```
# This jupyter notebook was prepared by Jason Saini

import warnings
warnings.filterwarnings('ignore')
```

1. Load and Perform Basic EDA

```
##### import libraries
import pandas as pd
import numpy as np

%matplotlib inline
import matplotlib.pyplot as plt

import seaborn as sns
import missingno as msno
from scipy import stats

import sklearn

# II. import the data to a dataframe and show number of rows & cols
df = pd.read_csv("hrdata2.csv")
print("Number of rows: " + str(df.shape[0]))
print("Number of cols: " + str(df.shape[1]))

Number of rows: 8955
Number of cols: 15

# Show top 5 and last 5 rows
df.head()

   Unnamed: 0  enrollee_id      city  city_development_index gender  \
0           1        29725   city_40                   0.776   Male
1           4          666  city_162                   0.767   Male
2           7          402   city_46                   0.762   Male
3           8        27107  city_103                   0.920   Male
4          11        23853  city_103                   0.920   Male

       relevent_experience enrolled_university education_level  \
0   No relevent experience       no_enrollment        Graduate
1  Has relevent experience       no_enrollment         Masters
2  Has relevent experience       no_enrollment        Graduate
3  Has relevent experience       no_enrollment        Graduate
4  Has relevent experience       no_enrollment        Graduate

  major_discipline  experience company_size    company_type
last_new_job  \
0             STEM          15        50-99         Pvt Ltd
>4
1             STEM          21        50-99  Funded Startup
4
2             STEM          13          <10         Pvt Ltd
```

```
>4
3             STEM           7        50-99         Pvt Ltd
1
4             STEM           5    5000-9999         Pvt Ltd
1

   training_hours  target
0              47       0
1               8       0
2              18       1
3              46       1
4             108       0
```

df.tail()

```
      Unnamed: 0  enrollee_id      city  city_development_index
gender  \
8950       19147        21319   city_21                   0.624
Male
8951       19149          251  city_103                   0.920
Male
8952       19150        32313  city_160                   0.920
Female
8953       19152        29754  city_103                   0.920
Female
8954       19155        24576  city_103                   0.920
Male

          relevent_experience enrolled_university education_level  \
8950   No relevent experience    Full time course        Graduate
8951  Has relevent experience       no_enrollment         Masters
8952  Has relevent experience       no_enrollment        Graduate
8953  Has relevent experience       no_enrollment        Graduate
8954  Has relevent experience       no_enrollment        Graduate

     major_discipline  experience company_size    company_type
last_new_job  \
8950             STEM           1      100-500         Pvt Ltd
1
8951             STEM           9        50-99         Pvt Ltd
1
8952             STEM          10      100-500   Public Sector
3
8953       Humanities           7       Oct-49  Funded Startup
1
8954             STEM          21        50-99         Pvt Ltd
4

      training_hours  target
8950              52       1
```

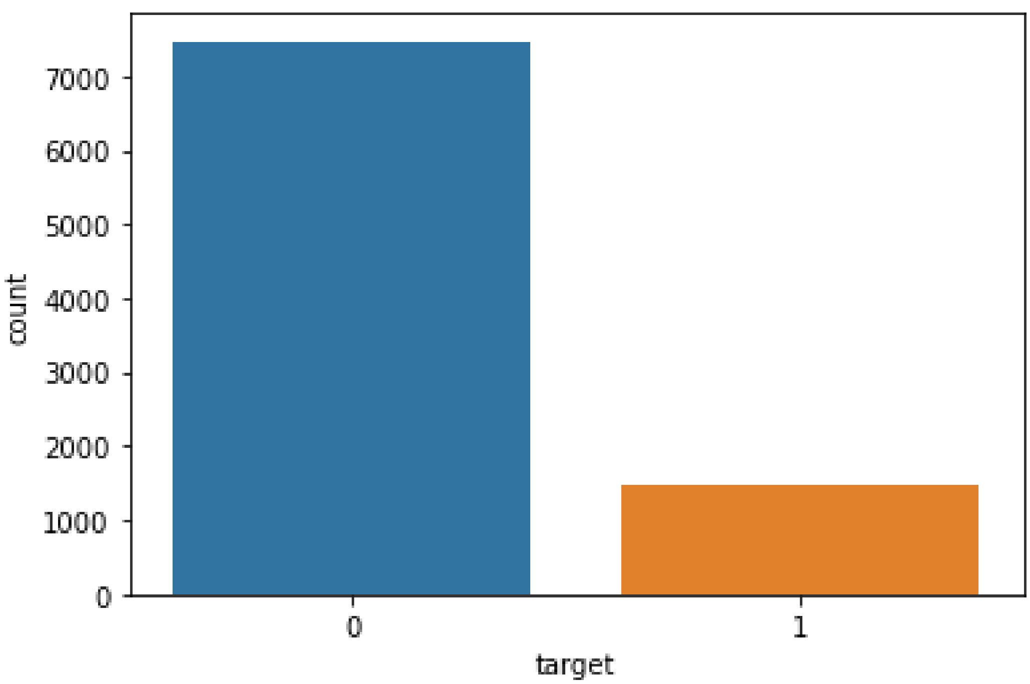
```
8951                  36       1
8952                  23       0
8953                  25       0
8954                  44       0
```

```
#Show how many columns have null values
df.isnull().any()
```

```
Unnamed: 0                  False
enrollee_id                 False
city                        False
city_development_index      False
gender                      False
relevent_experience         False
enrolled_university         False
education_level             False
major_discipline            False
experience                  False
company_size                False
company_type                False
last_new_job                False
training_hours              False
target                      False
dtype: bool
```

