DoCCMLResultsFINAL1

March 29, 2023

1 Default On Credit Cards Data - Machine Learning

The dataset being used for this analysis is the Default on Credit Cards Client Data Set. This the data is comprised of 30000 customers from a major Taiwanese bank, in which 22% have defaulted on a credit card payment. The goal is to train a machine learning model to predict if a customer will default on payement.

1.0.1 Features of the Dataset

Note all variables in dataset of of type integer - **ID**: identifier for each client in the dataset - **LIMIT_BAL**: amount of credit given in NTD - **SEX**: gender (1 = male; 2 = female) - **EDUCATION**: Education (1 = graduate school; 2 = university; 3 = high school; 4 = others). - **MARRIAGE**: Marital status (1 = married; 2 = single; 3 = others) - **AGE**: age in years - **PAY_0 to PAY_6**: history of past payements made on credit card in NTD from April to September, 2005 (each pay period represents a month). -1 = pay duly, 1 = payment delay for one month; 2 = payment delay for two months; . . .; 8 = payment delay for eight months; 9 = payment delay for nine months and above. - **BILL_AMT1 to BILL_AMT6**: Amount of the bill payment due for each month from April to September, 2005 in NTD - **PAY_AMT1 to PAY_AMT1**: amount of the previous payment fro the month from April to September, 2005 in NTD

Target variable: default payment next month (Yes = 1, No = 0)

1.1 Exploring the dataset and Data Cleaning

[1]:
```
import warnings
warnings.filterwarnings("ignore", category=FutureWarning)
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
```

1.1.1 Reading In Data

[2]:
```
credit = pd.read_excel("C:/Users/Thomshu/Dropbox/COMP-3710 AI Concepts/Final␣
↪Proj/Default-Credit-Card-Prediction-master/default of credit card clients.
↪xls", header=1)
credit.head()
```

[2]:
```
   ID  LIMIT_BAL  SEX  EDUCATION  MARRIAGE  AGE  PAY_0  PAY_2  PAY_3  PAY_4  \
0   1      20000    2          2         1   24      2      2     -1     -1
1   2     120000    2          2         2   26     -1      2      0      0
2   3      90000    2          2         2   34      0      0      0      0
3   4      50000    2          2         1   37      0      0      0      0
4   5      50000    1          2         1   57     -1      0     -1      0

   …  BILL_AMT4  BILL_AMT5  BILL_AMT6  PAY_AMT1  PAY_AMT2  PAY_AMT3  \
0  …          0          0          0         0       689         0
1  …       3272       3455       3261         0      1000      1000
2  …      14331      14948      15549      1518      1500      1000
3  …      28314      28959      29547      2000      2019      1200
4  …      20940      19146      19131      2000     36681     10000

   PAY_AMT4  PAY_AMT5  PAY_AMT6  default payment next month
0         0         0         0                           1
1      1000         0      2000                           1
2      1000      1000      5000                           0
3      1100      1069      1000                           0
4      9000       689       679                           0

[5 rows x 25 columns]
```

[3]:
```python
# basic cleaning
# drop ID column as it provides no useful information
credit.drop(['ID'], axis= 1, inplace=True)
# shorten name of target variable to something easier to remember
credit.rename(columns={"PAY_0": "PAY_1", "default payment next month":
 "DEFAULT"}, inplace=True)
#  Because PAY_1 doesn't exist and it goes from PAY 0, PAY_2 to PAY_6, so we
 rename PAY_0 to PAY_1
credit.head()
```

[3]:
```
   LIMIT_BAL  SEX  EDUCATION  MARRIAGE  AGE  PAY_1  PAY_2  PAY_3  PAY_4  \
0      20000    2          2         1   24      2      2     -1     -1
1     120000    2          2         2   26     -1      2      0      0
2      90000    2          2         2   34      0      0      0      0
3      50000    2          2         1   37      0      0      0      0
4      50000    1          2         1   57     -1      0     -1      0

   PAY_5  …  BILL_AMT4  BILL_AMT5  BILL_AMT6  PAY_AMT1  PAY_AMT2  PAY_AMT3  \
0     -2  …          0          0          0         0       689         0
1      0  …       3272       3455       3261         0      1000      1000
2      0  …      14331      14948      15549      1518      1500      1000
3      0  …      28314      28959      29547      2000      2019      1200
4      0  …      20940      19146      19131      2000     36681     10000
```

```
   PAY_AMT4  PAY_AMT5  PAY_AMT6  DEFAULT
0         0         0         0        1
1      1000         0      2000        1
2      1000      1000      5000        0
3      1100      1069      1000        0
4      9000       689       679        0

[5 rows x 24 columns]
```

