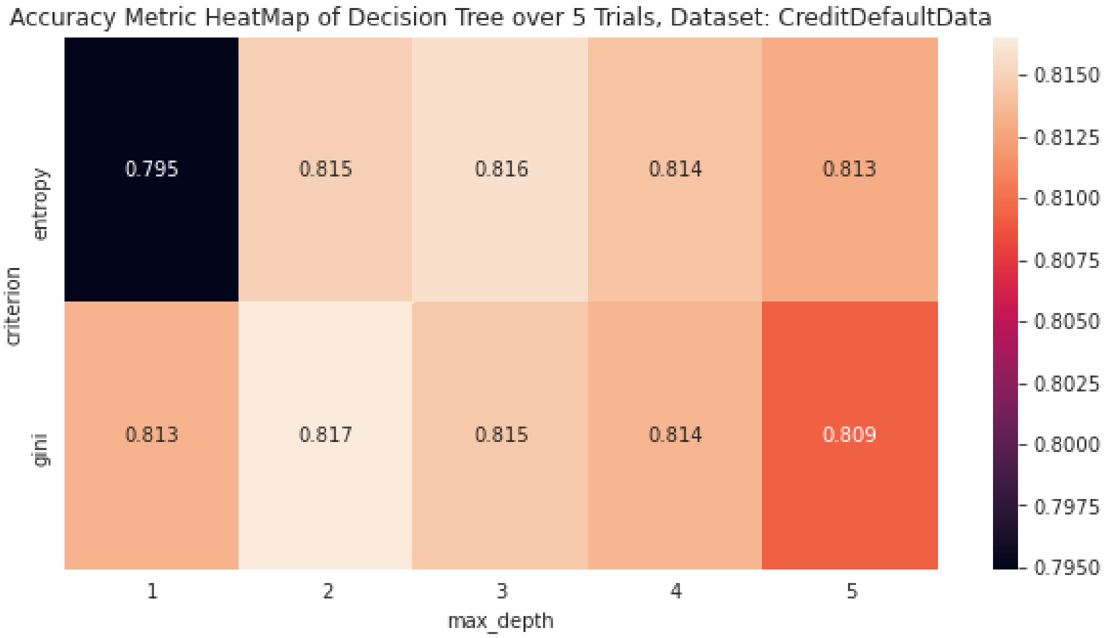

F1 Metric HeatMap of Decision Tree over 5 Trials, Dataset: ElectricGridData
criterion
entropy
gini
0.473
0.480
0.558
0.644
0.683
0.470
0.501
0.561
0.638
0.698
1
2
3
4
5
max_depth
0.65
0.60
0.55
0.50

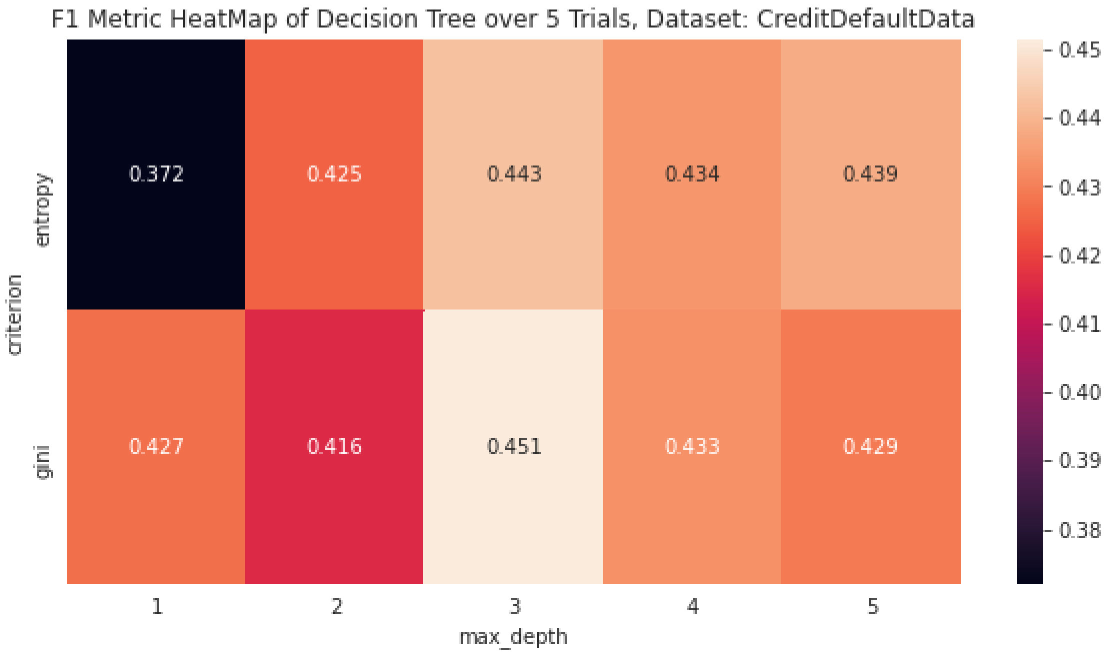


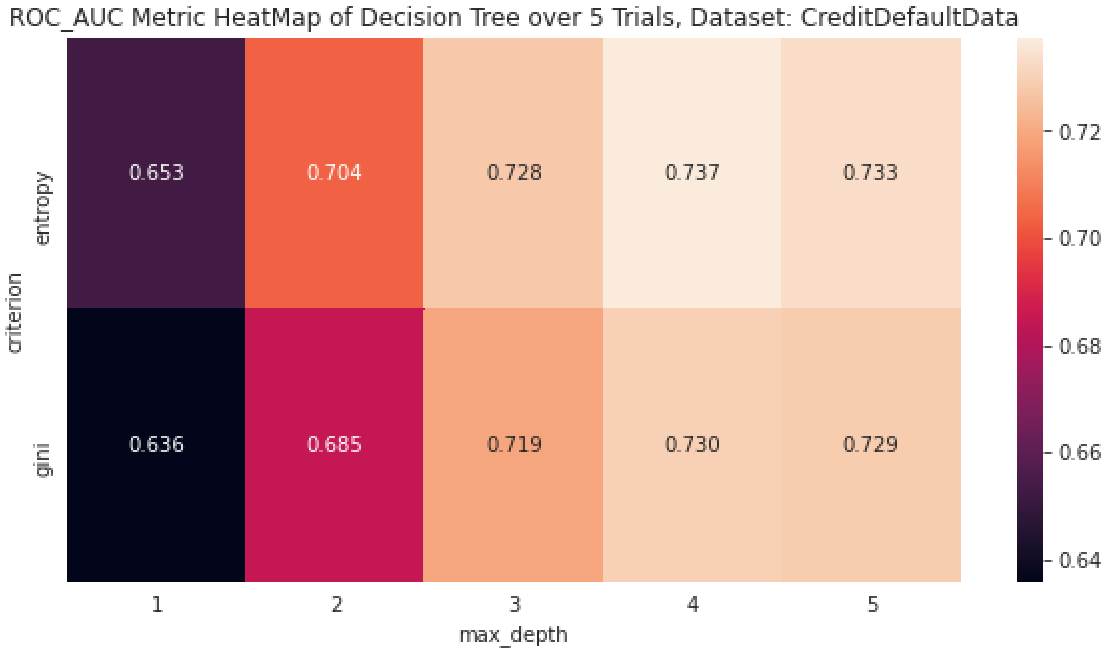
```
Starting Dataset #3
DataSet CreditDefaultData
[[0.72268    0.3991684  0.6165659 ]
 [0.7224     0.41087923 0.61951548]
 [0.71968    0.39592082 0.6116199 ]
 [0.72352    0.38895241 0.60688386]
 [0.72152    0.39323828 0.61200286]]
```




Precision-Recall of Decision Tree over 5 Trials, Dataset: CreditDefaultData
Precision
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Recall
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of Decision Tree over 5 Trials, Dataset: CreditDefaultData
criterion
entropy
gini
0.795
0.815
0.816
0.814
0.813
0.813
0.817
0.815
0.814
0.809
max_depth
1
2
3
4
5
0.8150
0.8125
0.8100
0.8075
0.8050
0.8025
0.8000
0.7975
0.7950


F1 Metric HeatMap of Decision Tree over 5 Trials, Dataset: CreditDefaultData


ROC_AUC Metric HeatMap of Decision Tree over 5 Trials, Dataset: CreditDefaultData

```
[[0.96797953 0.82167796 0.90802067]
 [0.98690231 0.9722275  0.98159674]
 [0.82956    0.76690879 0.81595167]
 [0.72196    0.39763183 0.6133176 ]]
```

```
CPU times: user 8.86 s, sys: 215 ms, total: 9.07 s
Wall time: 11.7 s
```

1.3 Running RandomForest

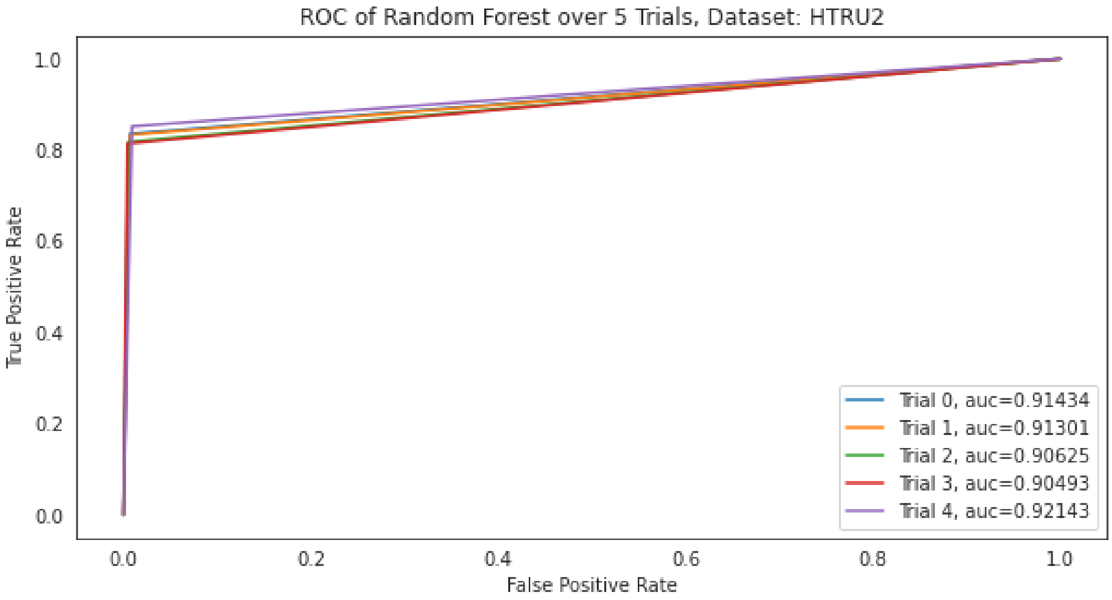
[15]:

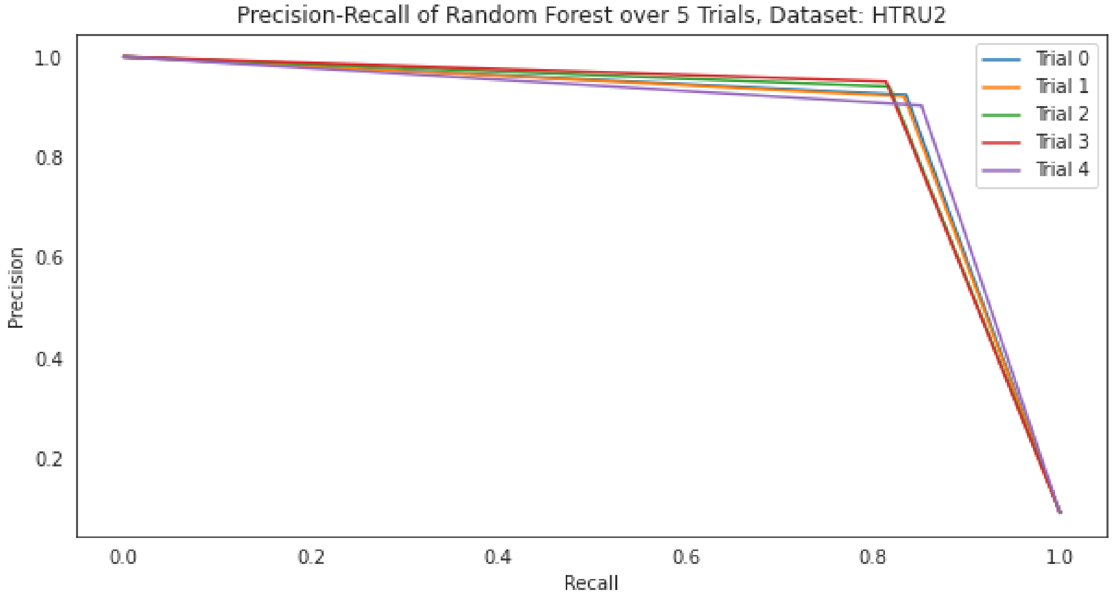
```
%%time

search_space = [{
                 'criterion': ['gini','entropy'],
                 'max_features': [1,2,4,6,8,12,16,20],
                }]

# Function to pass in hyperparameters later
def RandomForest_create(self, **kwargs):
    return RandomForestClassifier(**kwargs)


all_trials_RandomForest = []
all_trials_train_Tree_RandomForest = []
all_gridsearch_trials_RandomForest = []

RandomForest_algorithm_results = np.zeros([4, 3])
RandomForest_results_training = np.zeros([4, 3])

for idx, dataset in enumerate(DatasetList):
    print("Starting Dataset #" + str(idx))
    trial_results = np.zeros([5, 3])
    trial_results_training = np.zeros([5, 3])

    plt.figure(0, figsize=(10,5)).clf()
    plt.figure(1, figsize=(10,5)).clf()
    plt.figure(2, figsize=(10,5)).clf()
    plt.figure(3, figsize=(10,5)).clf()
    plt.figure(4, figsize=(10,5)).clf()

    gridsearch_trials_RandomForest = []

    for trial in range(5):

        #Creating new data split and grid searching for params

        X_train, X_test, y_train, y_test = train_test_split(
        dataset.iloc[:,:-1], dataset.iloc[:,-1:], train_size=5000)

        clf = GridSearchCV(estimator = RandomForestClassifier(), param_grid =␣
↪search_space, cv=StratifiedKFold(n_splits=5),
                    scoring=['accuracy', 'f1', 'roc_auc'], refit=False,
                   verbose=0, n_jobs = -1)

        best_model = clf.fit(X_train, y_train)

        #Accuracy
        Accuracy_index = np.argmin(best_model.cv_results_['rank_test_accuracy'])
        Accuracy_param = clf.cv_results_['params'][Accuracy_index]
        Accuracy_model = RandomForest_create(Accuracy_param).fit(X_train,␣
↪y_train)
        y_predict = Accuracy_model.predict(X_test)
        train_predict = Accuracy_model.predict(X_train)
        trial_results_training[trial][0] = accuracy_score(y_train,␣
↪train_predict)
        trial_results[trial][0] = accuracy_score(y_test, y_predict)

        #F1
        F1_index = np.argmin(best_model.cv_results_['rank_test_f1'])
        F1_param = clf.cv_results_['params'][F1_index]
        F1_model = RandomForest_create(F1_param).fit(X_train, y_train)
        y_predict = F1_model.predict(X_test)
        train_predict = F1_model.predict(X_train)
        trial_results_training[trial][1] = f1_score(y_train, train_predict)
        trial_results[trial][1] = f1_score(y_test, y_predict)

        #AUC
        AUC_index = np.argmin(best_model.cv_results_['rank_test_roc_auc'])
        AUC_param = clf.cv_results_['params'][AUC_index]
        AUC_model = RandomForest_create(AUC_param).fit(X_train, y_train)
        train_predict = AUC_model.predict(X_train)
        y_predict = AUC_model.predict(X_test)
        trial_results_training[trial][2] = roc_auc_score(y_train, train_predict)
        trial_results[trial][2] = roc_auc_score(y_test, y_predict)

        #Performances during hyperparameter search
        results = pd.DataFrame( best_model.cv_results_['params'] )
        results['accuracy'] = best_model.cv_results_['mean_test_accuracy']
        results['f1'] = best_model.cv_results_['mean_test_f1']
        results['roc_auc'] = best_model.cv_results_['mean_test_roc_auc']
        gridsearch_trials_RandomForest.append(results)

        #Plotting curves for each trial
        plt.figure(0)
        fpr, tpr, thresh = roc_curve(y_test, y_predict)
        plt.plot(fpr,tpr,label="Trial " + str(trial) + ",␣
↪auc="+str(round(trial_results[trial][2], 5)))

        plt.figure(1)
        precision, recall, thresholds = precision_recall_curve(y_test,␣
↪y_predict)
        plt.plot(recall,precision,label="Trial " + str(trial))

    print("DataSet " + DatasetNames[idx])
    print(trial_results)

    #Creating graphics and saving to file

    plt.figure(0)
    plt.title('ROC of Random Forest over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.legend(loc=0)
    plt.savefig('./ROC_Graphs/Random_Forest_ROC_Dataset:'+ DatasetNames[idx]+'.
↪png')

    plt.figure(1)
    plt.title('Precision-Recall of Random Forest over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.xlabel('Recall')
    plt.ylabel('Precision')
    plt.legend(loc=0)
    plt.savefig('./PR_Graphs/Random_Forest_PR_Dataset:'+ DatasetNames[idx]+'.
↪png')

    all_gridsearch_trials_RandomForest.append(gridsearch_trials_RandomForest)
    avg_gridsearch = pd.concat(gridsearch_trials_RandomForest).
↪groupby(['classifier'],level=0).agg(
        {'criterion':'first', 'max_features':'first', 'accuracy':'mean', 'f1':
↪'mean', 'roc_auc':'mean'})


    plt.figure(2)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('criterion','max_features','accuracy'),
             annot=True, fmt='.3f')
    plt.title('Accuracy Metric HeatMap of Random Forest over 5 Trials, Dataset:␣
↪' + DatasetNames[idx])
    plt.savefig('./Accuracy_HeatMaps/Random_Forest_Dataset:'+␣
↪DatasetNames[idx]+'.png')

    plt.figure(3)
    sns.heatmap( avg_gridsearch.dropna().pivot('criterion','max_features','f1'),
             annot=True, fmt='.3f')
    plt.title('F1 Metric HeatMap of Random Forest over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.savefig('./F1_HeatMaps/Random_Forest_Dataset:'+ DatasetNames[idx]+'.
↪png')

    plt.figure(4)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('criterion','max_features','roc_auc'),
              annot=True, fmt='.3f')
    plt.title('ROC_AUC Metric HeatMap of Random Forest over 5 Trials, Dataset:␣
↪' + DatasetNames[idx])
    plt.savefig('./ROC_HeatMaps/Random_Forest_Dataset:'+ DatasetNames[idx]+'.
↪png')

    plt.show()

    #Adding results to data arrays for later analysis

    all_trials_RandomForest.append(trial_results)
    all_trials_train_Tree_RandomForest.append(trial_results_training)

    RandomForest_algorithm_results[idx] = np.mean(trial_results, axis = 0)
    RandomForest_results_training[idx] = np.mean(trial_results_training, axis =␣
↪0)


print(RandomForest_algorithm_results)
```