[4]:
```
credit.describe()
```

[4]:
```
             LIMIT_BAL           SEX     EDUCATION      MARRIAGE           AGE  \
count     30000.000000  30000.000000  30000.000000  30000.000000  30000.000000
mean     167484.322667      1.603733      1.853133      1.551867     35.485500
std      129747.661567      0.489129      0.790349      0.521970      9.217904
min       10000.000000      1.000000      0.000000      0.000000     21.000000
25%       50000.000000      1.000000      1.000000      1.000000     28.000000
50%      140000.000000      2.000000      2.000000      2.000000     34.000000
75%      240000.000000      2.000000      2.000000      2.000000     41.000000
max     1000000.000000      2.000000      6.000000      3.000000     79.000000

              PAY_1         PAY_2         PAY_3         PAY_4         PAY_5  \
count  30000.000000  30000.000000  30000.000000  30000.000000  30000.000000
mean      -0.016700     -0.133767     -0.166200     -0.220667     -0.266200
std        1.123802      1.197186      1.196868      1.169139      1.133187
min       -2.000000     -2.000000     -2.000000     -2.000000     -2.000000
25%       -1.000000     -1.000000     -1.000000     -1.000000     -1.000000
50%        0.000000      0.000000      0.000000      0.000000      0.000000
75%        0.000000      0.000000      0.000000      0.000000      0.000000
max        8.000000      8.000000      8.000000      8.000000      8.000000

       …      BILL_AMT4      BILL_AMT5      BILL_AMT6       PAY_AMT1  \
count  …   30000.000000   30000.000000   30000.000000   30000.000000
mean   …   43262.948967   40311.400967   38871.760400    5663.580500
std    …   64332.856134   60797.155770   59554.107537   16563.280354
min    … -170000.000000  -81334.000000 -339603.000000       0.000000
25%    …    2326.750000    1763.000000    1256.000000    1000.000000
50%    …   19052.000000   18104.500000   17071.000000    2100.000000
75%    …   54506.000000   50190.500000   49198.250000    5006.000000
max    …  891586.000000  927171.000000  961664.000000  873552.000000

           PAY_AMT2      PAY_AMT3       PAY_AMT4       PAY_AMT5  \
count  3.000000e+04   30000.00000   30000.000000   30000.000000
mean   5.921163e+03    5225.68150    4826.076867    4799.387633
std    2.304087e+04   17606.96147   15666.159744   15278.305679
min    0.000000e+00       0.00000       0.000000       0.000000
25%    8.330000e+02     390.00000     296.000000     252.500000
```

```
50%    2.009000e+03    1800.00000    1500.000000    1500.000000
75%    5.000000e+03    4505.00000    4013.250000    4031.500000
max    1.684259e+06  896040.00000  621000.000000  426529.000000

            PAY_AMT6       DEFAULT
count   30000.000000  30000.000000
mean     5215.502567      0.221200
std     17777.465775      0.415062
min         0.000000      0.000000
25%       117.750000      0.000000
50%      1500.000000      0.000000
75%      4000.000000      0.000000
max    528666.000000      1.000000

[8 rows x 24 columns]
```

1.1.2 Exploring data

[5]:
```
credit.isnull().sum() #Checking for null values based on outputted table, no␣
↪null values
```

[5]:
```
LIMIT_BAL    0
SEX          0
EDUCATION    0
MARRIAGE     0
AGE          0
PAY_1        0
PAY_2        0
PAY_3        0
PAY_4        0
PAY_5        0
PAY_6        0
BILL_AMT1    0
BILL_AMT2    0
BILL_AMT3    0
BILL_AMT4    0
BILL_AMT5    0
BILL_AMT6    0
PAY_AMT1     0
PAY_AMT2     0
PAY_AMT3     0
PAY_AMT4     0
PAY_AMT5     0
PAY_AMT6     0
DEFAULT      0
dtype: int64
```

1.1.3 Exploring categorical data

[6]:
```python
categories = ["MARRIAGE", "EDUCATION", "SEX"]
for col in categories:
    print(col)
    print(credit[col].value_counts())
```

```
MARRIAGE
2    15964
1    13659
3      323
0       54
Name: MARRIAGE, dtype: int64
EDUCATION
2    14030
1    10585
3     4917
5      280
4      123
6       51
0       14
Name: EDUCATION, dtype: int64
SEX
2    18112
1    11888
Name: SEX, dtype: int64
```

When observing the values present for Marriage, Education and Sex, we notice that there are values not documented to a described category, e.g. Marriage (Marital Status) describes 1, 2, 3 as married, single or other respectively, but there is an additional 0 category with 54 values. Similarly, for Education 1-4 is documented as graduate, university, high school or others but we see additional values for the undocumented categories of 0, 5, 6.

For these undocumented categories, there are two ways to correct for them, either delete the rows associated with them or assign those rows with the mode for that feature (e.g. for marriage it would be 2).

Based on the low number of values in respect to the total number of values for these undocumented categories, we decided to just simply remove those rows of values as done in the next cell below. As a result only 399 values were removed of the total 30000 values, which is minimal.

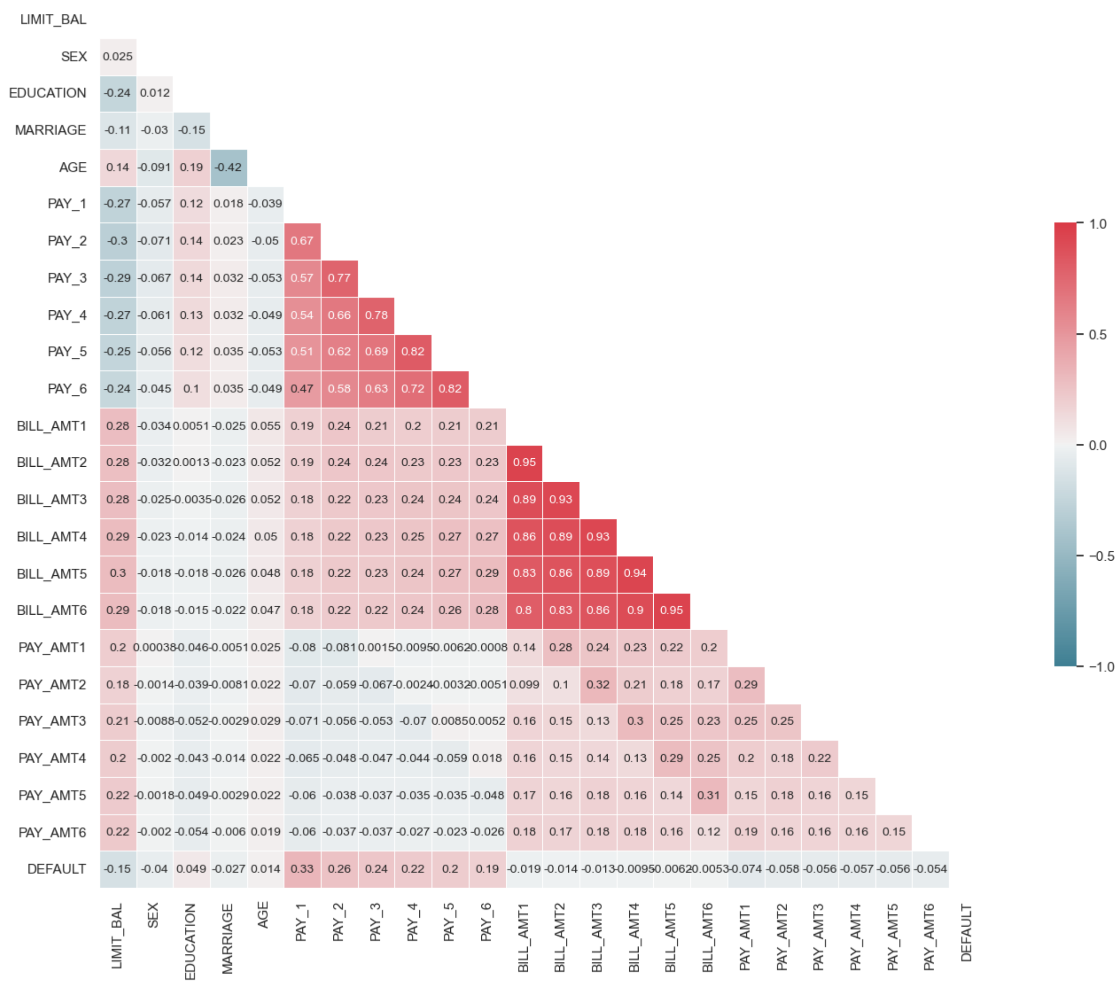
[7]:
```python
credit.shape
credit = credit.loc[credit["MARRIAGE"] != 0]
credit = credit.loc[credit["EDUCATION"] != 0]
credit = credit.loc[credit["EDUCATION"] != 5]
credit = credit.loc[credit["EDUCATION"] != 6]

credit.shape
```

[7]: (29601, 24)

[8]:
```python
# Correlation matrix
sns.set(style = "white", font_scale = 1)
corr = credit.corr() # .corr is used to find corelation

mask = np.triu(np.ones_like(corr, dtype = bool))
fig, ax = plt.subplots(figsize = (20, 13))
cmap = sns.diverging_palette(220, 10, as_cmap = True)
ax=sns.heatmap(corr, mask = mask, vmax = 1, vmin = -1, center = 0, square =␣
↪True, linewidths = .5, cmap = cmap, cbar_kws = {"shrink": .5}, annot=True,␣
↪annot_kws={"size": 10})
cbar=ax.collections[0].colorbar
cbar.set_ticks([-1, -0.50, 0, 0.50, 1])
plt.savefig('Figure - Correlation matrix by means of the Pearson's coefficient␣
↪for all feature pairs.png')
```



This program takes the listed num values and produced a correlation maxtrix using the pearson's coefficient.

1.2 Data Preprocessing

1.2.1 Train, Validation, test Datasets

[9]:
```
from sklearn.model_selection import train_test_split

features = credit.drop('DEFAULT', axis=1)
labels = credit['DEFAULT']

X_train, X_test, y_train, y_test = train_test_split(features, labels,␣
↪test_size=0.2, random_state=42) #random_state is the initializer seed for␣
↪the randomizer

#We split the data into 80/20 percentage split, so we have 80% of the data in␣
↪the training set and 20% of the data in the test set
```

[10]:
```
y_train.value_counts() #Confirming the training set contains 80% of the data␣
↪(29601 * 0.8) <- recall we removed 399 values out of our 30000 dataset
```

[10]:
```
0    18405
1     5275
Name: DEFAULT, dtype: int64
```

Feature Scaling

[11]:
```
# Standard Scaler
from sklearn.preprocessing import StandardScaler
scaler = StandardScaler()
X_train = scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)
```

[12]:
```
df = pd.DataFrame(X_train, columns = credit.columns[:-1])
df.head()
```

[12]:
```
   LIMIT_BAL       SEX  EDUCATION  MARRIAGE       AGE     PAY_1     PAY_2  \
0   0.481095  0.809332   0.254274 -1.074526 -0.051489  0.009536  0.106744
1  -0.827493  0.809332   0.254274 -1.074526  0.057364  0.009536  0.106744
2   0.173192 -1.235587   0.254274  0.858673 -0.813461 -1.768501 -1.561150
3  -0.519590 -1.235587  -1.150582  0.858673 -0.922314  0.009536  0.106744
4  -1.058420  0.809332   0.254274 -1.074526 -0.160342  0.009536 -0.727203

      PAY_3     PAY_4     PAY_5  …  BILL_AMT3  BILL_AMT4  BILL_AMT5  \
0  0.132057  0.186462  0.228234  …   1.501486   1.686391   1.772691
1  0.132057  0.186462  0.228234  …  -0.015526  -0.104602  -0.049441
2 -1.533071 -1.521962 -1.532789  …  -0.675463  -0.671231  -0.662749
```

```
3  0.132057  0.186462  0.228234  …   0.264321   0.279651   0.404593
4 -0.700507  0.186462  0.228234  …  -0.327152  -0.286466  -0.288138

   BILL_AMT6  PAY_AMT1  PAY_AMT2  PAY_AMT3  PAY_AMT4  PAY_AMT5  PAY_AMT6
0   1.918806  0.255960  0.163816  0.264113  0.134481  0.337266  0.264700
1  -0.012449 -0.209107 -0.161962 -0.197435 -0.214656 -0.221946 -0.207390
2  -0.652792 -0.332545 -0.243305 -0.291969 -0.309875 -0.312981 -0.290700
3   0.460547 -0.097425 -0.150737 -0.159788  0.007522 -0.156206 -0.158293
4  -0.472382 -0.258482  0.738301 -0.236360 -0.182916  0.385710  0.740788

[5 rows x 23 columns]
```

Oversampling

[13]:
```python
#Checking for the Binary Defaults, then determining if we need to Oversample
y_train.value_counts()
```