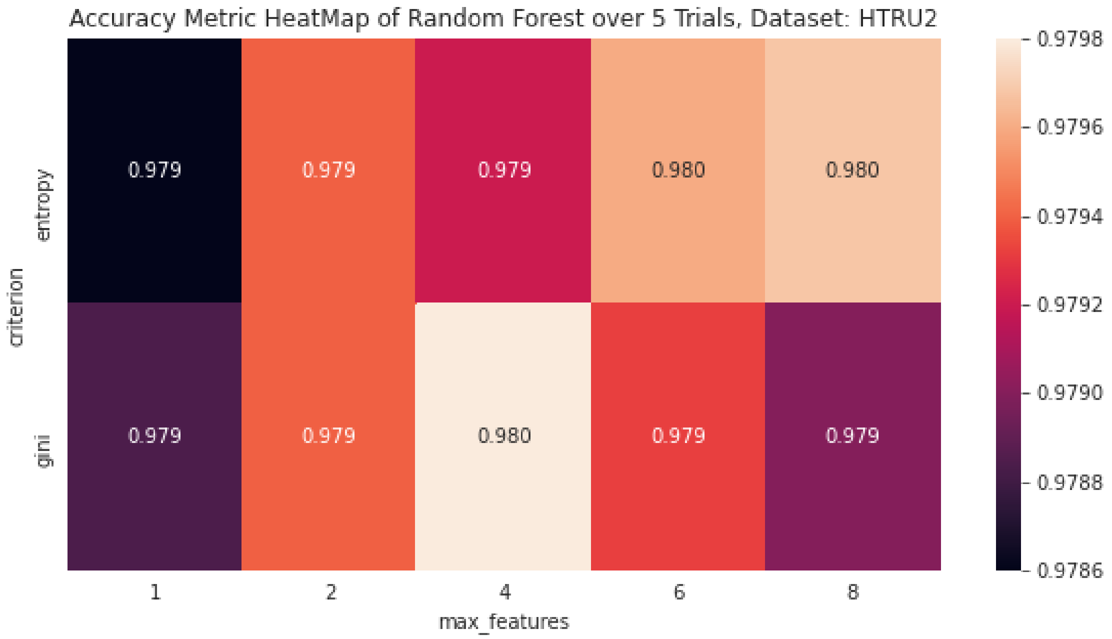
```
Starting Dataset #0

<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
```

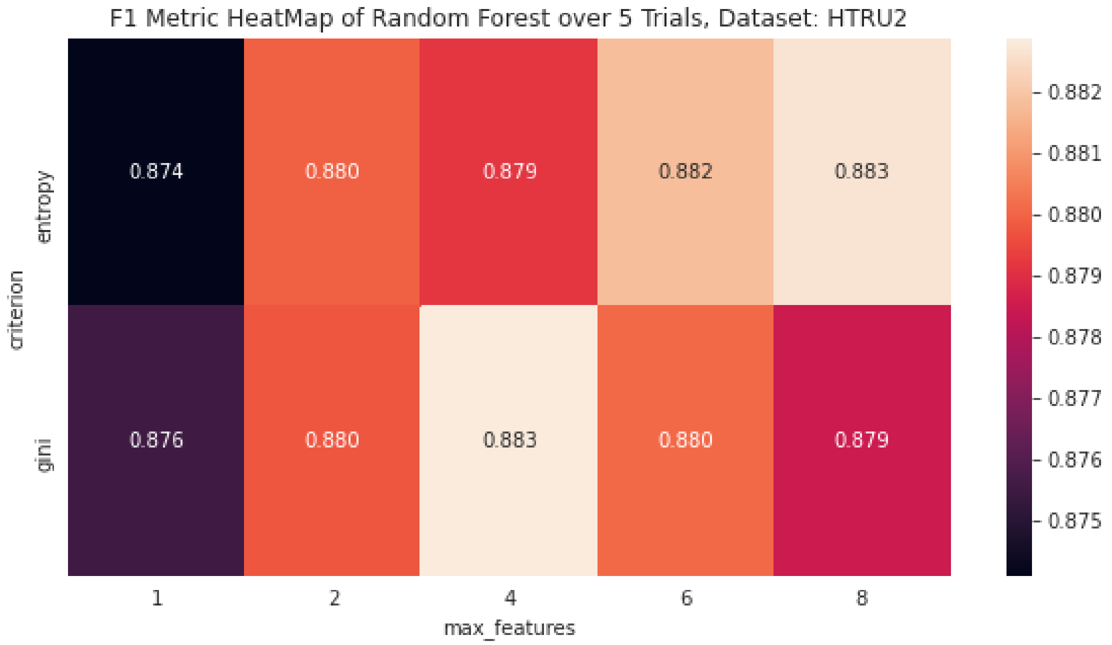
```
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
```

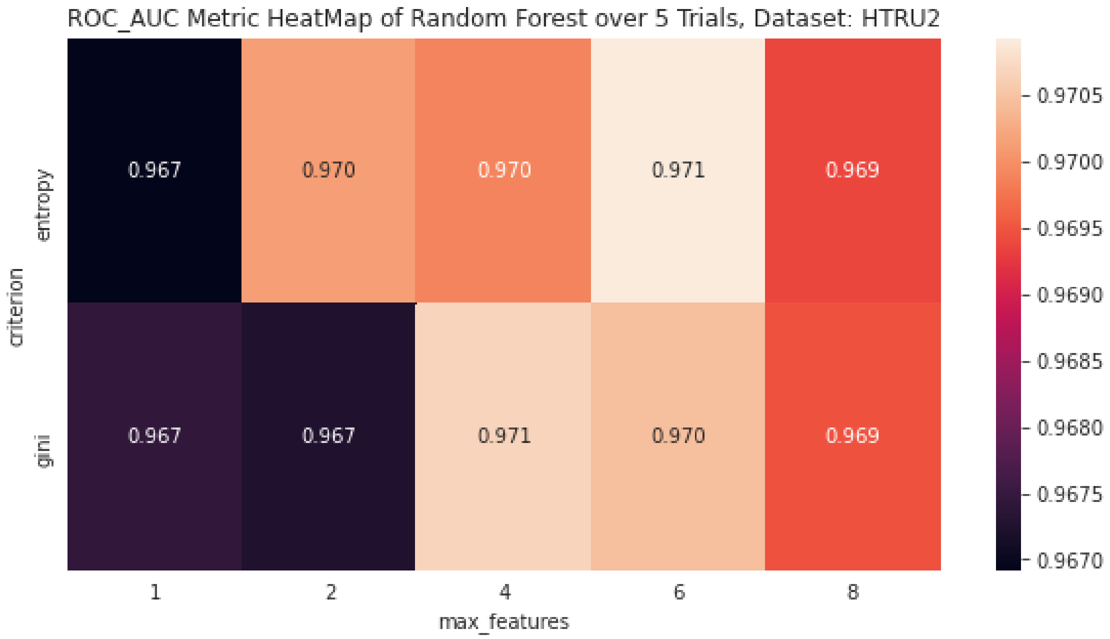
```
DataSet HTRU2
[[0.97836874 0.87683415 0.91434039]
 [0.97813615 0.87567084 0.91301157]
 [0.97860133 0.87778769 0.90625135]
 [0.97968677 0.87771739 0.90492965]
 [0.97774849 0.87668845 0.92142603]]
```


ROC of Random Forest over 5 Trials, Dataset: HTRU2
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0, auc=0.91434
Trial 1, auc=0.91301
Trial 2, auc=0.90625
Trial 3, auc=0.90493
Trial 4, auc=0.92143


Precision-Recall of Random Forest over 5 Trials, Dataset: HTRU2
Precision
Recall
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of Random Forest over 5 Trials, Dataset: HTRU2
criterion
entropy
gini
0.979
0.979
0.979
0.980
0.980
0.979
0.979
0.980
0.979
0.979
1
2
4
6
8
max_features
0.9798
0.9796
0.9794
0.9792
0.9790
0.9788
0.9786


F1 Metric HeatMap of Random Forest over 5 Trials, Dataset: HTRU2
criterion
entropy
gini
0.874
0.880
0.879
0.882
0.883
0.876
0.880
0.883
0.880
0.879
1
2
4
6
8
max_features
0.882
0.881
0.880
0.879
0.878
0.877
0.876
0.875

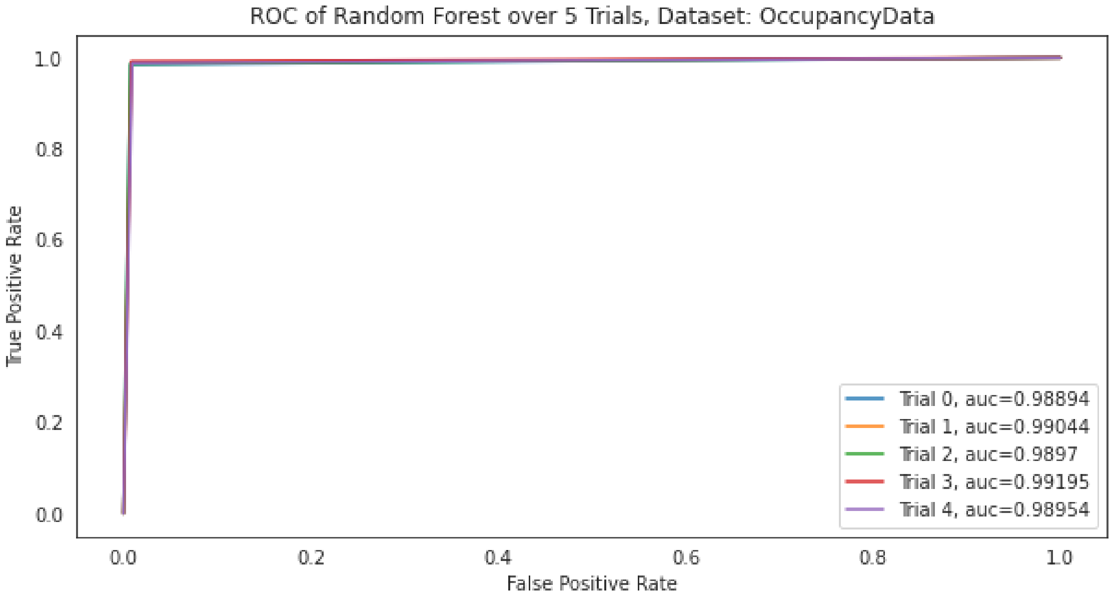


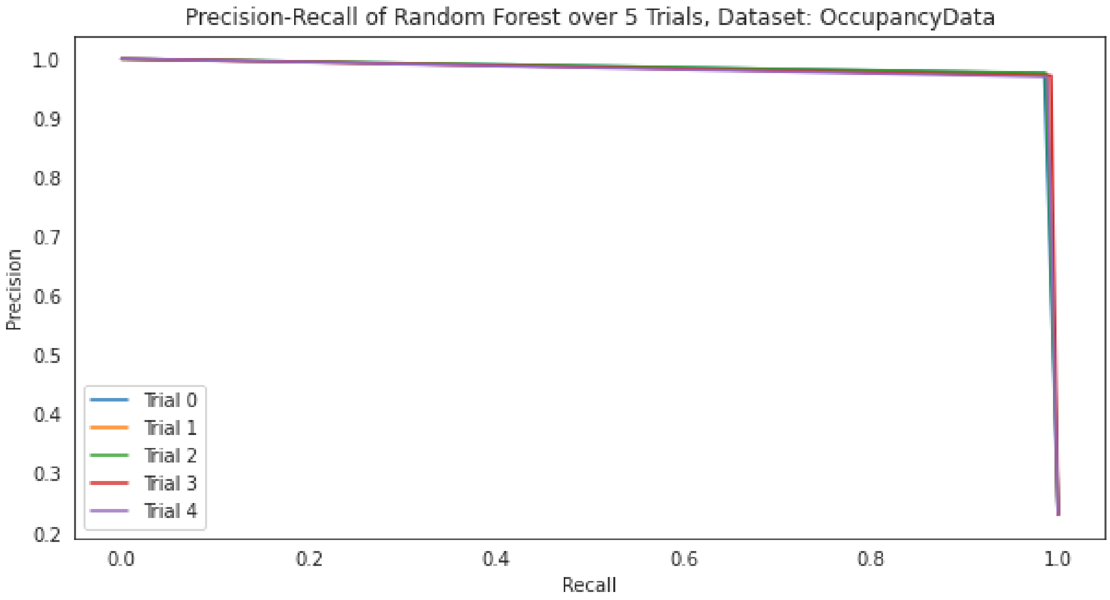
```
Starting Dataset #1
```

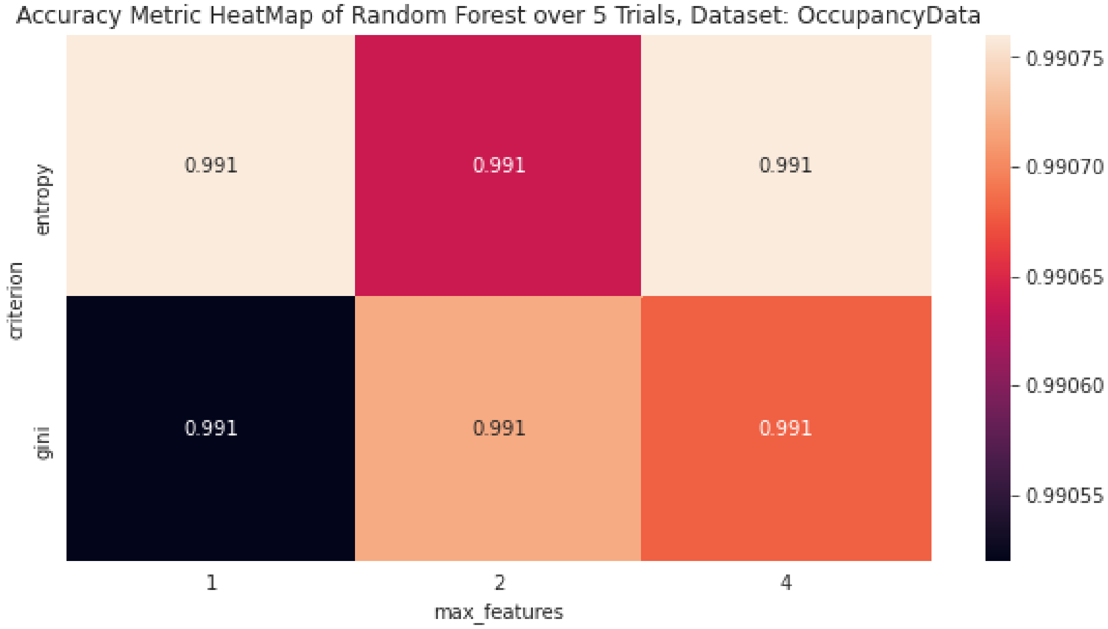
```
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
```

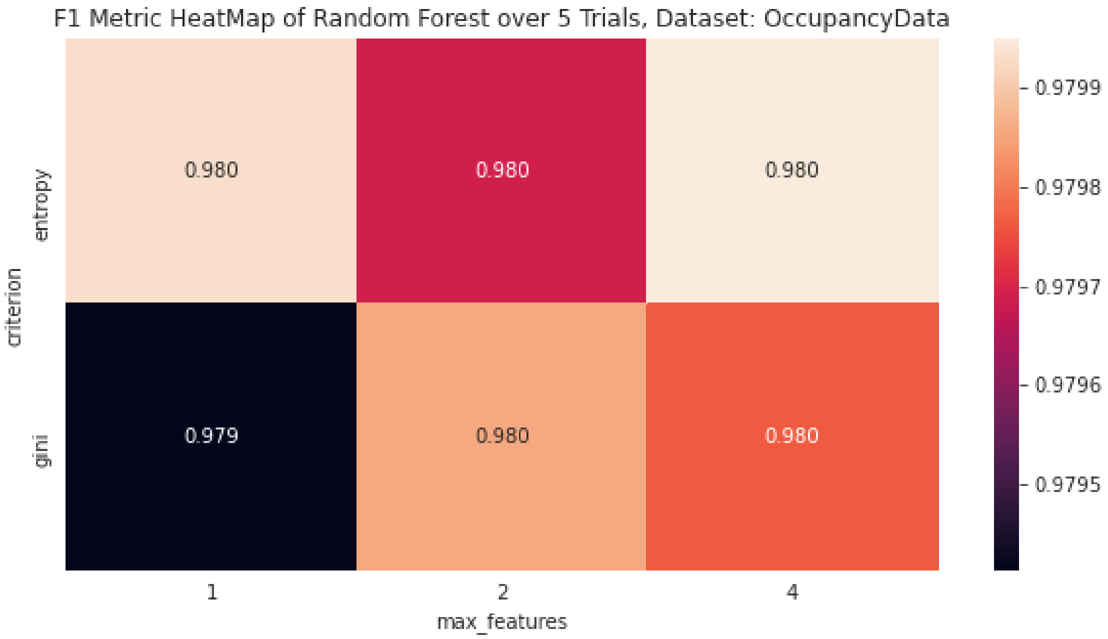
```
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
```

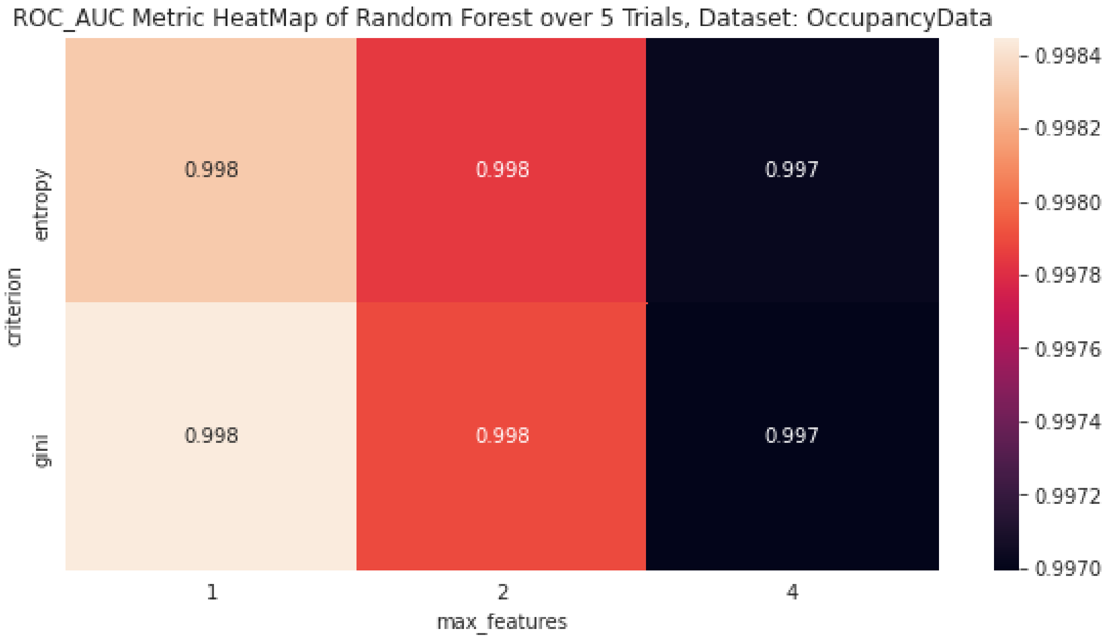
```
DataSet OccupancyData
[[0.9907455  0.98044616 0.98894402]
 [0.99132391 0.980679   0.99043641]
 [0.99125964 0.9808114  0.98969571]
 [0.99170951 0.98199808 0.99194534]
 [0.98978149 0.97847841 0.9895397 ]]
```




Precision-Recall of Random Forest over 5 Trials, Dataset: OccupancyData
Precision
Recall
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4

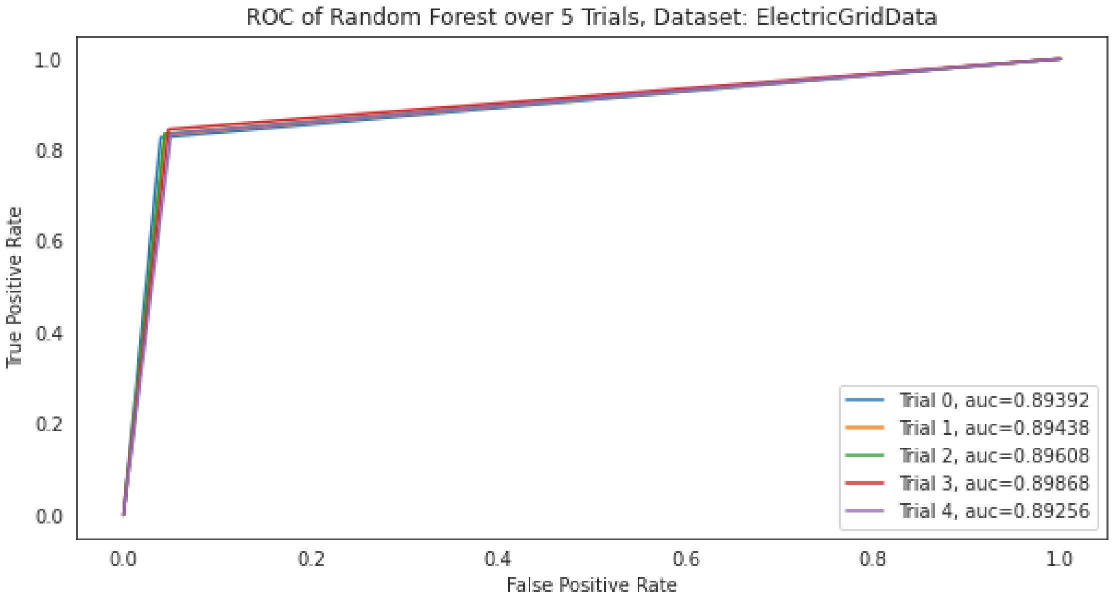

Accuracy Metric HeatMap of Random Forest over 5 Trials, Dataset: OccupancyData
criterion
entropy
gini
max_features
1
2
4
0.991
0.991
0.991
0.991
0.991
0.991
0.99075
0.99070
0.99065
0.99060
0.99055

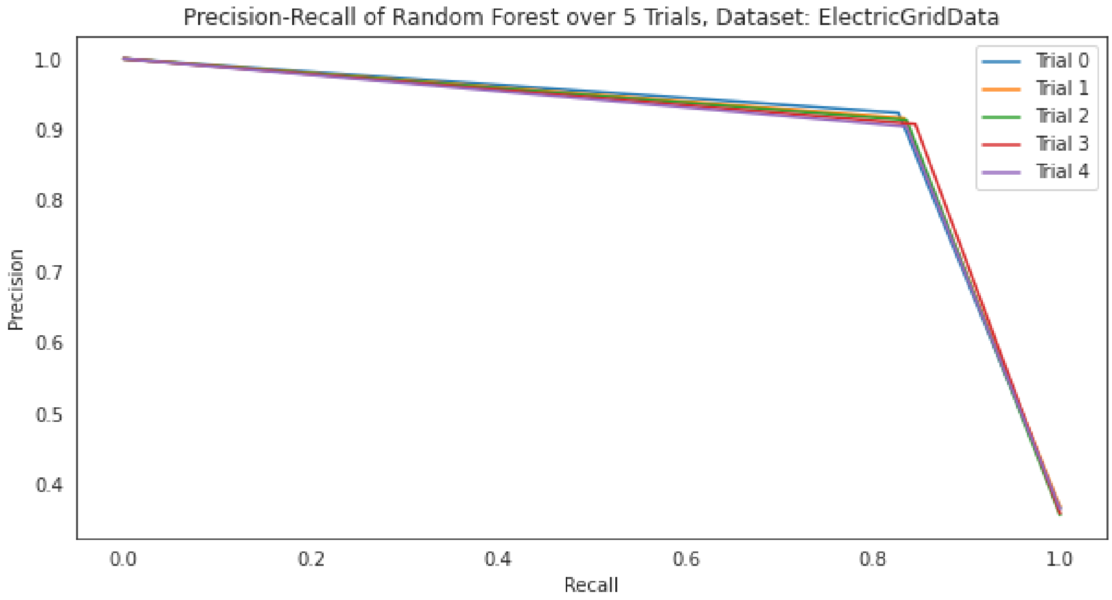


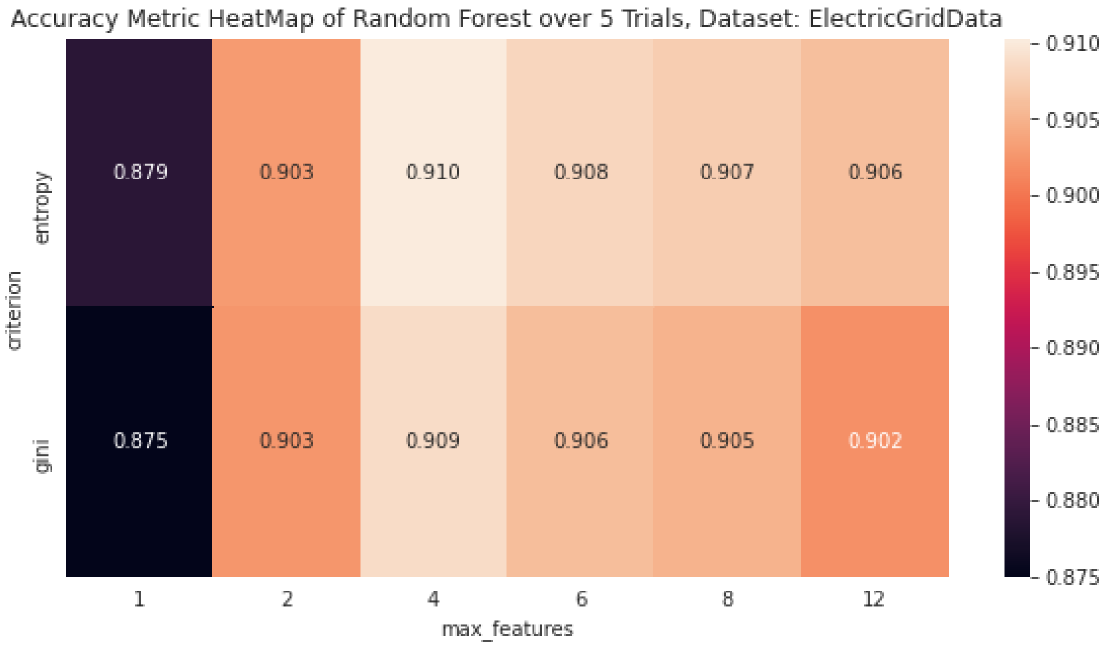


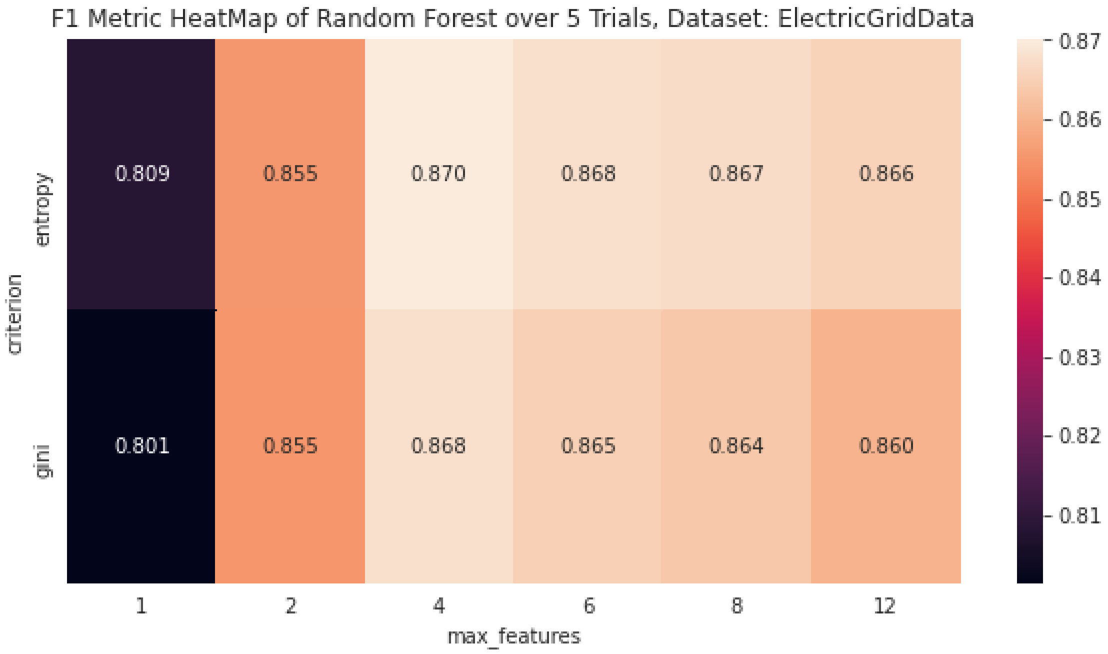
```
Starting Dataset #2

<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
```

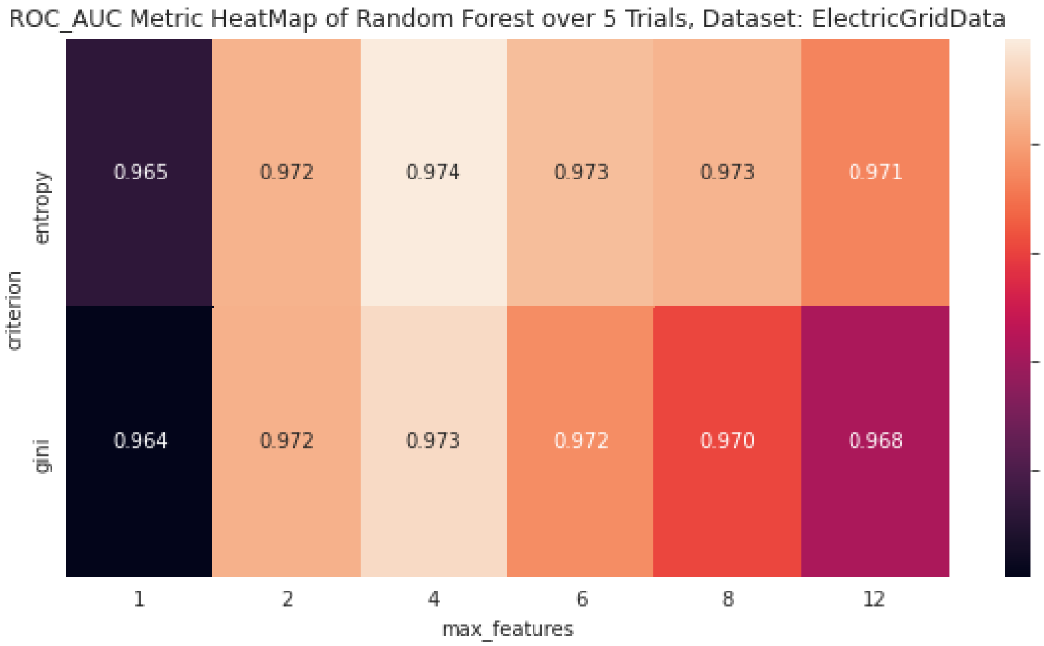
```
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().

DataSet ElectricGridData
[[0.9096     0.86565454 0.89391755]
 [0.9102     0.87365439 0.89438234]
 [0.9152     0.86964233 0.89607692]
 [0.9164     0.8771223  0.89867987]
 [0.9114     0.86956522 0.8925648 ]]
```


ROC of Random Forest over 5 Trials, Dataset: ElectricGridData
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0, auc=0.89392
Trial 1, auc=0.89438
Trial 2, auc=0.89608
Trial 3, auc=0.89868
Trial 4, auc=0.89256


Precision-Recall of Random Forest over 5 Trials, Dataset: ElectricGridData
Precision
Recall
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of Random Forest over 5 Trials, Dataset: ElectricGridData
criterion
entropy
gini
0.879
0.903
0.910
0.908
0.907
0.906
0.875
0.903
0.909
0.906
0.905
0.902
1
2
4
6
8
12
max_features
0.910
0.905
0.900
0.895
0.890
0.885
0.880
0.875

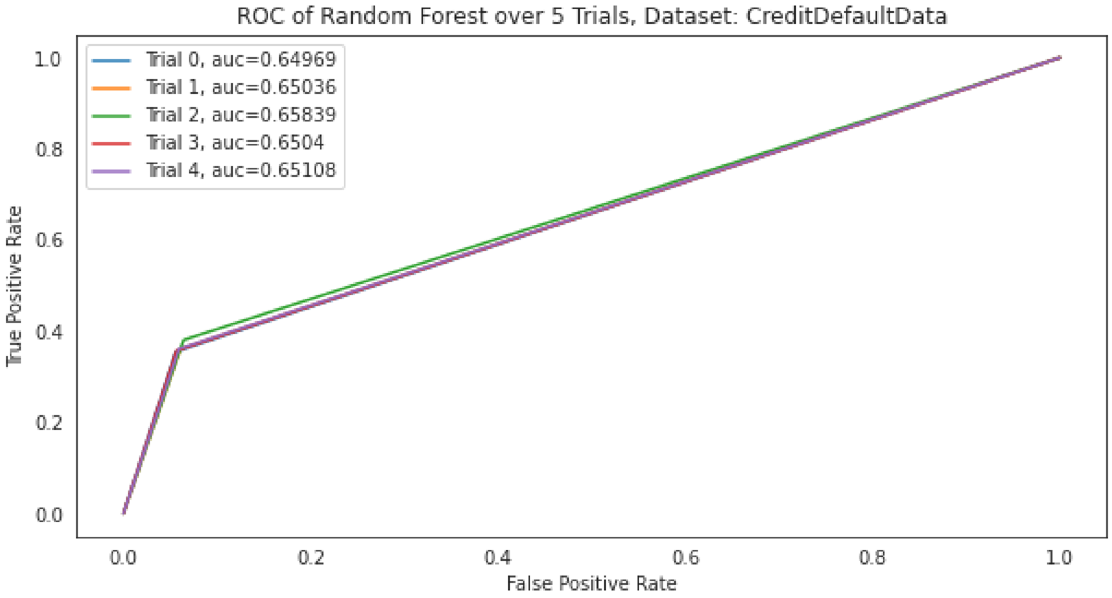

F1 Metric HeatMap of Random Forest over 5 Trials, Dataset: ElectricGridData
criterion
entropy
gini
0.809
0.855
0.870
0.868
0.867
0.866
0.801
0.855
0.868
0.865
0.864
0.860
1
2
4
6
8
12
max_features
0.87
0.86
0.85
0.84
0.83
0.82
0.81

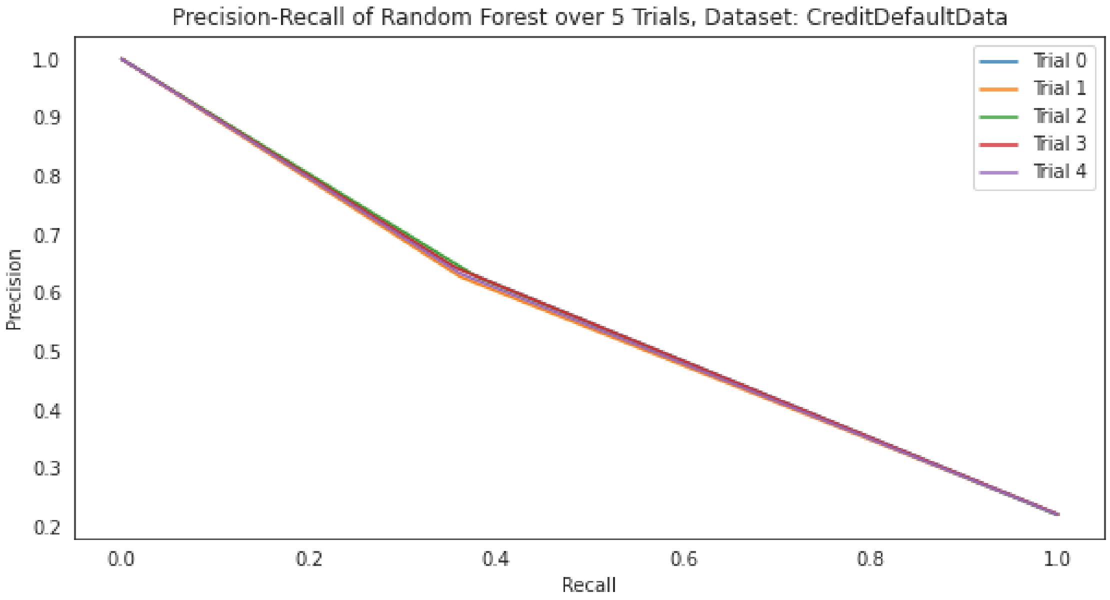


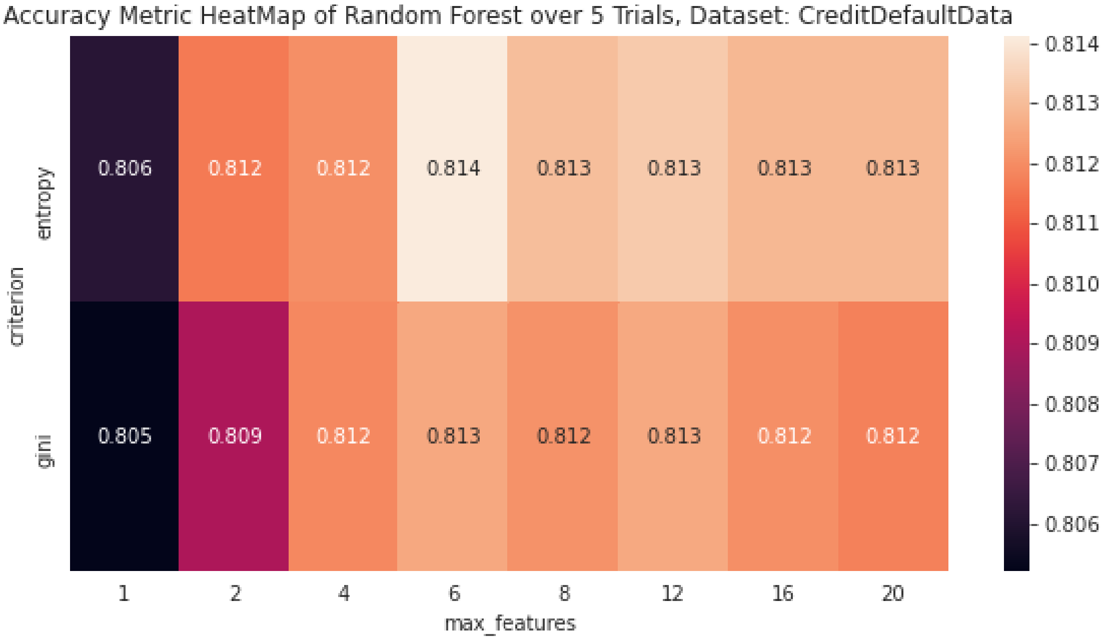
```
Starting Dataset #3

<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
```