[13]:
```
0    18405
1     5275
Name: DEFAULT, dtype: int64
```

[14]:
```python
#Oversampling
# Two choices for Oversampling, either use SMOTE (Synthetic Minority
 ↪Over-sampling Technique) or ROS (Random Over Sampling), we chose ROS in this
 ↪case
from imblearn.over_sampling import RandomOverSampler
ros = RandomOverSampler()
X_train, y_train = ros.fit_resample(X_train, y_train)

y_train.value_counts()

# DELETE COMMENT FOR OUR OWN INFORMATION
# In general, oversampling is useful when the minority class is severely
 ↪underrepresented, and the dataset has a large number of features.
# By increasing the number of instances in the minority class, oversampling can
 ↪help the model learn more about the patterns of the minority class and
# improve the model's ability to make accurate predictions.
```

[14]:
```
0    18405
1    18405
Name: DEFAULT, dtype: int64
```

1.3 Hyperparameter tuning using GridSearchCV

[15]:
```
# import libraries for SVC and hyperparameter tuning
from sklearn.model_selection import GridSearchCV
```

[16]:
```
# function for printing out results from GridSearchCV

def print_results(results):
    print('BEST PARAMS: {}\n'.format(results.best_params_))

    means = results.cv_results_['mean_test_score']
    stds = results.cv_results_['std_test_score']
    for mean, std, params in zip(means, stds, results.cv_results_['params']):
        print('{} (+/-{}) for {}'.format(round(mean, 3), round(std * 2, 3),␣
 ↪params))
```

1.3.1 Decision Tree Training and Testing

[19]:
```
from sklearn.tree import DecisionTreeClassifier

dt = DecisionTreeClassifier()

param_grid = {
    'criterion': ['gini', 'entropy'], #Gini impurity
    'splitter': ['best', 'random'],
    'max_depth': [None] + list(range(1, 21)),
    'max_features': [None] + list(range(1,23))
}

dtcv = GridSearchCV(estimator=dt, param_grid = param_grid, cv=3, n_jobs=6,␣
 ↪verbose=1)

dtcv.fit(X_train, y_train)

print_results(dtcv)
```

```
Fitting 3 folds for each of 1932 candidates, totalling 5796 fits
BEST PARAMS: {'criterion': 'entropy', 'max_depth': None, 'max_features': 9,
'splitter': 'best'}

0.877 (+/-0.023) for {'criterion': 'gini', 'max_depth': None, 'max_features':
None, 'splitter': 'best'}
0.878 (+/-0.023) for {'criterion': 'gini', 'max_depth': None, 'max_features':
None, 'splitter': 'random'}
0.876 (+/-0.02) for {'criterion': 'gini', 'max_depth': None, 'max_features': 1,
'splitter': 'best'}
0.875 (+/-0.027) for {'criterion': 'gini', 'max_depth': None, 'max_features': 1,
```

```
'splitter': 'random'}
0.875 (+/-0.015) for {'criterion': 'gini', 'max_depth': None, 'max_features': 2,
'splitter': 'best'}
0.877 (+/-0.019) for {'criterion': 'gini', 'max_depth': None, 'max_features': 2,
'splitter': 'random'}
0.876 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features': 3,
'splitter': 'best'}
0.878 (+/-0.025) for {'criterion': 'gini', 'max_depth': None, 'max_features': 3,
'splitter': 'random'}
0.879 (+/-0.017) for {'criterion': 'gini', 'max_depth': None, 'max_features': 4,
'splitter': 'best'}
0.877 (+/-0.016) for {'criterion': 'gini', 'max_depth': None, 'max_features': 4,
'splitter': 'random'}
0.878 (+/-0.024) for {'criterion': 'gini', 'max_depth': None, 'max_features': 5,
'splitter': 'best'}
0.875 (+/-0.023) for {'criterion': 'gini', 'max_depth': None, 'max_features': 5,
'splitter': 'random'}
0.877 (+/-0.019) for {'criterion': 'gini', 'max_depth': None, 'max_features': 6,
'splitter': 'best'}
0.877 (+/-0.025) for {'criterion': 'gini', 'max_depth': None, 'max_features': 6,
'splitter': 'random'}
0.88 (+/-0.024) for {'criterion': 'gini', 'max_depth': None, 'max_features': 7,
'splitter': 'best'}
0.877 (+/-0.019) for {'criterion': 'gini', 'max_depth': None, 'max_features': 7,
'splitter': 'random'}
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'splitter': 'best'}
0.875 (+/-0.017) for {'criterion': 'gini', 'max_depth': None, 'max_features': 8,
'splitter': 'random'}
0.879 (+/-0.025) for {'criterion': 'gini', 'max_depth': None, 'max_features': 9,
'splitter': 'best'}
0.874 (+/-0.024) for {'criterion': 'gini', 'max_depth': None, 'max_features': 9,
'splitter': 'random'}
0.876 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features':
10, 'splitter': 'best'}
0.874 (+/-0.019) for {'criterion': 'gini', 'max_depth': None, 'max_features':
10, 'splitter': 'random'}
0.879 (+/-0.026) for {'criterion': 'gini', 'max_depth': None, 'max_features':
11, 'splitter': 'best'}
0.875 (+/-0.026) for {'criterion': 'gini', 'max_depth': None, 'max_features':
11, 'splitter': 'random'}
0.878 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features':
12, 'splitter': 'best'}
0.876 (+/-0.02) for {'criterion': 'gini', 'max_depth': None, 'max_features': 12,
'splitter': 'random'}
0.88 (+/-0.018) for {'criterion': 'gini', 'max_depth': None, 'max_features': 13,
'splitter': 'best'}
0.877 (+/-0.019) for {'criterion': 'gini', 'max_depth': None, 'max_features':
```

```
13, 'splitter': 'random'}
0.877 (+/-0.019) for {'criterion': 'gini', 'max_depth': None, 'max_features':
14, 'splitter': 'best'}
0.875 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features':
14, 'splitter': 'random'}
0.876 (+/-0.021) for {'criterion': 'gini', 'max_depth': None, 'max_features':
15, 'splitter': 'best'}
0.877 (+/-0.027) for {'criterion': 'gini', 'max_depth': None, 'max_features':
15, 'splitter': 'random'}
0.875 (+/-0.02) for {'criterion': 'gini', 'max_depth': None, 'max_features': 16,
'splitter': 'best'}
0.874 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features':
16, 'splitter': 'random'}
0.879 (+/-0.021) for {'criterion': 'gini', 'max_depth': None, 'max_features':
17, 'splitter': 'best'}
0.876 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features':
17, 'splitter': 'random'}
0.877 (+/-0.026) for {'criterion': 'gini', 'max_depth': None, 'max_features':
18, 'splitter': 'best'}
0.877 (+/-0.018) for {'criterion': 'gini', 'max_depth': None, 'max_features':
18, 'splitter': 'random'}
0.874 (+/-0.023) for {'criterion': 'gini', 'max_depth': None, 'max_features':
19, 'splitter': 'best'}
0.876 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features':
19, 'splitter': 'random'}
0.877 (+/-0.021) for {'criterion': 'gini', 'max_depth': None, 'max_features':
20, 'splitter': 'best'}
0.878 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features':
20, 'splitter': 'random'}
0.877 (+/-0.021) for {'criterion': 'gini', 'max_depth': None, 'max_features':
21, 'splitter': 'best'}
0.874 (+/-0.026) for {'criterion': 'gini', 'max_depth': None, 'max_features':
21, 'splitter': 'random'}
0.877 (+/-0.022) for {'criterion': 'gini', 'max_depth': None, 'max_features':
22, 'splitter': 'best'}
0.876 (+/-0.026) for {'criterion': 'gini', 'max_depth': None, 'max_features':
22, 'splitter': 'random'}
0.688 (+/-0.004) for {'criterion': 'gini', 'max_depth': 1, 'max_features': None,
'splitter': 'best'}
0.615 (+/-0.024) for {'criterion': 'gini', 'max_depth': 1, 'max_features': None,
'splitter': 'random'}
0.573 (+/-0.16) for {'criterion': 'gini', 'max_depth': 1, 'max_features': 1,
'splitter': 'best'}
0.536 (+/-0.099) for {'criterion': 'gini', 'max_depth': 1, 'max_features': 1,
'splitter': 'random'}
0.574 (+/-0.029) for {'criterion': 'gini', 'max_depth': 1, 'max_features': 2,
'splitter': 'best'}
0.501 (+/-0.001) for {'criterion': 'gini', 'max_depth': 1, 'max_features': 2,
```

```
'splitter': 'random'}
0.609 (+/-0.079) for {'criterion': 'gini', 'max_depth': 1, 'max_features': 3,
'splitter': 'best'}
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0.832 (+/-0.018) for {'criterion': 'entropy', 'max_depth': 20, 'max_features':
22, 'splitter': 'best'}
0.795 (+/-0.035) for {'criterion': 'entropy', 'max_depth': 20, 'max_features':
22, 'splitter': 'random'}
```