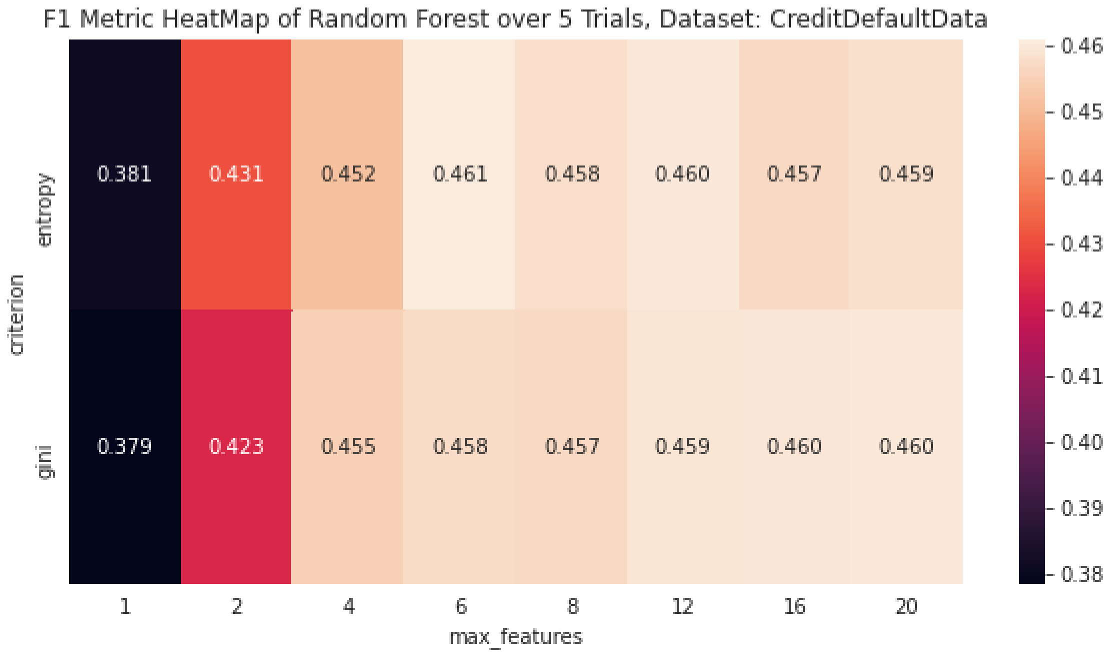
```
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:44: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:53: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
<timed exec>:62: DataConversionWarning: A column-vector y was passed when a 1d
array was expected. Please change the shape of y to (n_samples,), for example
using ravel().
```

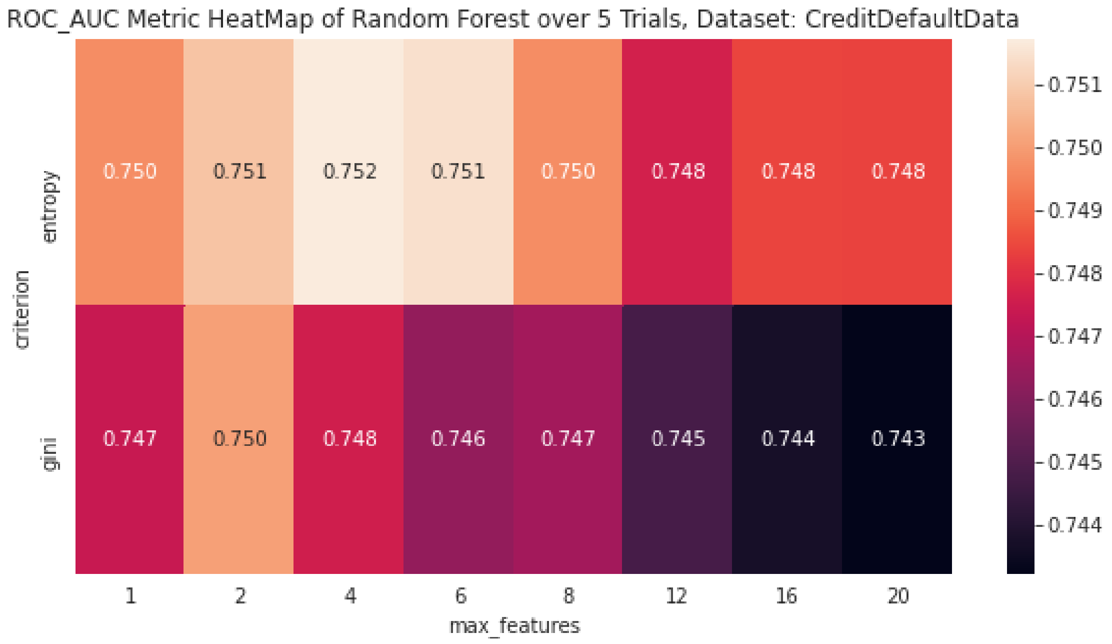
```
DataSet CreditDefaultData
[[0.813      0.45705664 0.64969101]
 [0.81128    0.45351264 0.65036322]
 [0.81332    0.47281001 0.65838867]
 [0.81396    0.45200373 0.65040069]
 [0.8118     0.46413019 0.65108406]]
```




Precision-Recall of Random Forest over 5 Trials, Dataset: CreditDefaultData
Precision
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Recall
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of Random Forest over 5 Trials, Dataset: CreditDefaultData
criterion
entropy
gini
max_features
1
2
4
6
8
12
16
20
0.806
0.812
0.812
0.814
0.813
0.813
0.813
0.813
0.805
0.809
0.812
0.813
0.812
0.813
0.812
0.812
0.814
0.813
0.812
0.811
0.810
0.809
0.808
0.807
0.806





```
[[0.9785083  0.8769397  0.9119918 ]
 [0.99096401 0.98048261 0.99011224]
 [0.91256    0.87112776 0.89512429]
 [0.812672   0.45990264 0.65198553]]
CPU times: user 58 s, sys: 612 ms, total: 58.6 s
```

```
Wall time: 3min 49s
```

1.4 Running Multilayer Perceptron Network

[16]:

```
%%time
pipe = Pipeline([('std', StandardScaler()),
                 ('classifier', MLPClassifier(max_iter=2000))])

search_space = [{'classifier': [MLPClassifier(max_iter=2000)],
                 'classifier__solver': ['adam'],
                 'classifier__hidden_layer_sizes': [1,2,4,8,32,128],
                 'classifier__alpha': np.logspace(-8, 4, 13)
                }]

# Function to pass in hyperparameters later
def MLP_create(self, **kwargs):
    return make_pipeline(StandardScaler(),
                         MLPClassifier(**kwargs, max_iter=2000))

all_trials_MLP = []
all_trials_train_MLP = []
all_gridsearch_trials_MLP = []

MLP_algorithm_results = np.zeros([4, 3])
MLP_algorithm_results_training = np.zeros([4, 3])

for idx, dataset in enumerate(DatasetList):
    print("Starting Dataset #" + str(idx))
    trial_results = np.zeros([5, 3])
    trial_results_training = np.zeros([5, 3])

    plt.figure(0, figsize=(10,5)).clf()
    plt.figure(1, figsize=(10,5)).clf()
    plt.figure(2, figsize=(10,5)).clf()
    plt.figure(3, figsize=(10,5)).clf()
    plt.figure(4, figsize=(10,5)).clf()

    gridsearch_trials_MLP = []

    for trial in range(5):

        #Creating new data split and grid searching for params

        X_train, X_test, y_train, y_test = train_test_split(
        dataset.iloc[:,:-1], dataset.iloc[:,-1:], train_size=5000)

        clf = GridSearchCV(pipe, search_space, cv=StratifiedKFold(n_splits=5),
                   scoring=['accuracy', 'f1', 'roc_auc'], refit=False,
                   verbose=0, n_jobs = -1)

        best_model = clf.fit(X_train, y_train)

        #Accuracy
        Accuracy_index = np.argmin(best_model.cv_results_['rank_test_accuracy'])
        Accuracy_param = clf.cv_results_['params'][Accuracy_index]
        Accuracy_model = MLP_create(Accuracy_param).fit(X_train, y_train)
        y_predict = Accuracy_model.predict(X_test)
        train_predict = Accuracy_model.predict(X_train)
        trial_results_training[trial][0] = accuracy_score(y_train,␣
↪train_predict)
        trial_results[trial][0] = accuracy_score(y_test, y_predict)

        #F1
        F1_index = np.argmin(best_model.cv_results_['rank_test_f1'])
        F1_param = clf.cv_results_['params'][F1_index]
        F1_model = MLP_create(F1_param).fit(X_train, y_train)
        y_predict = F1_model.predict(X_test)
        train_predict = F1_model.predict(X_train)
        trial_results_training[trial][1] = f1_score(y_train, train_predict)
        trial_results[trial][1] = f1_score(y_test, y_predict)

        #AUC
        AUC_index = np.argmin(best_model.cv_results_['rank_test_roc_auc'])
        AUC_param = clf.cv_results_['params'][AUC_index]
        AUC_model = MLP_create(AUC_param).fit(X_train, y_train)
        train_predict = AUC_model.predict(X_train)
        y_predict = AUC_model.predict(X_test)
        trial_results_training[trial][2] = roc_auc_score(y_train, train_predict)
        trial_results[trial][2] = roc_auc_score(y_test, y_predict)

        #Performances during hyperparameter search
        results = pd.DataFrame( best_model.cv_results_['params'] )
        results['accuracy'] = best_model.cv_results_['mean_test_accuracy']
        results['f1'] = best_model.cv_results_['mean_test_f1']
        results['roc_auc'] = best_model.cv_results_['mean_test_roc_auc']
        gridsearch_trials_MLP.append(results)

        #Plotting curves for each trial
        plt.figure(0)
        fpr, tpr, thresh = roc_curve(y_test, y_predict)
        plt.plot(fpr,tpr,label="Trial " + str(trial) + ",␣
↪auc="+str(round(trial_results[trial][2], 5)))

        plt.figure(1)
        precision, recall, thresholds = precision_recall_curve(y_test,␣
↪y_predict)
        plt.plot(recall,precision,label="Trial " + str(trial))

    print("DataSet " + DatasetNames[idx])
    print(trial_results)

    #Creating graphics and saving to file

    plt.figure(0)
    plt.title('ROC of MLP over 5 Trials, Dataset: ' + DatasetNames[idx])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.legend(loc=0)
    plt.savefig('./ROC_Graphs/MLP_ROC_Dataset:'+ DatasetNames[idx]+'.png')

    plt.figure(1)
    plt.title('Precision-Recall of MLP over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.xlabel('Recall')
    plt.ylabel('Precision')
    plt.legend(loc=0)
    plt.savefig('./PR_Graphs/MLP_PR_Dataset:'+ DatasetNames[idx]+'.png')

    all_gridsearch_trials_MLP.append(gridsearch_trials_MLP)
    avg_gridsearch = pd.concat(gridsearch_trials_MLP).
↪groupby(['classifier'],level=0).agg(
        {'classifier__alpha':'first', 'classifier__hidden_layer_sizes':'first',␣
↪'accuracy':'mean', 'f1':'mean', 'roc_auc':'mean'})

    plt.figure(2)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('classifier__hidden_layer_sizes','classifier__alpha','accuracy'),
             annot=True, fmt='.3f')
    plt.title('Accuracy Metric HeatMap of MLP over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.savefig('./Accuracy_HeatMaps/MLP_Dataset:'+ DatasetNames[idx]+'.png')

    plt.figure(3)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('classifier__hidden_layer_sizes','classifier__alpha','f1'),
             annot=True, fmt='.3f')
    plt.title('F1 Metric HeatMap of MLP over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.savefig('./F1_HeatMaps/MLP_Dataset:'+ DatasetNames[idx]+'.png')
    plt.figure(4)
    sns.heatmap( avg_gridsearch.dropna().
↪pivot('classifier__hidden_layer_sizes','classifier__alpha','roc_auc'),
              annot=True, fmt='.3f')
    plt.title('ROC_AUC Metric HeatMap of MLP over 5 Trials, Dataset: ' +␣
↪DatasetNames[idx])
    plt.savefig('./ROC_HeatMaps/MLP_Dataset:'+ DatasetNames[idx]+'.png')


    plt.show()

    #Adding results to data arrays for later analysis

    all_trials_MLP.append(trial_results)
    all_trials_train_MLP.append(trial_results_training)

    MLP_algorithm_results[idx] = np.mean(trial_results, axis = 0)
    MLP_algorithm_results_training[idx] = np.mean(trial_results_training, axis␣
↪= 0)


print(MLP_algorithm_results)
```

```
Starting Dataset #0

/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
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/home/joshua/anaconda3/lib/python3.8/site-
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  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
```

```
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
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(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
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  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
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  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
```
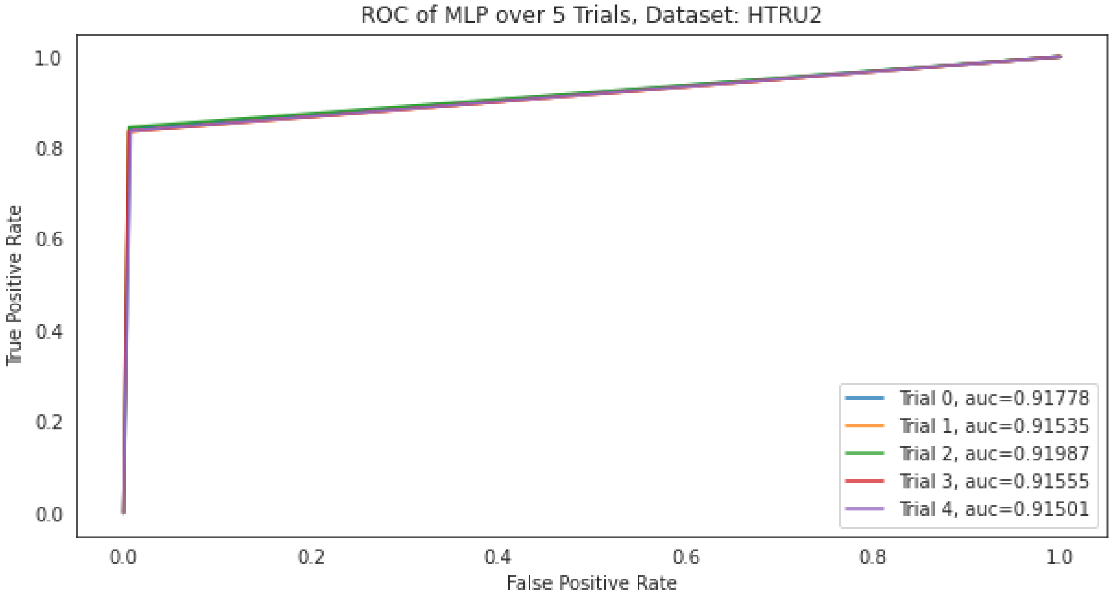
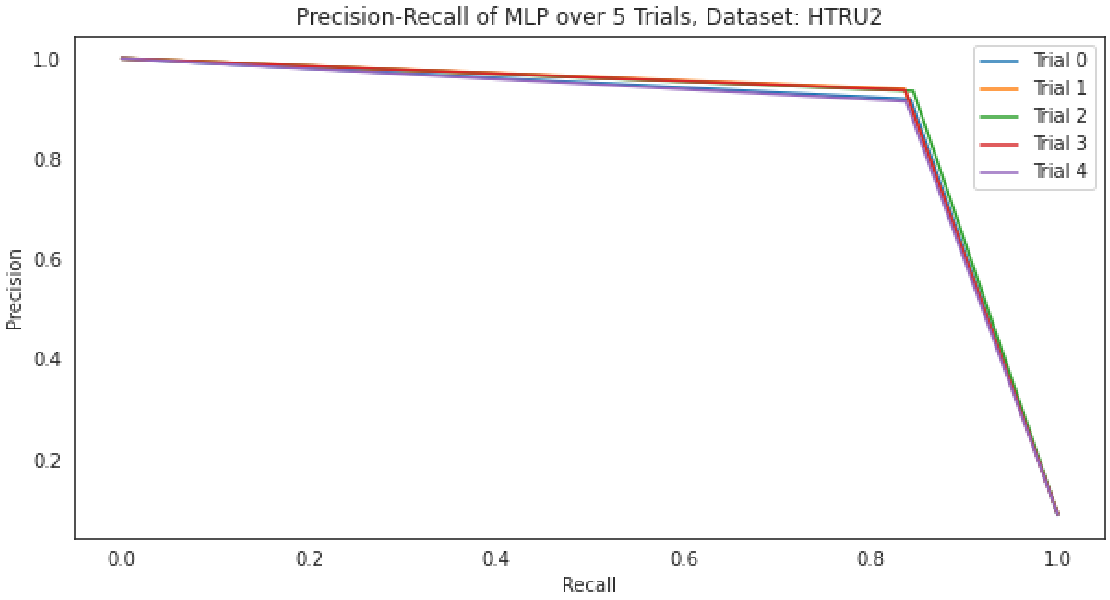
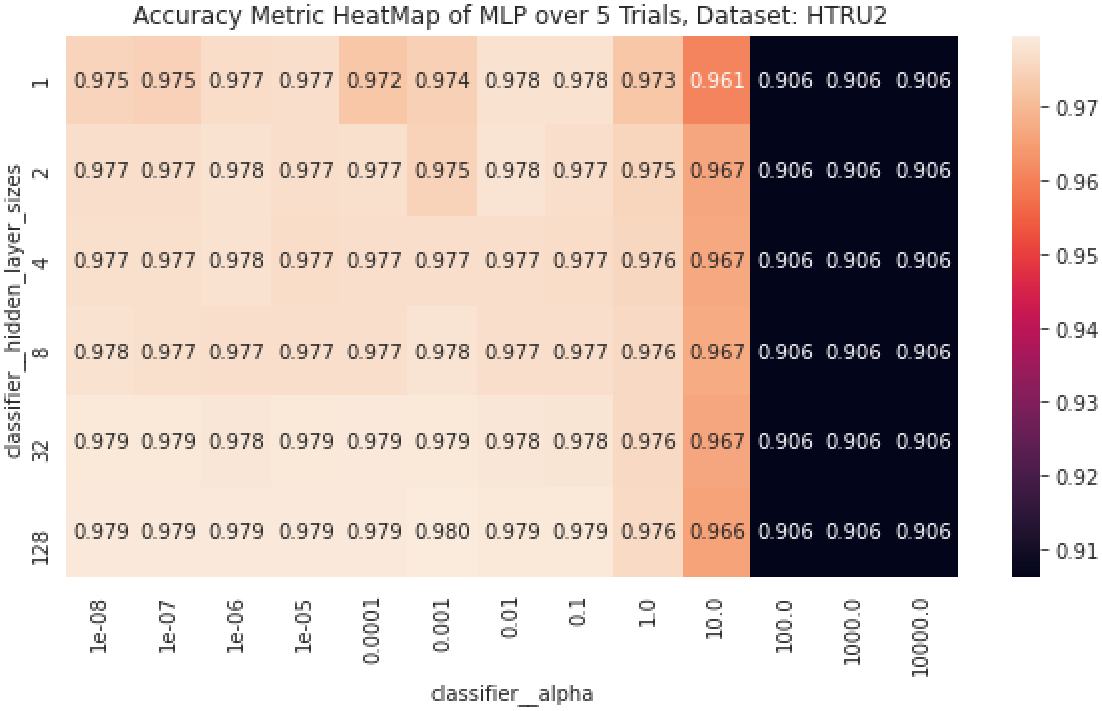
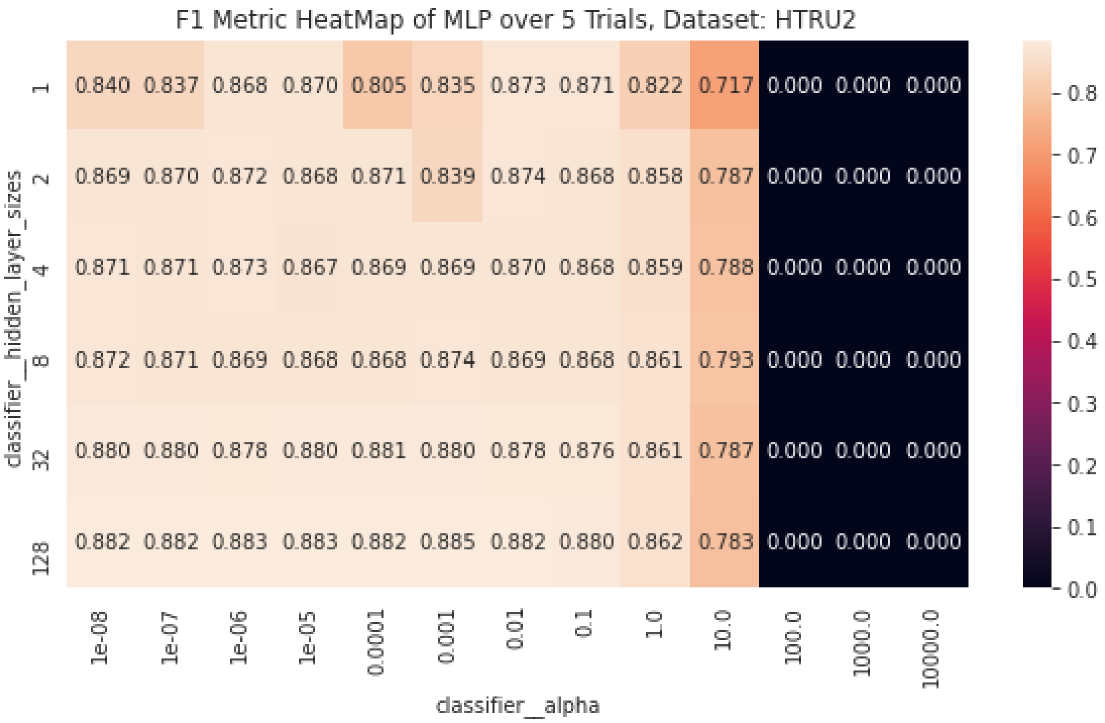

```
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
```