Gini Impurity measures the impurity of the data set. entropy maximizes the info gain at each node split

max_features looks for best split possible (none considers all features (sqrt & log2)

[20]:
```
print(dtcv.best_score_)
print(dtcv.best_estimator_)
print(dtcv.best_params_)
```

```
0.8801412659603368
DecisionTreeClassifier(criterion='entropy', max_features=9)
{'criterion': 'entropy', 'max_depth': None, 'max_features': 9, 'splitter':
'best'}
```

[21]:
```
#Training model using best hyperparameters
dtcv_trainer = DecisionTreeClassifier(criterion= 'entropy', max_depth= None,␣
↪max_features= 9, splitter = 'best', random_state=42)
dtcv_trainer.fit(X_train, y_train)
```

[21]:
```
DecisionTreeClassifier(criterion='entropy', max_features=9, random_state=42)
```

[22]:
```
dtcv_pred = dtcv_trainer.predict(X_test)

from sklearn.metrics import classification_report, confusion_matrix

# this prints the graph that tells you how well prediction went
print(classification_report(y_test, dtcv_pred))
# prints confusion matrix
print(confusion_matrix(y_test, dtcv_pred))
```

```
              precision    recall  f1-score   support
```

```
           0       0.83      0.84      0.83      4591
           1       0.42      0.41      0.41      1330

    accuracy                           0.74      5921
   macro avg       0.62      0.62      0.62      5921
weighted avg       0.74      0.74      0.74      5921

[[3835  756]
 [ 785  545]]
```