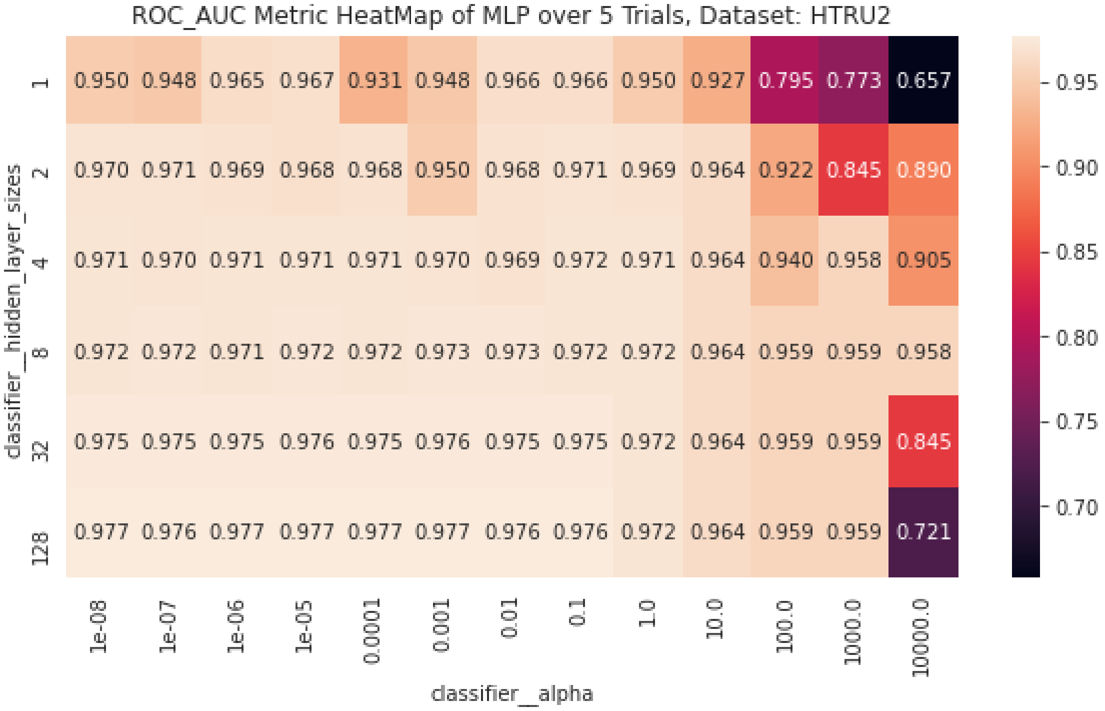
```
DataSet HTRU2
[[0.97914405 0.88126411 0.91778015]
 [0.97968677 0.88184699 0.91535112]
 [0.98077221 0.88937858 0.91987201]
 [0.98030702 0.8881932  0.91555213]
 [0.97844627 0.87285843 0.91500617]]
```




Precision-Recall of MLP over 5 Trials, Dataset: HTRU2
Precision
1.0
0.8
0.6
0.4
0.2
Recall
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of MLP over 5 Trials, Dataset: HTRU2
classifier__hidden_layer_sizes
1
0.975 0.975 0.977 0.977 0.972 0.974 0.978 0.978 0.973 0.961 0.906 0.906 0.906
2
0.977 0.977 0.978 0.977 0.977 0.975 0.978 0.977 0.975 0.967 0.906 0.906 0.906
4
0.977 0.977 0.978 0.977 0.977 0.977 0.977 0.977 0.976 0.967 0.906 0.906 0.906
8
0.978 0.977 0.977 0.977 0.977 0.978 0.977 0.977 0.976 0.967 0.906 0.906 0.906
32
0.979 0.979 0.978 0.979 0.979 0.979 0.978 0.978 0.976 0.967 0.906 0.906 0.906
128
0.979 0.979 0.979 0.979 0.979 0.980 0.979 0.979 0.976 0.966 0.906 0.906 0.906
1e-08
1e-07
1e-06
1e-05
0.0001
0.001
0.01
0.1
1.0
10.0
100.0
1000.0
10000.0
classifier__alpha
0.97
0.96
0.95
0.94
0.93
0.92
0.91





```
Starting Dataset #1
```

```
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
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/home/joshua/anaconda3/lib/python3.8/site-
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packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
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  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
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/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
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(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
```
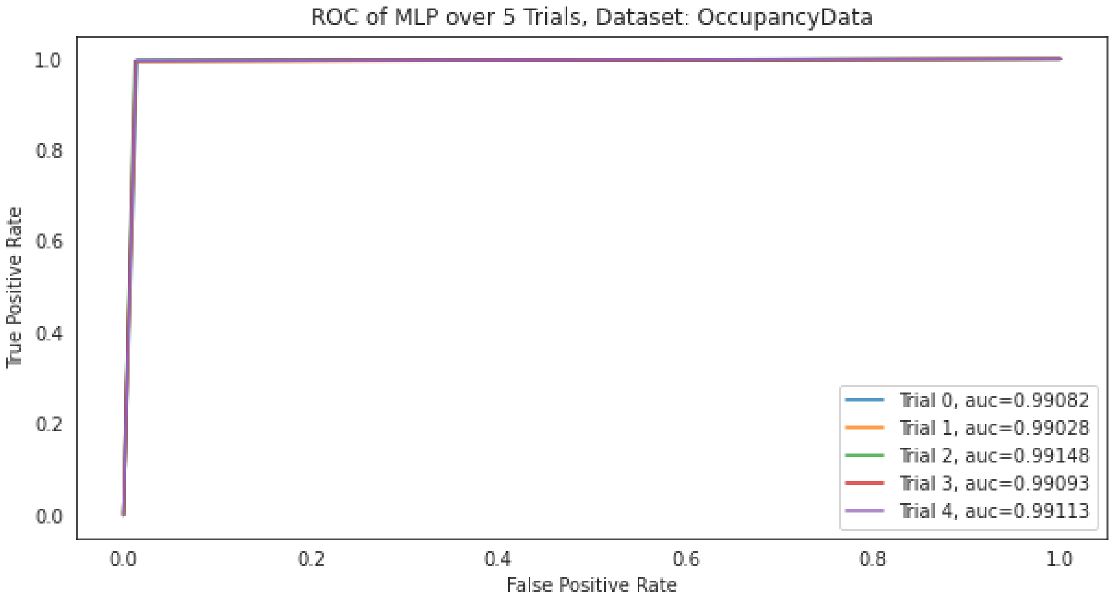
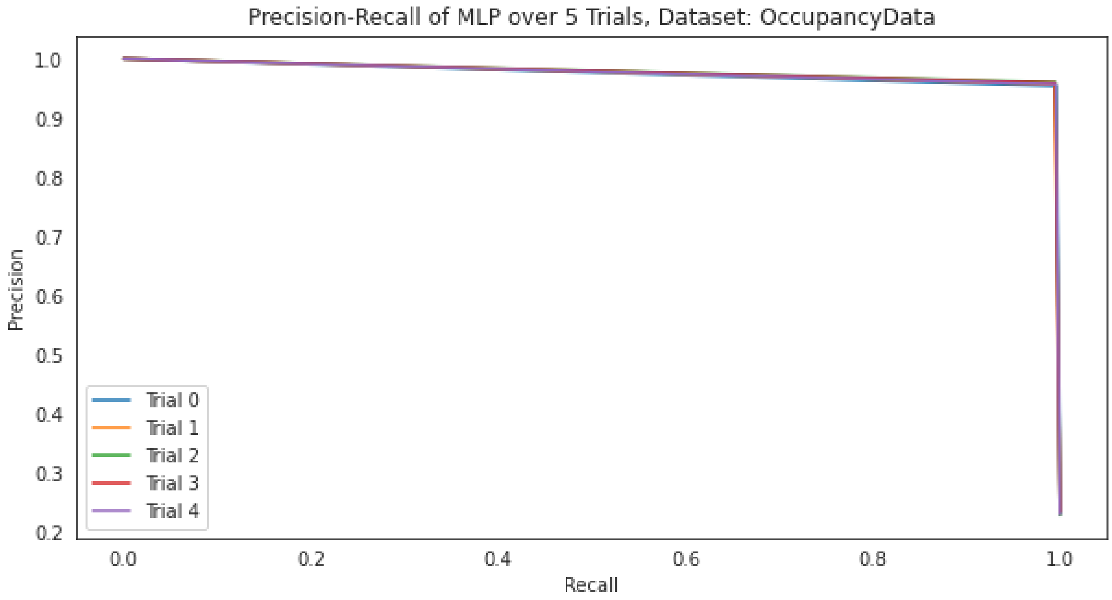
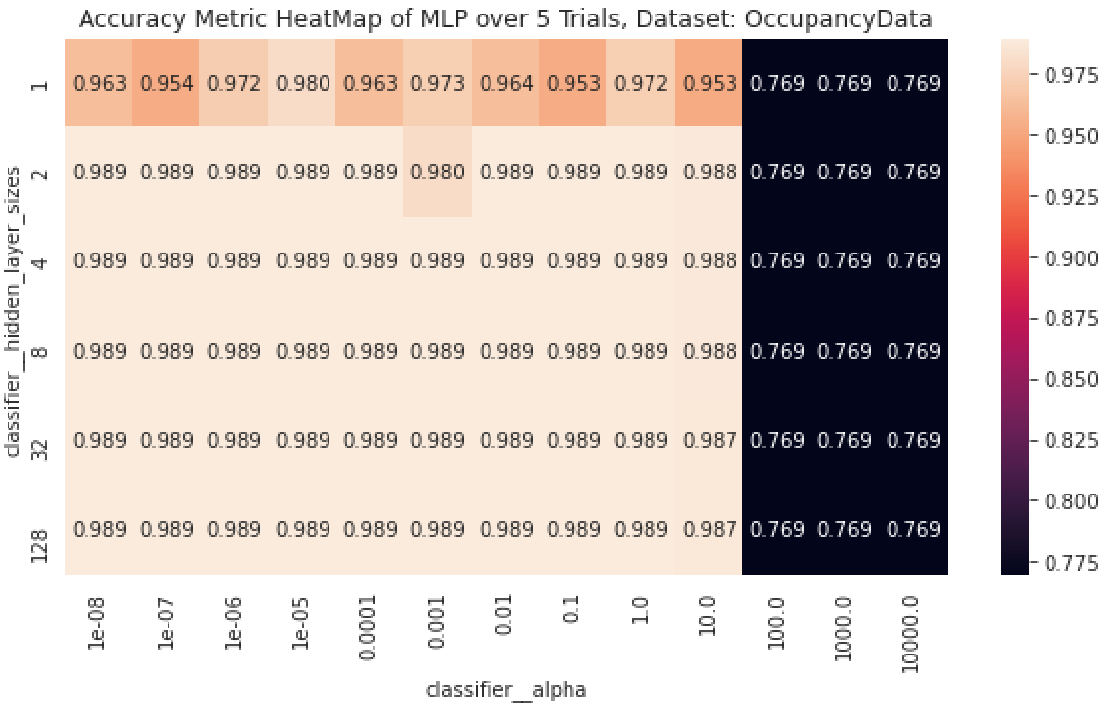
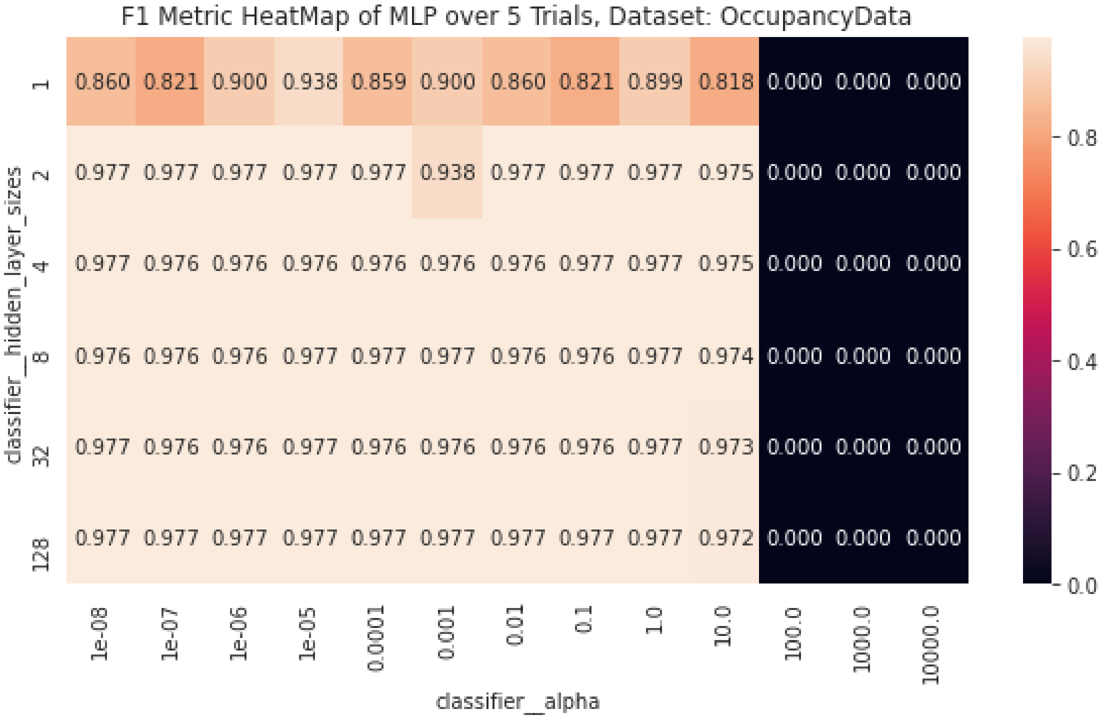

```
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
```

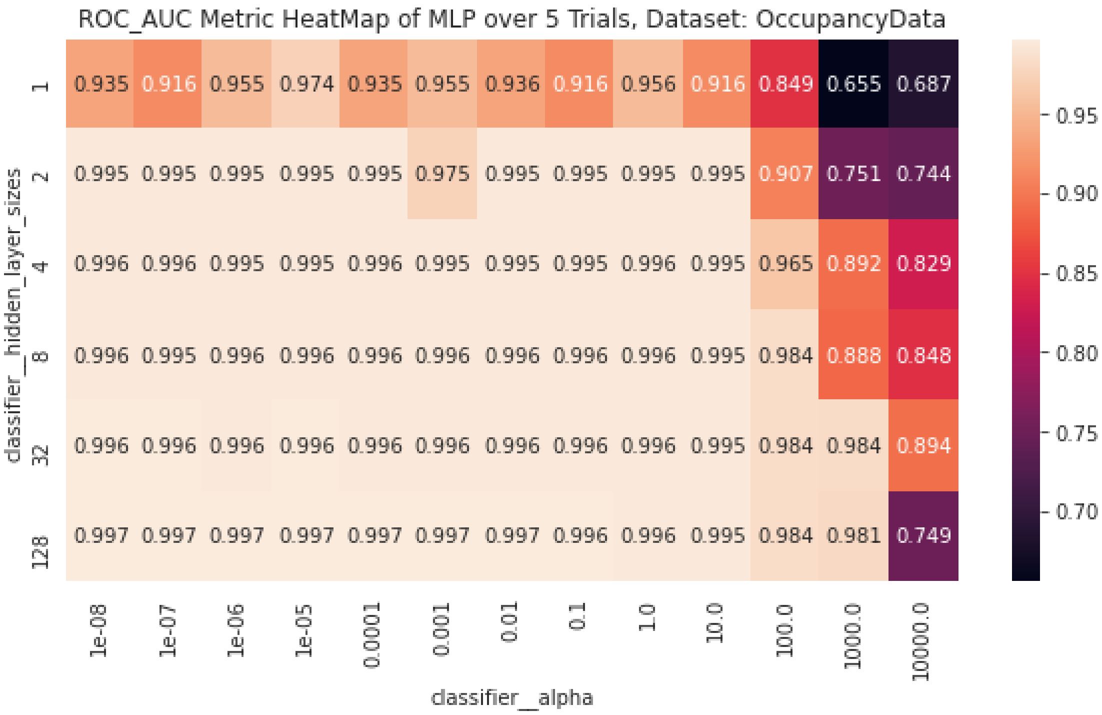
```
DataSet OccupancyData
[[0.98804627 0.97474199 0.99082298]
 [0.98849614 0.97521552 0.99027835]
 [0.98939589 0.97728532 0.99148474]
 [0.98881748 0.97635455 0.99092896]
 [0.98888175 0.97633462 0.99112804]]
```


ROC of MLP over 5 Trials, Dataset: OccupancyData
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0, auc=0.99082
Trial 1, auc=0.99028
Trial 2, auc=0.99148
Trial 3, auc=0.99093
Trial 4, auc=0.99113


Precision-Recall of MLP over 5 Trials, Dataset: OccupancyData
Precision
Recall
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of MLP over 5 Trials, Dataset: OccupancyData
classifier__hidden_layer_sizes
1
0.963 0.954 0.972 0.980 0.963 0.973 0.964 0.953 0.972 0.953 0.769 0.769 0.769
2
0.989 0.989 0.989 0.989 0.989 0.980 0.989 0.989 0.989 0.988 0.769 0.769 0.769
4
0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.988 0.769 0.769 0.769
8
0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.988 0.769 0.769 0.769
32
0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.987 0.769 0.769 0.769
128
0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.989 0.987 0.769 0.769 0.769
1e-08
1e-07
1e-06
1e-05
0.0001
0.001
0.01
0.1
1.0
10.0
100.0
1000.0
10000.0
classifier__alpha
0.975
0.950
0.925
0.900
0.875
0.850
0.825
0.800
0.775


F1 Metric HeatMap of MLP over 5 Trials, Dataset: OccupancyData
classifier__hidden_layer_sizes
1
0.860 0.821 0.900 0.938 0.859 0.900 0.860 0.821 0.899 0.818 0.000 0.000 0.000
2
0.977 0.977 0.977 0.977 0.977 0.938 0.977 0.977 0.977 0.975 0.000 0.000 0.000
4
0.977 0.976 0.976 0.976 0.976 0.976 0.976 0.977 0.977 0.975 0.000 0.000 0.000
8
0.976 0.976 0.976 0.977 0.977 0.977 0.976 0.976 0.977 0.974 0.000 0.000 0.000
32
0.977 0.976 0.976 0.977 0.976 0.976 0.976 0.976 0.977 0.973 0.000 0.000 0.000
128
0.977 0.977 0.977 0.977 0.977 0.977 0.977 0.977 0.977 0.972 0.000 0.000 0.000
1e-08
1e-07
1e-06
1e-05
0.0001
0.001
0.01
0.1
1.0
10.0
100.0
1000.0
10000.0
classifier__alpha
0.8
0.6
0.4
0.2
0.0

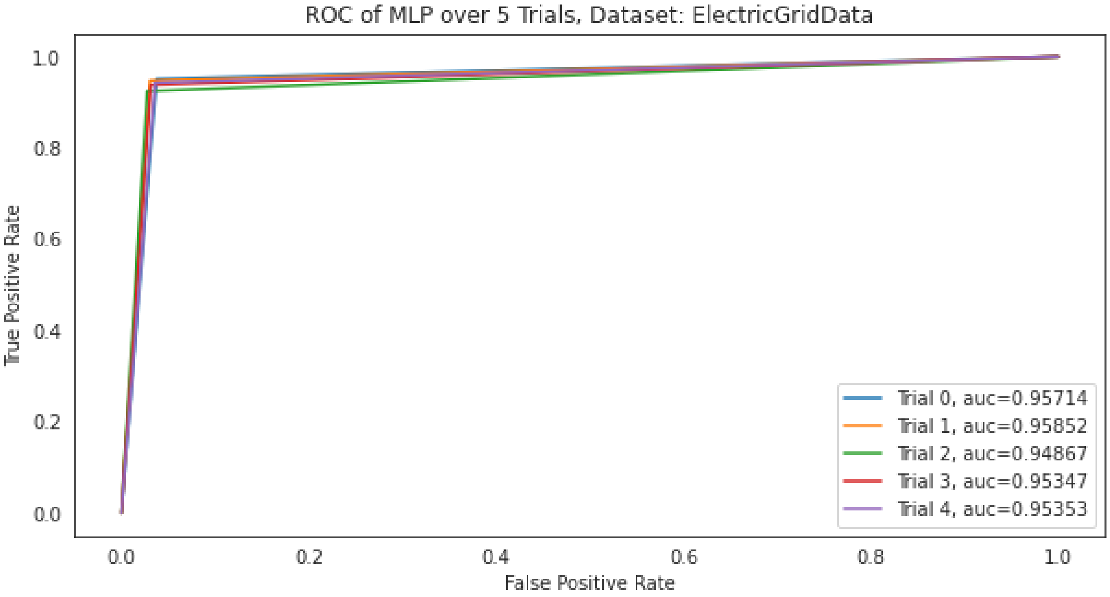


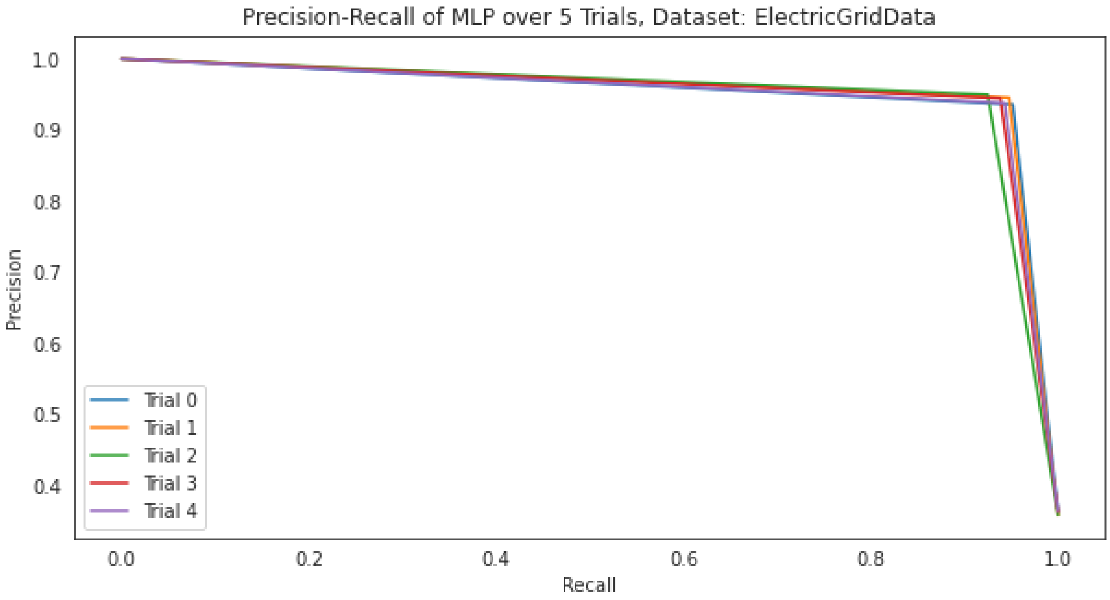
```
Starting Dataset #2

/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
```

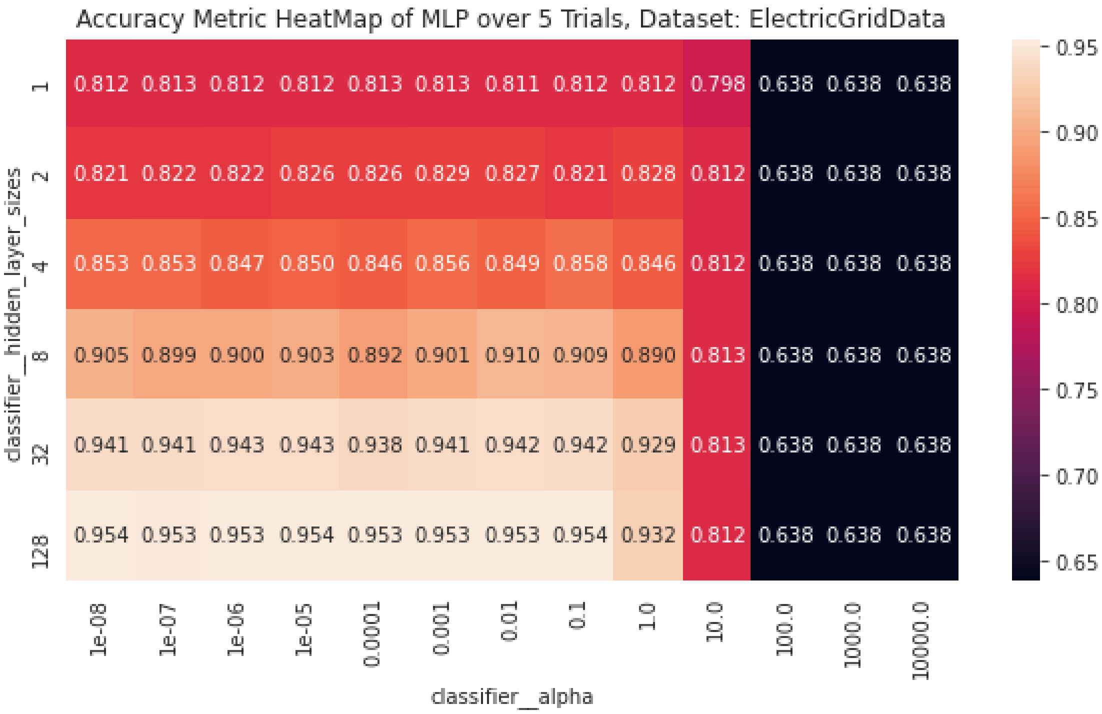
```
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
```

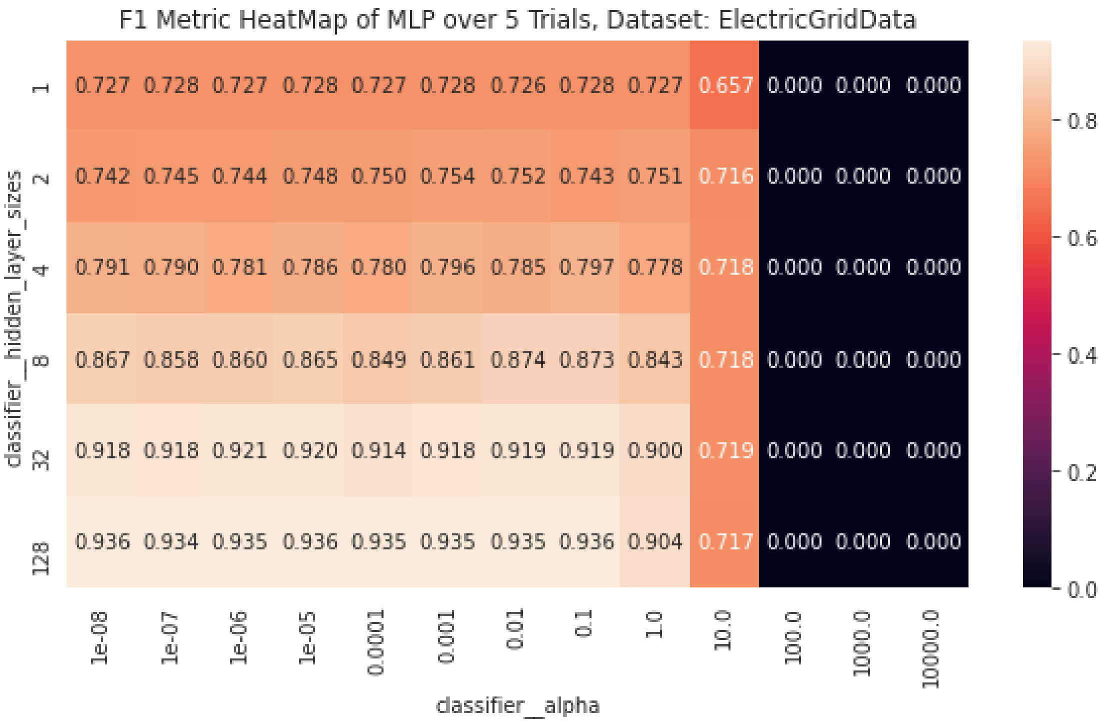
```
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
```

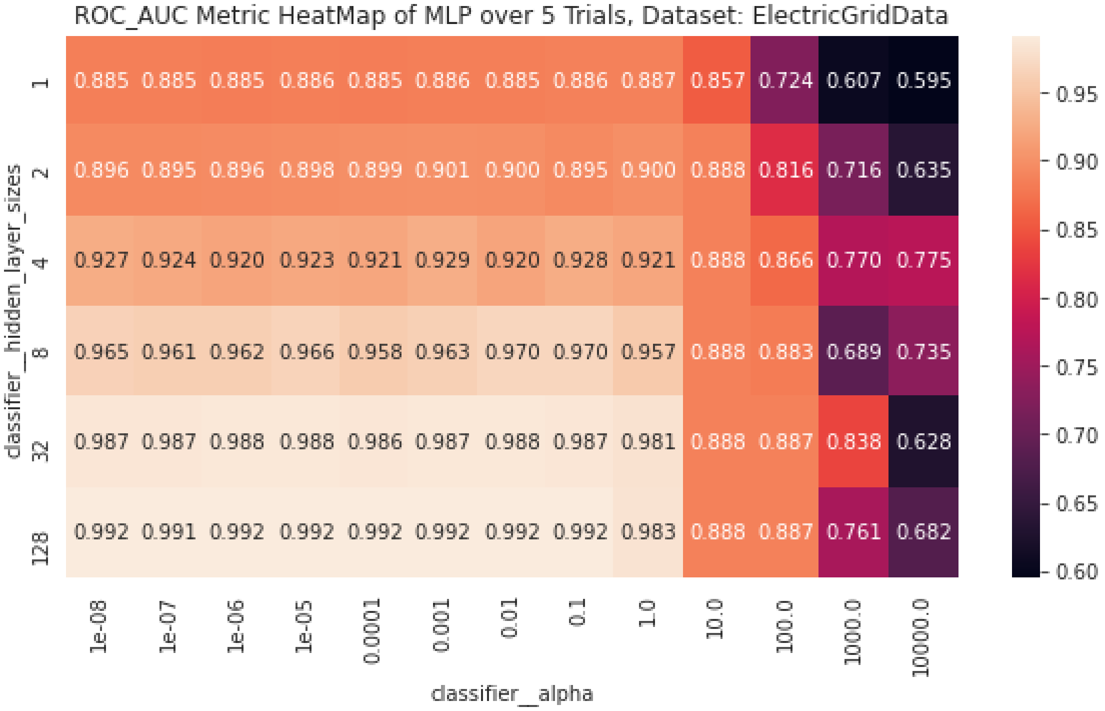
```
DataSet ElectricGridData
[[0.9584     0.94104803 0.9571356 ]
 [0.9568     0.93890135 0.95851772]
 [0.9566     0.94084976 0.94866699]
 [0.9512     0.93770673 0.95347152]
 [0.9568     0.94375857 0.95353414]]
```




Precision-Recall of MLP over 5 Trials, Dataset: ElectricGridData
Precision
1.0
0.9
0.8
0.7
0.6
0.5
0.4
Recall
0.0
0.2
0.4
0.6
0.8
1.0
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4


Accuracy Metric HeatMap of MLP over 5 Trials, Dataset: ElectricGridData
classifier__hidden_layer_sizes
1
0.812 0.813 0.812 0.812 0.813 0.813 0.811 0.812 0.812 0.798 0.638 0.638 0.638
2
0.821 0.822 0.822 0.826 0.826 0.829 0.827 0.821 0.828 0.812 0.638 0.638 0.638
4
0.853 0.853 0.847 0.850 0.846 0.856 0.849 0.858 0.846 0.812 0.638 0.638 0.638
8
0.905 0.899 0.900 0.903 0.892 0.901 0.910 0.909 0.890 0.813 0.638 0.638 0.638
32
0.941 0.941 0.943 0.943 0.938 0.941 0.942 0.942 0.929 0.813 0.638 0.638 0.638
128
0.954 0.953 0.953 0.954 0.953 0.953 0.953 0.954 0.932 0.812 0.638 0.638 0.638
1e-08
1e-07
1e-06
1e-05
0.0001
0.001
0.01
0.1
1.0
10.0
100.0
1000.0
10000.0
classifier__alpha
0.95
0.90
0.85
0.80
0.75
0.70
0.65