1.3.2 K-Nearest Neighbours Training and Testing

[21]:
```python
from sklearn.neighbors import KNeighborsClassifier

knn = KNeighborsClassifier()

# Define the parameter grid
knnparameters = {
    'n_neighbors': list(range(1, 20)), # Arbirtrarily chose to explore ranges␣
 ↪of 1 to 20 for how many neighbors, when using GridSearchCV hyperparameter␣
 ↪tuning
    'weights': ['uniform', 'distance'], #only two available pre-defined weights␣
 ↪in sklearn
    'metric': ['euclidean', 'manhattan', 'minkowski'] #Commonly used distance␣
 ↪metrics
}

# Create an instance of GridSearchCV
knncv = GridSearchCV(estimator = knn, param_grid = knnparameters, cv=3,␣
 ↪n_jobs=6, verbose=1)

# Fit the grid search on the training data
knncv.fit(X_train, y_train)

print_results(knncv)
```

```
Fitting 3 folds for each of 114 candidates, totalling 342 fits
BEST PARAMS: {'metric': 'euclidean', 'n_neighbors': 1, 'weights': 'uniform'}

0.877 (+/-0.019) for {'metric': 'euclidean', 'n_neighbors': 1, 'weights':
'uniform'}
0.877 (+/-0.019) for {'metric': 'euclidean', 'n_neighbors': 1, 'weights':
'distance'}
0.822 (+/-0.012) for {'metric': 'euclidean', 'n_neighbors': 2, 'weights':
'uniform'}
0.877 (+/-0.019) for {'metric': 'euclidean', 'n_neighbors': 2, 'weights':
```

```
'distance'}
0.783 (+/-0.012) for {'metric': 'euclidean', 'n_neighbors': 3, 'weights':
'uniform'}
0.835 (+/-0.02) for {'metric': 'euclidean', 'n_neighbors': 3, 'weights':
'distance'}
0.758 (+/-0.008) for {'metric': 'euclidean', 'n_neighbors': 4, 'weights':
'uniform'}
0.843 (+/-0.02) for {'metric': 'euclidean', 'n_neighbors': 4, 'weights':
'distance'}
0.742 (+/-0.011) for {'metric': 'euclidean', 'n_neighbors': 5, 'weights':
'uniform'}
0.829 (+/-0.027) for {'metric': 'euclidean', 'n_neighbors': 5, 'weights':
'distance'}
0.735 (+/-0.008) for {'metric': 'euclidean', 'n_neighbors': 6, 'weights':
'uniform'}
0.838 (+/-0.027) for {'metric': 'euclidean', 'n_neighbors': 6, 'weights':
'distance'}
0.731 (+/-0.012) for {'metric': 'euclidean', 'n_neighbors': 7, 'weights':
'uniform'}
0.834 (+/-0.027) for {'metric': 'euclidean', 'n_neighbors': 7, 'weights':
'distance'}
0.728 (+/-0.012) for {'metric': 'euclidean', 'n_neighbors': 8, 'weights':
'uniform'}
0.841 (+/-0.027) for {'metric': 'euclidean', 'n_neighbors': 8, 'weights':
'distance'}
0.724 (+/-0.01) for {'metric': 'euclidean', 'n_neighbors': 9, 'weights':
'uniform'}
0.838 (+/-0.026) for {'metric': 'euclidean', 'n_neighbors': 9, 'weights':
'distance'}
0.722 (+/-0.007) for {'metric': 'euclidean', 'n_neighbors': 10, 'weights':
'uniform'}
0.843 (+/-0.025) for {'metric': 'euclidean', 'n_neighbors': 10, 'weights':
'distance'}
0.719 (+/-0.009) for {'metric': 'euclidean', 'n_neighbors': 11, 'weights':
'uniform'}
0.842 (+/-0.026) for {'metric': 'euclidean', 'n_neighbors': 11, 'weights':
'distance'}
0.718 (+/-0.009) for {'metric': 'euclidean', 'n_neighbors': 12, 'weights':
'uniform'}
0.846 (+/-0.026) for {'metric': 'euclidean', 'n_neighbors': 12, 'weights':
'distance'}
0.716 (+/-0.011) for {'metric': 'euclidean', 'n_neighbors': 13, 'weights':
'uniform'}
0.847 (+/-0.027) for {'metric': 'euclidean', 'n_neighbors': 13, 'weights':
'distance'}
0.717 (+/-0.005) for {'metric': 'euclidean', 'n_neighbors': 14, 'weights':
'uniform'}
0.851 (+/-0.027) for {'metric': 'euclidean', 'n_neighbors': 14, 'weights':
```

```
'distance'}
0.713 (+/-0.007) for {'metric': 'euclidean', 'n_neighbors': 15, 'weights':
'uniform'}
0.851 (+/-0.028) for {'metric': 'euclidean', 'n_neighbors': 15, 'weights':
'distance'}
0.712 (+/-0.004) for {'metric': 'euclidean', 'n_neighbors': 16, 'weights':
'uniform'}
0.853 (+/-0.027) for {'metric': 'euclidean', 'n_neighbors': 16, 'weights':
'distance'}
0.712 (+/-0.009) for {'metric': 'euclidean', 'n_neighbors': 17, 'weights':
'uniform'}
0.853 (+/-0.026) for {'metric': 'euclidean', 'n_neighbors': 17, 'weights':
'distance'}
0.711 (+/-0.007) for {'metric': 'euclidean', 'n_neighbors': 18, 'weights':
'uniform'}
0.856 (+/-0.026) for {'metric': 'euclidean', 'n_neighbors': 18, 'weights':
'distance'}
0.711 (+/-0.011) for {'metric': 'euclidean', 'n_neighbors': 19, 'weights':
'uniform'}
0.856 (+/-0.025) for {'metric': 'euclidean', 'n_neighbors': 19, 'weights':
'distance'}
0.874 (+/-0.02) for {'metric': 'manhattan', 'n_neighbors': 1, 'weights':
'uniform'}
0.874 (+/-0.02) for {'metric': 'manhattan', 'n_neighbors': 1, 'weights':
'distance'}
0.822 (+/-0.012) for {'metric': 'manhattan', 'n_neighbors': 2, 'weights':
'uniform'}
0.874 (+/-0.02) for {'metric': 'manhattan', 'n_neighbors': 2, 'weights':
'distance'}
0.784 (+/-0.011) for {'metric': 'manhattan', 'n_neighbors': 3, 'weights':
'uniform'}
0.832 (+/-0.019) for {'metric': 'manhattan', 'n_neighbors': 3, 'weights':
'distance'}
0.762 (+/-0.006) for {'metric': 'manhattan', 'n_neighbors': 4, 'weights':
'uniform'}
0.84 (+/-0.018) for {'metric': 'manhattan', 'n_neighbors': 4, 'weights':
'distance'}
0.745 (+/-0.01) for {'metric': 'manhattan', 'n_neighbors': 5, 'weights':
'uniform'}
0.827 (+/-0.022) for {'metric': 'manhattan', 'n_neighbors': 5, 'weights':
'distance'}
0.739 (+/-0.009) for {'metric': 'manhattan', 'n_neighbors': 6, 'weights':
'uniform'}
0.837 (+/-0.023) for {'metric': 'manhattan', 'n_neighbors': 6, 'weights':
'distance'}
0.732 (+/-0.008) for {'metric': 'manhattan', 'n_neighbors': 7, 'weights':
'uniform'}
0.833 (+/-0.024) for {'metric': 'manhattan', 'n_neighbors': 7, 'weights':