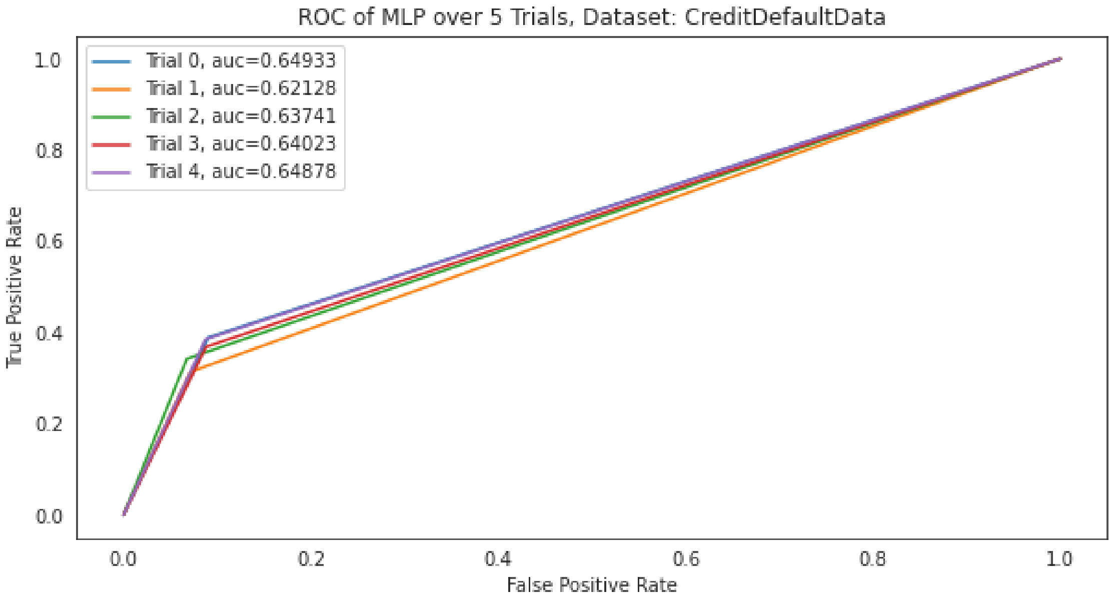


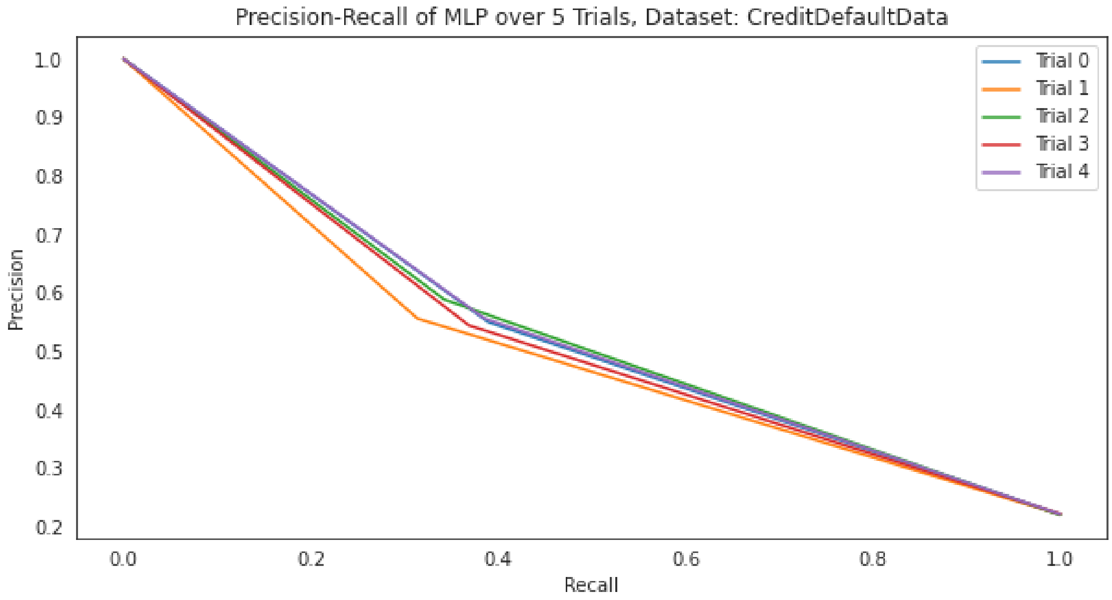


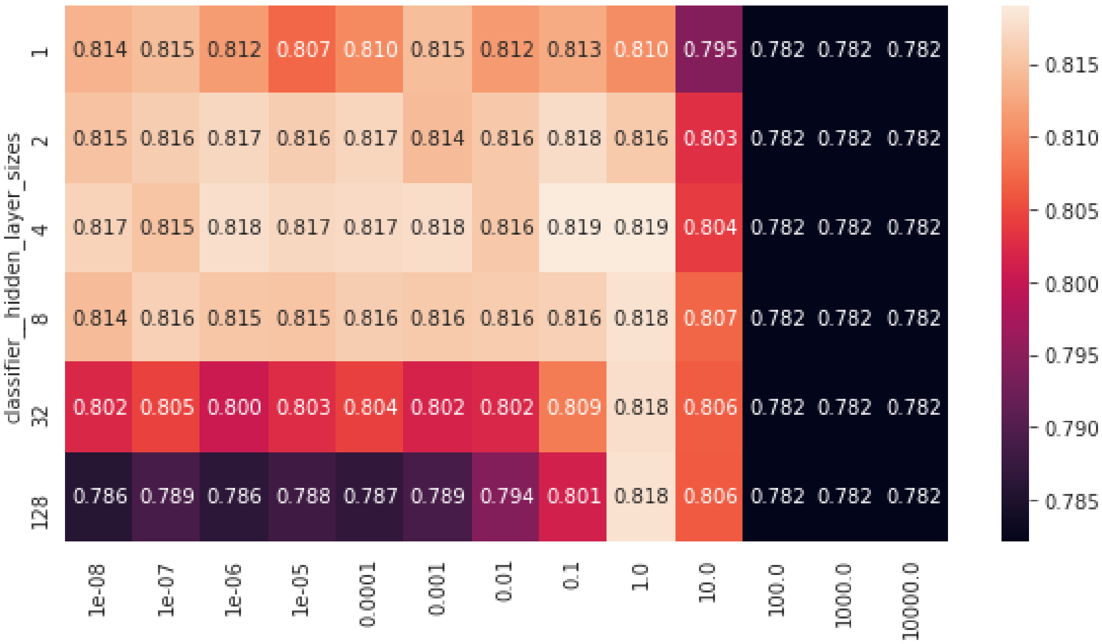
```
Starting Dataset #3
```

```
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
```

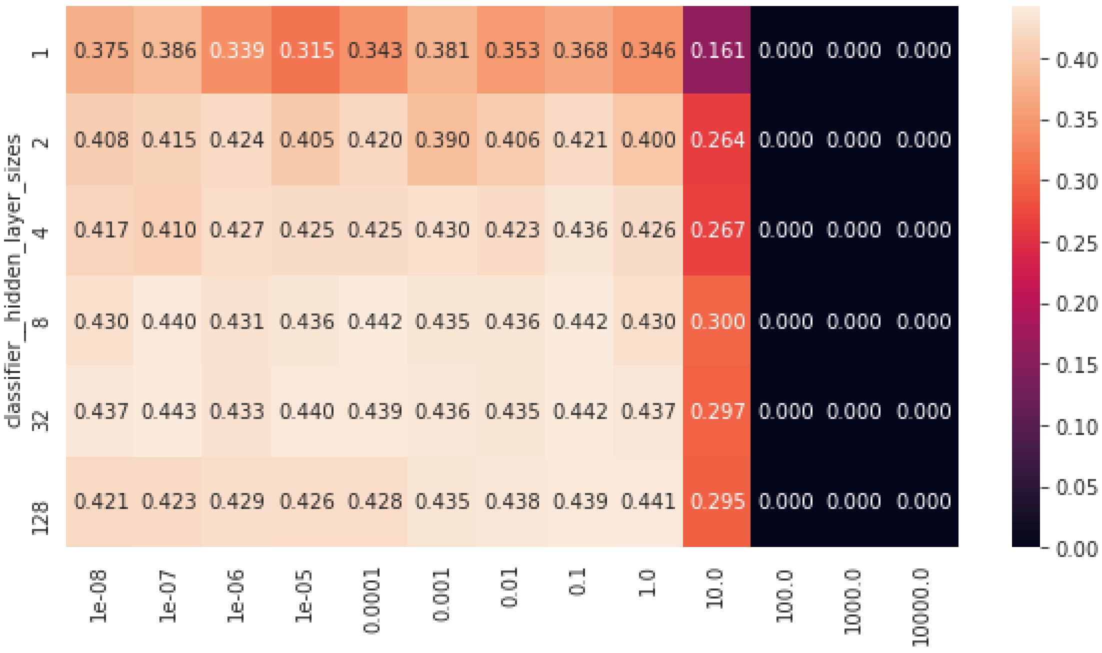
```
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)
/home/joshua/anaconda3/lib/python3.8/site-
packages/sklearn/utils/validation.py:73: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
(n_samples, ), for example using ravel().
  return f(**kwargs)

DataSet CreditDefaultData
[[0.79708    0.43003042 0.64932842]
 [0.78772    0.45570927 0.62127765]
 [0.79496    0.44598571 0.63741365]
 [0.79168    0.45637058 0.64023174]
 [0.79568    0.44739057 0.64877599]]
```


ROC of MLP over 5 Trials, Dataset: CreditDefaultData
Trial 0, auc=0.64933
Trial 1, auc=0.62128
Trial 2, auc=0.63741
Trial 3, auc=0.64023
Trial 4, auc=0.64878
True Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0

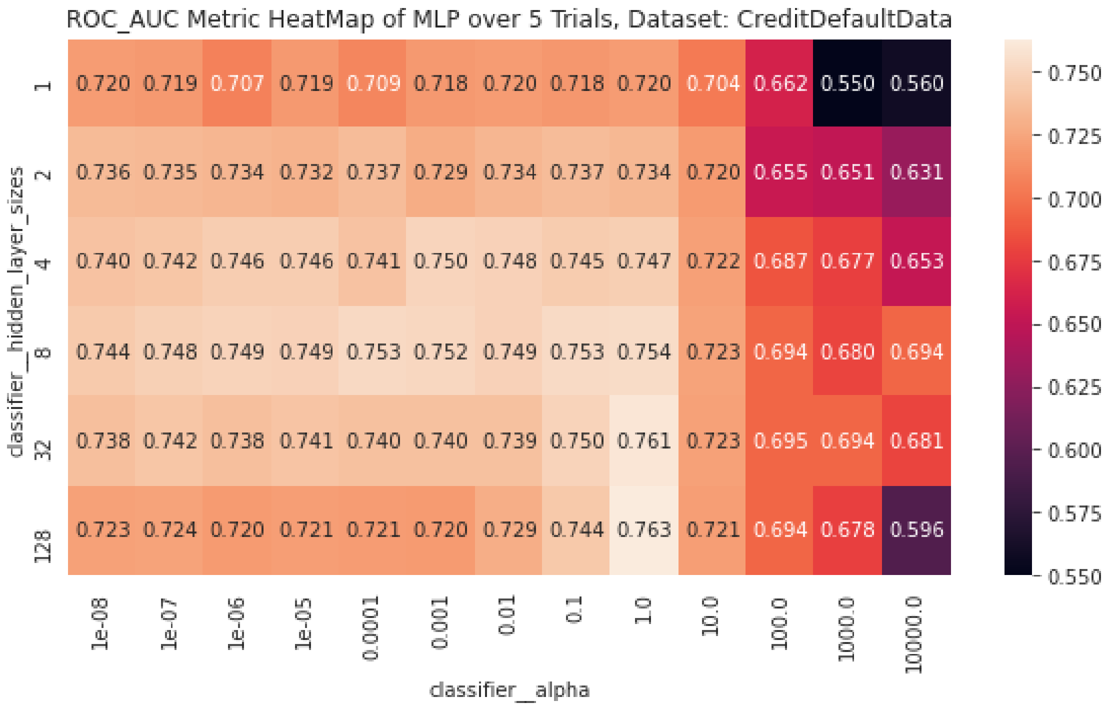

Precision-Recall of MLP over 5 Trials, Dataset: CreditDefaultData
Trial 0
Trial 1
Trial 2
Trial 3
Trial 4
Precision
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Recall
0.0
0.2
0.4
0.6
0.8
1.0



Accuracy Metric HeatMap of MLP over 5 Trials, Dataset: CreditDefaultData



F1 Metric HeatMap of MLP over 5 Trials, Dataset: CreditDefaultData



```
[[0.97967127 0.88270826 0.91671232]
 [0.98872751 0.9759864  0.99092862]
 [0.95596    0.94045289 0.95426519]
 [0.793424   0.44709731 0.63940549]]
CPU times: user 34min 45s, sys: 41.4 s, total: 35min 26s
Wall time: 37min 6s
```

[17]:

```
print(algorithm_results)
print(Tree_algorithm_results)
print(RandomForest_algorithm_results)
print(MLP_algorithm_results)
```

```
[[0.97785703 0.87049391 0.90354053]
 [0.98877892 0.97615534 0.99085413]
 [0.8156     0.73397394 0.79123003]
 [0.81192    0.37842889 0.61396647]]
[[0.96797953 0.82167796 0.90802067]
 [0.98690231 0.9722275  0.98159674]
 [0.82956    0.76690879 0.81595167]
 [0.72196    0.39763183 0.6133176 ]]
[[0.9785083  0.8769397  0.9119918 ]
 [0.99096401 0.98048261 0.99011224]
 [0.91256    0.87112776 0.89512429]
 [0.812672   0.45990264 0.65198553]]
[[0.97967127 0.88270826 0.91671232]
```

```
 [0.98872751 0.9759864  0.99092862]
 [0.95596    0.94045289 0.95426519]
 [0.793424   0.44709731 0.63940549]]
```

[18]:
```
print(algorithm_results_training)
print(Tree_algorithm_results_training)
print(RandomForest_results_training)
print(MLP_algorithm_results_training)
```

```
[[0.97892    0.87629369 0.90577973]
 [0.98956    0.97787777 0.99205672]
 [0.81672    0.73700566 0.79359675]
 [0.81156    0.38058196 0.61497809]]
[[1.         1.         1.        ]
 [1.         1.         1.        ]
 [1.         1.         1.        ]
 [0.9998     0.99954742 0.9995477 ]]
[[1.         1.         0.99997798]
 [1.         1.         1.        ]
 [1.         1.         1.        ]
 [0.99992    0.99972922 0.99979349]]
[[0.9814     0.89515497 0.92335172]
 [0.9896     0.97813854 0.99217795]
 [0.99988    1.         0.99996878]
 [0.879      0.71678802 0.76529801]]
```

[20]:
```
print(all_trials_logisticReg)
print(all_trials_Tree_algorithm)
print(all_trials_RandomForest)
print(all_trials_MLP)
```

```
[array([[0.97705071, 0.86129335, 0.89679879],
       [0.97743836, 0.87186262, 0.90724044],
       [0.97914405, 0.87744875, 0.90889521],
       [0.9787564 , 0.87442713, 0.90369693],
       [0.97689564, 0.86743772, 0.90107127]]), array([[0.98881748, 0.9760989 ,
0.99077761],
       [0.98894602, 0.97647059, 0.9910598 ],
       [0.98868895, 0.97605442, 0.99079866],
       [0.98888175, 0.97628513, 0.99082131],
       [0.98856041, 0.97586768, 0.99081327]]), array([[0.8166    , 0.7336625 ,
0.78860039],
       [0.8178    , 0.73323572, 0.79179548],
       [0.8162    , 0.73765344, 0.79329705],
       [0.8116    , 0.72868664, 0.78852304],
       [0.8158    , 0.7366314 , 0.79393417]]), array([[0.8094    , 0.35928466,
0.60613208],
       [0.81324   , 0.3951289 , 0.62083804],
       [0.81468   , 0.38660135, 0.61751732],
       [0.81132   , 0.37958701, 0.61429018],
       [0.81096   , 0.37154255, 0.61105473]])]
[array([[0.96929757, 0.83381924, 0.90729767],
       [0.96611878, 0.81112985, 0.9058204 ],
       [0.96883238, 0.8211047 , 0.91493886],
       [0.96712669, 0.82372739, 0.91263991],
       [0.96852225, 0.81860862, 0.89940652]]), array([[0.98849614, 0.97499651,
0.98421307],
       [0.98663239, 0.97029148, 0.98093458],
       [0.98746787, 0.97475302, 0.98534599],
       [0.98701799, 0.97356401, 0.98126074],
       [0.98489717, 0.96753247, 0.97622932]]), array([[0.826     , 0.77188108,
0.8161103 ],
       [0.8254    , 0.75912822, 0.80937802],
       [0.8292    , 0.75476053, 0.81350184],
       [0.8346    , 0.77529346, 0.82067134],
       [0.8326    , 0.77348066, 0.82009685]]), array([[0.72268   , 0.3991684 ,
0.6165659 ],
       [0.7224    , 0.41087923, 0.61951548],
       [0.71968   , 0.39592082, 0.6116199 ],
       [0.72352   , 0.38895241, 0.60688386],
       [0.72152   , 0.39323828, 0.61200286]])]
[array([[0.97836874, 0.87683415, 0.91434039],
       [0.97813615, 0.87567084, 0.91301157],
       [0.97860133, 0.87778769, 0.90625135],
       [0.97968677, 0.87771739, 0.90492965],
       [0.97774849, 0.87668845, 0.92142603]]), array([[0.9907455 , 0.98044616,
0.98894402],
       [0.99132391, 0.980679  , 0.99043641],
       [0.99125964, 0.9808114 , 0.98969571],
       [0.99170951, 0.98199808, 0.99194534],
       [0.98978149, 0.97847841, 0.9895397 ]]), array([[0.9096    , 0.86565454,
0.89391755],
       [0.9102    , 0.87365439, 0.89438234],
       [0.9152    , 0.86964233, 0.89607692],
       [0.9164    , 0.8771223 , 0.89867987],
       [0.9114    , 0.86956522, 0.8925648 ]]), array([[0.813     , 0.45705664,
0.64969101],
       [0.81128   , 0.45351264, 0.65036322],
       [0.81332   , 0.47281001, 0.65838867],
       [0.81396   , 0.45200373, 0.65040069],
       [0.8118    , 0.46413019, 0.65108406]])]
[array([[0.97914405, 0.88126411, 0.91778015],
       [0.97968677, 0.88184699, 0.91535112],
       [0.98077221, 0.88937858, 0.91987201],
       [0.98030702, 0.8881932 , 0.91555213],
       [0.97844627, 0.87285843, 0.91500617]]), array([[0.98804627, 0.97474199,
0.99082298],
       [0.98849614, 0.97521552, 0.99027835],
       [0.98939589, 0.97728532, 0.99148474],
       [0.98881748, 0.97635455, 0.99092896],
       [0.98888175, 0.97633462, 0.99112804]]), array([[0.9584    , 0.94104803,
0.9571356 ],
       [0.9568    , 0.93890135, 0.95851772],
       [0.9566    , 0.94084976, 0.94866699],
       [0.9512    , 0.93770673, 0.95347152],
       [0.9568    , 0.94375857, 0.95353414]]), array([[0.79708    , 0.43003042,
0.64932842],
       [0.78772    , 0.45570927, 0.62127765],
       [0.79496    , 0.44598571, 0.63741365],
       [0.79168    , 0.45637058, 0.64023174],
       [0.79568    , 0.44739057, 0.64877599]])]
```

1.5 Average Metric Performance (Algorithm/Metric Combinations)

```
[21]: avg_metric_algorithm = pd.DataFrame(index=['Log_Reg', 'Tree', 'Random_Forest',␣
       ↪'MLP'], columns = ['Accuracy','F1','ROC_AUC', 'Mean Performance'])
      avg_metric_algorithm.loc['Log_Reg'] = np.append(np.mean(algorithm_results, axis␣
       ↪= 0), np.mean(np.mean(algorithm_results, axis = 0)))
      avg_metric_algorithm.loc['Tree'] = np.append(np.mean(Tree_algorithm_results,␣
       ↪axis = 0), np.mean(np.mean(Tree_algorithm_results, axis = 0)))
      avg_metric_algorithm.loc['Random_Forest'] = np.append(np.
       ↪mean(RandomForest_algorithm_results, axis = 0), np.mean(np.
       ↪mean(RandomForest_algorithm_results, axis = 0)))
      avg_metric_algorithm.loc['MLP'] = np.append(np.mean(MLP_algorithm_results, axis␣
       ↪= 0), np.mean(np.mean(MLP_algorithm_results, axis = 0)))
```

```
[22]: display(avg_metric_algorithm)
```

```
               Accuracy        F1   ROC_AUC Mean Performance
Log_Reg        0.898539  0.739763  0.824898         0.821067
Tree             0.8766  0.739612  0.829722         0.815311
Random_Forest  0.923676  0.797113  0.862303         0.861031
MLP            0.929446  0.811561  0.875328         0.872112
```

1.6 Average Test Performance (Algorithm/Dataset Combinations)

```
[23]: avg_problem_algorithm = pd.DataFrame(index=['Log_Reg', 'Tree', 'Random_Forest',␣
       ↪'MLP'], columns = ['HTRU2','Occupancy','ElectricGrid','CreditDefault', 'Mean␣
       ↪Performance'])
      avg_problem_algorithm.loc['Log_Reg'] = np.append(np.mean(algorithm_results,␣
       ↪axis = 1), np.mean(np.mean(algorithm_results, axis = 1)))
```

```
avg_problem_algorithm.loc['Tree'] = np.append(np.mean(Tree_algorithm_results,␣
 ↪axis = 1), np.mean(np.mean(Tree_algorithm_results, axis = 1)))
avg_problem_algorithm.loc['Random_Forest'] = np.append(np.
 ↪mean(RandomForest_algorithm_results, axis = 1), np.mean(np.
 ↪mean(RandomForest_algorithm_results, axis = 1)))
avg_problem_algorithm.loc['MLP'] = np.append(np.mean(MLP_algorithm_results,␣
 ↪axis = 1), np.mean(np.mean(MLP_algorithm_results, axis = 1)))
```

[24]:

```
display(avg_problem_algorithm)
```

```
                  HTRU2 Occupancy ElectricGrid CreditDefault Mean Performance
Log_Reg        0.917297  0.985263     0.780268      0.601438         0.821067
Tree           0.899226  0.980242      0.80414      0.577636         0.815311
Random_Forest   0.92248  0.987186     0.892937       0.64152         0.861031
MLP            0.926364  0.985214     0.950226      0.626642         0.872112
```

1.7 Average Training Performance (Algorithm/Dataset Combinations)

[25]:

```
avg_training_performance = pd.DataFrame(index=['Log_Reg', 'Tree',␣
 ↪'Random_Forest', 'MLP'], columns =␣
 ↪['HTRU2','Occupancy','ElectricGrid','CreditDefault', 'Mean Performance'])
avg_training_performance.loc['Log_Reg'] = np.append(np.
 ↪mean(algorithm_results_training, axis = 1), np.mean(np.
 ↪mean(algorithm_results_training, axis = 1)))
avg_training_performance.loc['Tree'] = np.append(np.
 ↪mean(Tree_algorithm_results_training, axis = 1), np.mean(np.
 ↪mean(Tree_algorithm_results_training, axis = 1)))
avg_training_performance.loc['Random_Forest'] = np.append(np.
 ↪mean(RandomForest_results_training, axis = 1), np.mean(np.
 ↪mean(RandomForest_results_training, axis = 1)))
avg_training_performance.loc['MLP'] = np.append(np.
 ↪mean(MLP_algorithm_results_training, axis = 1), np.mean(np.
 ↪mean(MLP_algorithm_results_training, axis = 1)))
```

[26]:

```
display(avg_training_performance)
```

```
                  HTRU2 Occupancy ElectricGrid CreditDefault Mean Performance
Log_Reg        0.920331  0.986498     0.782441      0.602373         0.822911
Tree                  1         1            1      0.999632         0.999908
Random_Forest  0.999993         1            1      0.999814         0.999952
MLP            0.933302  0.986639      0.99995      0.787029          0.92673
```

1.8 Raw scores for Logistic Regression

[27]:
```
MetricList = ["Accuracy", "F1", "ROC_AUC"]
log_reg_raw = pd.DataFrame(columns = ["Trial 1","Trial 2","Trial 3","Trial 4",␣
 ↪"Trial 5", "Avg"])
for idx, dataset in enumerate(DatasetNames):
    for idy, metric in enumerate(MetricList):
        log_reg_raw.loc[dataset + "_" + metric] = np.append(
            all_trials_logisticReg[idx][0][idy], [
                all_trials_logisticReg[idx][1][idy],
                all_trials_logisticReg[idx][2][idy],
                all_trials_logisticReg[idx][3][idy],
                all_trials_logisticReg[idx][4][idy],
                algorithm_results[idx][idy]
            ])
display(log_reg_raw)
```

```
                             Trial 1   Trial 2   Trial 3   Trial 4   Trial 5  \
HTRU2_Accuracy              0.977051  0.977438  0.979144  0.978756  0.976896
HTRU2_F1                    0.861293  0.871863  0.877449  0.874427  0.867438
HTRU2_ROC_AUC               0.896799  0.907240  0.908895  0.903697  0.901071
OccupancyData_Accuracy      0.988817  0.988946  0.988689  0.988882  0.988560
OccupancyData_F1            0.976099  0.976471  0.976054  0.976285  0.975868
OccupancyData_ROC_AUC       0.990778  0.991060  0.990799  0.990821  0.990813
ElectricGridData_Accuracy   0.816600  0.817800  0.816200  0.811600  0.815800
ElectricGridData_F1         0.733663  0.733236  0.737653  0.728687  0.736631
ElectricGridData_ROC_AUC    0.788600  0.791795  0.793297  0.788523  0.793934
CreditDefaultData_Accuracy  0.809400  0.813240  0.814680  0.811320  0.810960
CreditDefaultData_F1        0.359285  0.395129  0.386601  0.379587  0.371543
CreditDefaultData_ROC_AUC   0.606132  0.620838  0.617517  0.614290  0.611055

                                 Avg
HTRU2_Accuracy              0.977857
HTRU2_F1                    0.870494
HTRU2_ROC_AUC               0.903541
OccupancyData_Accuracy      0.988779
OccupancyData_F1            0.976155
OccupancyData_ROC_AUC       0.990854
ElectricGridData_Accuracy   0.815600
ElectricGridData_F1         0.733974
ElectricGridData_ROC_AUC    0.791230
CreditDefaultData_Accuracy  0.811920
CreditDefaultData_F1        0.378429
CreditDefaultData_ROC_AUC   0.613966
```

1.9 Raw scores for Tree Algorithm

[28]:

```
MetricList = ["Accuracy", "F1", "ROC_AUC"]
tree_raw = pd.DataFrame(columns = ["Trial 1","Trial 2","Trial 3","Trial 4",␣
 ↪"Trial 5", "Avg"])
for idx, dataset in enumerate(DatasetNames):
    for idy, metric in enumerate(MetricList):
        tree_raw.loc[dataset + "_" + metric] = np.append(
            all_trials_Tree_algorithm[idx][0][idy], [
                all_trials_Tree_algorithm[idx][1][idy],
                all_trials_Tree_algorithm[idx][2][idy],
                all_trials_Tree_algorithm[idx][3][idy],
                all_trials_Tree_algorithm[idx][4][idy],
                Tree_algorithm_results[idx][idy]
            ])
display(tree_raw)
```

```
                             Trial 1   Trial 2   Trial 3   Trial 4   Trial 5  \
HTRU2_Accuracy              0.969298  0.966119  0.968832  0.967127  0.968522
HTRU2_F1                    0.833819  0.811130  0.821105  0.823727  0.818609
HTRU2_ROC_AUC               0.907298  0.905820  0.914939  0.912640  0.899407
OccupancyData_Accuracy      0.988496  0.986632  0.987468  0.987018  0.984897
OccupancyData_F1            0.974997  0.970291  0.974753  0.973564  0.967532
OccupancyData_ROC_AUC       0.984213  0.980935  0.985346  0.981261  0.976229
ElectricGridData_Accuracy   0.826000  0.825400  0.829200  0.834600  0.832600
ElectricGridData_F1         0.771881  0.759128  0.754761  0.775293  0.773481
ElectricGridData_ROC_AUC    0.816110  0.809378  0.813502  0.820671  0.820097
CreditDefaultData_Accuracy  0.722680  0.722400  0.719680  0.723520  0.721520
CreditDefaultData_F1        0.399168  0.410879  0.395921  0.388952  0.393238
CreditDefaultData_ROC_AUC   0.616566  0.619515  0.611620  0.606884  0.612003

                                 Avg
HTRU2_Accuracy              0.967980
HTRU2_F1                    0.821678
HTRU2_ROC_AUC               0.908021
OccupancyData_Accuracy      0.986902
OccupancyData_F1            0.972227
OccupancyData_ROC_AUC       0.981597
ElectricGridData_Accuracy   0.829560
ElectricGridData_F1         0.766909
ElectricGridData_ROC_AUC    0.815952
CreditDefaultData_Accuracy  0.721960
CreditDefaultData_F1        0.397632
CreditDefaultData_ROC_AUC   0.613318
```

1.10 Raw scores for Random Forest

```
[29]: MetricList = ["Accuracy", "F1", "ROC_AUC"]
      randomforest_raw = pd.DataFrame(columns = ["Trial 1","Trial 2","Trial 3","Trial␣
       ↪4", "Trial 5", "Avg"])
      for idx, dataset in enumerate(DatasetNames):
          for idy, metric in enumerate(MetricList):
              randomforest_raw.loc[dataset + "_" + metric] = np.append(
                  all_trials_RandomForest[idx][0][idy], [
                      all_trials_RandomForest[idx][1][idy],
                      all_trials_RandomForest[idx][2][idy],
                      all_trials_RandomForest[idx][3][idy],
                      all_trials_RandomForest[idx][4][idy],
                      RandomForest_algorithm_results[idx][idy]
                  ])
      display(randomforest_raw)
```

```
                              Trial 1   Trial 2   Trial 3   Trial 4   Trial 5  \
HTRU2_Accuracy               0.978369  0.978136  0.978601  0.979687  0.977748
HTRU2_F1                     0.876834  0.875671  0.877788  0.877717  0.876688
HTRU2_ROC_AUC                0.914340  0.913012  0.906251  0.904930  0.921426
OccupancyData_Accuracy       0.990746  0.991324  0.991260  0.991710  0.989781
OccupancyData_F1             0.980446  0.980679  0.980811  0.981998  0.978478
OccupancyData_ROC_AUC        0.988944  0.990436  0.989696  0.991945  0.989540
ElectricGridData_Accuracy    0.909600  0.910200  0.915200  0.916400  0.911400
ElectricGridData_F1          0.865655  0.873654  0.869642  0.877122  0.869565
ElectricGridData_ROC_AUC     0.893918  0.894382  0.896077  0.898680  0.892565
CreditDefaultData_Accuracy   0.813000  0.811280  0.813320  0.813960  0.811800
CreditDefaultData_F1         0.457057  0.453513  0.472810  0.452004  0.464130
CreditDefaultData_ROC_AUC    0.649691  0.650363  0.658389  0.650401  0.651084

                                  Avg
HTRU2_Accuracy               0.978508
HTRU2_F1                     0.876940
HTRU2_ROC_AUC                0.911992
OccupancyData_Accuracy       0.990964
OccupancyData_F1             0.980483
OccupancyData_ROC_AUC        0.990112
ElectricGridData_Accuracy    0.912560
ElectricGridData_F1          0.871128
ElectricGridData_ROC_AUC     0.895124
CreditDefaultData_Accuracy   0.812672
CreditDefaultData_F1         0.459903
CreditDefaultData_ROC_AUC    0.651986
```

1.11 Raw scores for MLP

[30]:
```
MetricList = ["Accuracy", "F1", "ROC_AUC"]
MLP_raw = pd.DataFrame(columns = ["Trial 1","Trial 2","Trial 3","Trial 4",␣
 ↪"Trial 5", "Avg"])
for idx, dataset in enumerate(DatasetNames):
    for idy, metric in enumerate(MetricList):
        MLP_raw.loc[dataset + "_" + metric] = np.append(
            all_trials_MLP[idx][0][idy], [
                all_trials_MLP[idx][1][idy],
                all_trials_MLP[idx][2][idy],
                all_trials_MLP[idx][3][idy],
                all_trials_MLP[idx][4][idy],
                MLP_algorithm_results[idx][idy]
            ])
display(MLP_raw)
```

```
                             Trial 1   Trial 2   Trial 3   Trial 4   Trial 5  \
HTRU2_Accuracy              0.979144  0.979687  0.980772  0.980307  0.978446
HTRU2_F1                    0.881264  0.881847  0.889379  0.888193  0.872858
HTRU2_ROC_AUC               0.917780  0.915351  0.919872  0.915552  0.915006
OccupancyData_Accuracy      0.988046  0.988496  0.989396  0.988817  0.988882
OccupancyData_F1            0.974742  0.975216  0.977285  0.976355  0.976335
OccupancyData_ROC_AUC       0.990823  0.990278  0.991485  0.990929  0.991128
ElectricGridData_Accuracy   0.958400  0.956800  0.956600  0.951200  0.956800
ElectricGridData_F1         0.941048  0.938901  0.940850  0.937707  0.943759
ElectricGridData_ROC_AUC    0.957136  0.958518  0.948667  0.953472  0.953534
CreditDefaultData_Accuracy  0.797080  0.787720  0.794960  0.791680  0.795680
CreditDefaultData_F1        0.430030  0.455709  0.445986  0.456371  0.447391
CreditDefaultData_ROC_AUC   0.649328  0.621278  0.637414  0.640232  0.648776

                                 Avg
HTRU2_Accuracy              0.979671
HTRU2_F1                    0.882708
HTRU2_ROC_AUC               0.916712
OccupancyData_Accuracy      0.988728
OccupancyData_F1            0.975986
OccupancyData_ROC_AUC       0.990929
ElectricGridData_Accuracy   0.955960
ElectricGridData_F1         0.940453
ElectricGridData_ROC_AUC    0.954265
CreditDefaultData_Accuracy  0.793424
CreditDefaultData_F1        0.447097
CreditDefaultData_ROC_AUC   0.639405
```

1.12 P-values for Average Metric Performance (Algorithm/Metric Combinations)

[31]:

```
display(avg_metric_algorithm)
```

```
                Accuracy        F1   ROC_AUC Mean Performance
Log_Reg         0.898539  0.739763  0.824898         0.821067
Tree              0.8766  0.739612  0.829722         0.815311
Random_Forest   0.923676  0.797113  0.862303         0.861031
MLP             0.929446  0.811561  0.875328         0.872112
```

[32]:

```
all_trials =␣
 ↪[all_trials_logisticReg,all_trials_Tree_algorithm,all_trials_RandomForest,all_trials_MLP]

avg_metric_p_values = pd.DataFrame(index=['Log_Reg', 'Tree', 'Random_Forest',␣
 ↪'MLP'], columns = ['Accuracy','F1','ROC_AUC', 'Mean Performance'])

best_ACC = avg_metric_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_metric_algorithm['Accuracy']).idxmax())
best_F1 = avg_metric_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_metric_algorithm['F1']).idxmax())
best_ROC = avg_metric_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_metric_algorithm['ROC_AUC']).idxmax())
best_mean = avg_metric_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_metric_algorithm['Mean Performance']).idxmax())

#Building arrays that include trials corrosponding to the best metric
best_acc_trials = []
for x in range(4):
    for y in range(5):
        best_acc_trials.append(all_trials[best_ACC][x][y][0])

best_f1_trials = []
for x in range(4):
    for y in range(5):
        best_f1_trials.append(all_trials[best_F1][x][y][1])

best_ROC_trials = []
for x in range(4):
    for y in range(5):
        best_ROC_trials.append(all_trials[best_ROC][x][y][2])

best_mean_trials = []
for x in range(4):
    for y in range(5):
        for z in range(3):
            best_mean_trials.append(all_trials[best_mean][x][y][z])

best_trial_metrics = [best_acc_trials,best_f1_trials,best_ROC_trials]

#Building arrays of each metric/algorithm combination and conducting unpaired␣
 ↪t-tests

for idx, algorithm in enumerate(avg_metric_algorithm.index):
    all_current_trials = []
    for metric in range(3):
        current_trials = []
        for x in range(4):
            for y in range(5):
                current_trials.append(all_trials[idx][x][y][metric])
                all_current_trials.append(all_trials[idx][x][y][metric])
        stat, p_value = scipy.stats.ttest_ind(best_trial_metrics[metric],␣
 ↪current_trials)
        avg_metric_p_values.iloc[idx,metric] = p_value
    stat, p_value = scipy.stats.ttest_ind(best_mean_trials, all_current_trials)
    avg_metric_p_values.iloc[idx,3] = p_value







display(avg_metric_p_values)
```

```
                Accuracy        F1   ROC_AUC Mean Performance
Log_Reg         0.253863  0.319739  0.273394         0.100798
Tree           0.0939635  0.302707  0.316436        0.0637869
Random_Forest    0.81435  0.830364  0.764214         0.701141
MLP                    1         1         1                1
```

1.13 P-values for Average Test Performance (Algorithm/Dataset Combinations)

```
[33]: display(avg_problem_algorithm)
```

```
                  HTRU2 Occupancy ElectricGrid CreditDefault Mean Performance
Log_Reg        0.917297  0.985263     0.780268      0.601438         0.821067
Tree           0.899226  0.980242      0.80414      0.577636         0.815311
Random_Forest   0.92248  0.987186     0.892937       0.64152         0.861031
MLP            0.926364  0.985214     0.950226      0.626642         0.872112
```

[34]:

```
all_trials =␣
 ↪[all_trials_logisticReg,all_trials_Tree_algorithm,all_trials_RandomForest,all_trials_MLP]

avg_problem_p_values = pd.DataFrame(index=['Log_Reg', 'Tree', 'Random_Forest',␣
 ↪'MLP'],
                                    columns =␣
 ↪['HTRU2','Occupancy','ElectricGrid','CreditDefault', 'Mean Performance'])

best_HTRU2 = avg_problem_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_problem_algorithm['HTRU2']).idxmax())
best_Occupancy = avg_problem_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_problem_algorithm['Occupancy']).idxmax())
best_ElectricGrid = avg_problem_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_problem_algorithm['ElectricGrid']).idxmax())
best_CreditDefault = avg_problem_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_problem_algorithm['CreditDefault']).idxmax())
best_mean = avg_problem_algorithm.index.get_loc(pd.
 ↪to_numeric(avg_problem_algorithm['Mean Performance']).idxmax())

#Building arrays that include trials corrosponding to the best algorithm

best_HTRU2_trials = []
for x in range(3):
    for y in range(5):
        best_HTRU2_trials.append(all_trials[best_HTRU2][0][y][x])

best_Occupancy_trials = []
for x in range(3):
    for y in range(5):
        best_Occupancy_trials.append(all_trials[best_Occupancy][1][y][x])

best_ElectricGrid_trials = []
for x in range(3):
    for y in range(5):
        best_ElectricGrid_trials.append(all_trials[best_ElectricGrid][2][y][x])

best_CreditDefault_trials = []
for x in range(3):
    for y in range(5):
        best_CreditDefault_trials.
 ↪append(all_trials[best_CreditDefault][3][y][x])

best_mean_trials = []
for x in range(4):
    for y in range(5):
        for z in range(3):
            best_mean_trials.append(all_trials[best_mean][x][y][z])

best_trial_datasets =␣
 ↪[best_HTRU2_trials,best_Occupancy_trials,best_ElectricGrid_trials,␣
 ↪best_CreditDefault_trials]

#Building arrays of each dataset/algorithm combination and conducting unpaired␣
 ↪t-tests

for idx, algorithm in enumerate(avg_metric_algorithm.index):
    all_current_trials = []
    for dataset in range(4):
        current_trials = []
        for x in range(3):
            for y in range(5):
                current_trials.append(all_trials[idx][dataset][y][x])
                all_current_trials.append(all_trials[idx][dataset][y][x])
        stat, p_value = scipy.stats.ttest_ind(best_trial_datasets[dataset],␣
 ↪current_trials)
        avg_problem_p_values.iloc[idx,dataset] = p_value
    stat, p_value = scipy.stats.ttest_ind(best_mean_trials, all_current_trials)
    avg_problem_p_values.iloc[idx,4] = p_value









display(avg_problem_p_values)
```

```
                  HTRU2   Occupancy ElectricGrid CreditDefault  \
Log_Reg        0.579396    0.382292  5.36764e-17      0.517229
Tree           0.172523  0.00361748  1.22665e-17      0.236327
Random_Forest  0.805368           1  4.89035e-12             1
MLP                   1    0.376069            1      0.785291

              Mean Performance
Log_Reg               0.100798
Tree                 0.0637869
Random_Forest         0.701141
MLP                          1
```

```
[ ]:
```