```

```
'distance'}
0.731 (+/-0.009) for {'metric': 'manhattan', 'n_neighbors': 8, 'weights':
'uniform'}
0.838 (+/-0.023) for {'metric': 'manhattan', 'n_neighbors': 8, 'weights':
'distance'}
0.724 (+/-0.013) for {'metric': 'manhattan', 'n_neighbors': 9, 'weights':
'uniform'}
0.834 (+/-0.027) for {'metric': 'manhattan', 'n_neighbors': 9, 'weights':
'distance'}
0.727 (+/-0.01) for {'metric': 'manhattan', 'n_neighbors': 10, 'weights':
'uniform'}
0.839 (+/-0.024) for {'metric': 'manhattan', 'n_neighbors': 10, 'weights':
'distance'}
0.719 (+/-0.009) for {'metric': 'manhattan', 'n_neighbors': 11, 'weights':
'uniform'}
0.836 (+/-0.022) for {'metric': 'manhattan', 'n_neighbors': 11, 'weights':
'distance'}
0.719 (+/-0.008) for {'metric': 'manhattan', 'n_neighbors': 12, 'weights':
'uniform'}
0.841 (+/-0.025) for {'metric': 'manhattan', 'n_neighbors': 12, 'weights':
'distance'}
0.715 (+/-0.008) for {'metric': 'manhattan', 'n_neighbors': 13, 'weights':
'uniform'}
0.84 (+/-0.025) for {'metric': 'manhattan', 'n_neighbors': 13, 'weights':
'distance'}
0.716 (+/-0.008) for {'metric': 'manhattan', 'n_neighbors': 14, 'weights':
'uniform'}
0.843 (+/-0.025) for {'metric': 'manhattan', 'n_neighbors': 14, 'weights':
'distance'}
0.713 (+/-0.013) for {'metric': 'manhattan', 'n_neighbors': 15, 'weights':
'uniform'}
0.843 (+/-0.024) for {'metric': 'manhattan', 'n_neighbors': 15, 'weights':
'distance'}
0.714 (+/-0.009) for {'metric': 'manhattan', 'n_neighbors': 16, 'weights':
'uniform'}
0.846 (+/-0.026) for {'metric': 'manhattan', 'n_neighbors': 16, 'weights':
'distance'}
0.714 (+/-0.012) for {'metric': 'manhattan', 'n_neighbors': 17, 'weights':
'uniform'}
0.847 (+/-0.027) for {'metric': 'manhattan', 'n_neighbors': 17, 'weights':
'distance'}
0.714 (+/-0.015) for {'metric': 'manhattan', 'n_neighbors': 18, 'weights':
'uniform'}
0.848 (+/-0.028) for {'metric': 'manhattan', 'n_neighbors': 18, 'weights':
'distance'}
0.714 (+/-0.011) for {'metric': 'manhattan', 'n_neighbors': 19, 'weights':
'uniform'}
0.849 (+/-0.026) for {'metric': 'manhattan', 'n_neighbors': 19, 'weights':
```

```
'distance'}
0.877 (+/-0.019) for {'metric': 'minkowski', 'n_neighbors': 1, 'weights':
'uniform'}
0.877 (+/-0.019) for {'metric': 'minkowski', 'n_neighbors': 1, 'weights':
'distance'}
0.822 (+/-0.012) for {'metric': 'minkowski', 'n_neighbors': 2, 'weights':
'uniform'}
0.877 (+/-0.019) for {'metric': 'minkowski', 'n_neighbors': 2, 'weights':
'distance'}
0.783 (+/-0.012) for {'metric': 'minkowski', 'n_neighbors': 3, 'weights':
'uniform'}
0.835 (+/-0.02) for {'metric': 'minkowski', 'n_neighbors': 3, 'weights':
'distance'}
0.758 (+/-0.008) for {'metric': 'minkowski', 'n_neighbors': 4, 'weights':
'uniform'}
0.843 (+/-0.02) for {'metric': 'minkowski', 'n_neighbors': 4, 'weights':
'distance'}
0.742 (+/-0.011) for {'metric': 'minkowski', 'n_neighbors': 5, 'weights':
'uniform'}
0.829 (+/-0.027) for {'metric': 'minkowski', 'n_neighbors': 5, 'weights':
'distance'}
0.735 (+/-0.008) for {'metric': 'minkowski', 'n_neighbors': 6, 'weights':
'uniform'}
0.838 (+/-0.027) for {'metric': 'minkowski', 'n_neighbors': 6, 'weights':
'distance'}
0.731 (+/-0.012) for {'metric': 'minkowski', 'n_neighbors': 7, 'weights':
'uniform'}
0.834 (+/-0.027) for {'metric': 'minkowski', 'n_neighbors': 7, 'weights':
'distance'}
0.728 (+/-0.012) for {'metric': 'minkowski', 'n_neighbors': 8, 'weights':
'uniform'}
0.841 (+/-0.027) for {'metric': 'minkowski', 'n_neighbors': 8, 'weights':
'distance'}
0.724 (+/-0.01) for {'metric': 'minkowski', 'n_neighbors': 9, 'weights':
'uniform'}
0.838 (+/-0.026) for {'metric': 'minkowski', 'n_neighbors': 9, 'weights':
'distance'}
0.722 (+/-0.007) for {'metric': 'minkowski', 'n_neighbors': 10, 'weights':
'uniform'}
0.843 (+/-0.025) for {'metric': 'minkowski', 'n_neighbors': 10, 'weights':
'distance'}
0.719 (+/-0.009) for {'metric': 'minkowski', 'n_neighbors': 11, 'weights':
'uniform'}
0.842 (+/-0.026) for {'metric': 'minkowski', 'n_neighbors': 11, 'weights':
'distance'}
0.718 (+/-0.009) for {'metric': 'minkowski', 'n_neighbors': 12, 'weights':
'uniform'}
0.846 (+/-0.026) for {'metric': 'minkowski', 'n_neighbors': 12, 'weights':
```

```
'distance'}
0.716 (+/-0.011) for {'metric': 'minkowski', 'n_neighbors': 13, 'weights':
'uniform'}
0.847 (+/-0.027) for {'metric': 'minkowski', 'n_neighbors': 13, 'weights':
'distance'}
0.717 (+/-0.005) for {'metric': 'minkowski', 'n_neighbors': 14, 'weights':
'uniform'}
0.851 (+/-0.027) for {'metric': 'minkowski', 'n_neighbors': 14, 'weights':
'distance'}
0.713 (+/-0.007) for {'metric': 'minkowski', 'n_neighbors': 15, 'weights':
'uniform'}
0.851 (+/-0.028) for {'metric': 'minkowski', 'n_neighbors': 15, 'weights':
'distance'}
0.712 (+/-0.004) for {'metric': 'minkowski', 'n_neighbors': 16, 'weights':
'uniform'}
0.853 (+/-0.027) for {'metric': 'minkowski', 'n_neighbors': 16, 'weights':
'distance'}
0.712 (+/-0.009) for {'metric': 'minkowski', 'n_neighbors': 17, 'weights':
'uniform'}
0.853 (+/-0.026) for {'metric': 'minkowski', 'n_neighbors': 17, 'weights':
'distance'}
0.711 (+/-0.007) for {'metric': 'minkowski', 'n_neighbors': 18, 'weights':
'uniform'}
0.856 (+/-0.026) for {'metric': 'minkowski', 'n_neighbors': 18, 'weights':
'distance'}
0.711 (+/-0.011) for {'metric': 'minkowski', 'n_neighbors': 19, 'weights':
'uniform'}
0.856 (+/-0.025) for {'metric': 'minkowski', 'n_neighbors': 19, 'weights':
'distance'}
```

[22]:
```
print(knncv.best_score_)
print(knncv.best_estimator_)
print(knncv.best_params_)
```

```
0.8770714479760935
KNeighborsClassifier(metric='euclidean', n_neighbors=1)
{'metric': 'euclidean', 'n_neighbors': 1, 'weights': 'uniform'}
```

[23]:
```
#Training model using best hyperparameters
knncv_trainer = KNeighborsClassifier(metric='euclidean', n_neighbors=1,␣
 ↪weights='uniform')
knncv_trainer.fit(X_train, y_train)
```

[23]:
```
KNeighborsClassifier(metric='euclidean', n_neighbors=1)
```

[24]:
```
knncv_pred = knncv_trainer.predict(X_test)
```

```
from sklearn.metrics import classification_report, confusion_matrix

# this prints the graph that tells you how well prediction went
print(classification_report(y_test, knncv_pred))
# prints confusion matrix
print(confusion_matrix(y_test, knncv_pred))
```

```
              precision    recall  f1-score   support

           0       0.82      0.83      0.83      4591
           1       0.40      0.38      0.39      1330

    accuracy                           0.73      5921
   macro avg       0.61      0.61      0.61      5921
weighted avg       0.73      0.73      0.73      5921

[[3827  764]
 [ 827  503]]
```

1.3.3 Support Vector Machine Training and Testing (using C-Support Vector Classification: SVC)

[25]:
```
from sklearn.svm import SVC

svc = SVC()
svcparameters = {
    'kernel': ['linear', 'rbf'],
    'C': [0.1, 1, 10]
}

svccv = GridSearchCV(estimator=svc, param_grid= svcparameters, cv=3, n_jobs=6,␣
 ↪verbose=1)
svccv.fit(X_train, y_train)

print_results(svccv)
```

```
Fitting 3 folds for each of 6 candidates, totalling 18 fits
BEST PARAMS: {'C': 10, 'kernel': 'rbf'}

0.683 (+/-0.004) for {'C': 0.1, 'kernel': 'linear'}
0.704 (+/-0.007) for {'C': 0.1, 'kernel': 'rbf'}
0.682 (+/-0.003) for {'C': 1, 'kernel': 'linear'}
0.717 (+/-0.005) for {'C': 1, 'kernel': 'rbf'}
0.682 (+/-0.003) for {'C': 10, 'kernel': 'linear'}
0.737 (+/-0.007) for {'C': 10, 'kernel': 'rbf'}
```

[26]:
```
print(svccv.best_score_)
print(svccv.best_estimator_)
print(svccv.best_params_)
```

```
0.7373811464276012
SVC(C=10)
{'C': 10, 'kernel': 'rbf'}
```

[27]:
```
#Training model using best hyperparameters
svc_trainer = SVC(kernel='rbf', C=10, random_state=42)
svc_trainer.fit(X_train, y_train)
```

[27]:
```
SVC(C=10, random_state=42)
```

[28]:
```
svc_pred = svc_trainer.predict(X_test)

from sklearn.metrics import classification_report, confusion_matrix

# this prints the graph that tells you how well prediction went
print(classification_report(y_test, svc_pred))
# prints confusion matrix
print(confusion_matrix(y_test, svc_pred))
```

```
              precision    recall  f1-score   support

           0       0.87      0.81      0.84      4591
           1       0.48      0.58      0.52      1330

    accuracy                           0.76      5921
   macro avg       0.67      0.70      0.68      5921
weighted avg       0.78      0.76      0.77      5921

[[3739  852]
 [ 555  775]]
```