dataset has no missing values.

```
# Plot the count of target
ax = sns.countplot(x = "target", data = df)
```



discuss its imbalances and probably issues and solutions:

Clearly the data has a lot more 0 values for target, which will definitely cause a bias in our classification models. Our classifier will not be able to properly identify each class, and will most likely overfit to the 0.0 labels. We could solve this by oversampling targets with value 1.0 or undersampling targets with 0.0. After researching from the assignment specs, I see that we can use SMOTE (Synthetic Minority Oversampling Technique) to oversample (in this case 1.0) to generate new instances of minority cases to help balance the data.

```
df = df.drop("Unnamed: 0",axis = 1)
df
```

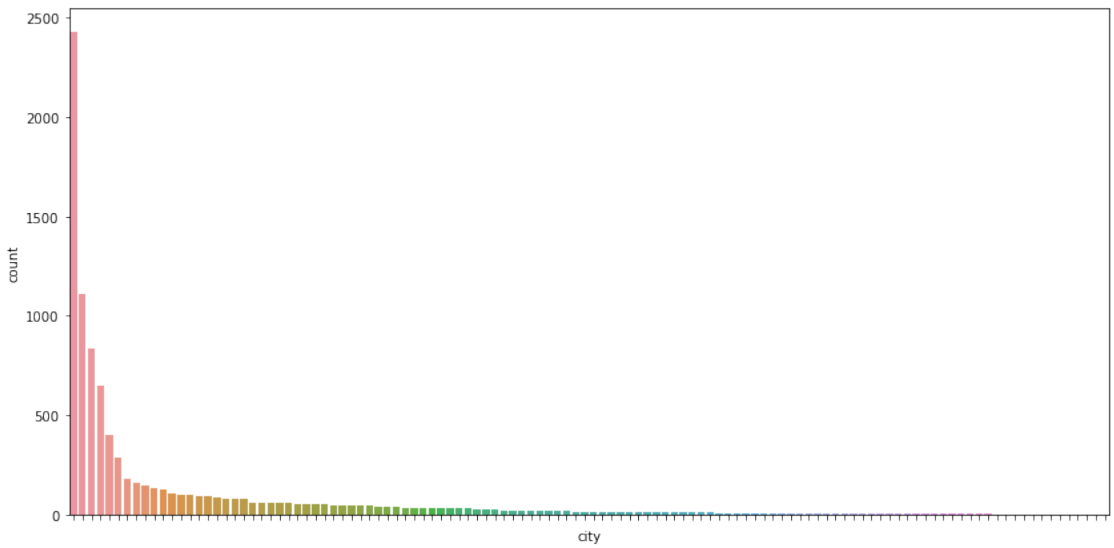
```
      enrollee_id      city  city_development_index  gender  \
0           29725   city_40                   0.776    Male
1             666  city_162                   0.767    Male
2             402   city_46                   0.762    Male
3           27107  city_103                   0.920    Male
4           23853  city_103                   0.920    Male
...           ...       ...                     ...     ...
8950        21319   city_21                   0.624    Male
8951          251  city_103                   0.920    Male
8952        32313  city_160                   0.920  Female
8953        29754  city_103                   0.920  Female
8954        24576  city_103                   0.920    Male

          relevent_experience enrolled_university education_level  \
0      No relevent experience       no_enrollment        Graduate
1     Has relevent experience       no_enrollment         Masters
2     Has relevent experience       no_enrollment        Graduate
3     Has relevent experience       no_enrollment        Graduate
4     Has relevent experience       no_enrollment        Graduate
...                       ...                 ...             ...
8950   No relevent experience    Full time course        Graduate
8951  Has relevent experience       no_enrollment         Masters
8952  Has relevent experience       no_enrollment        Graduate
8953  Has relevent experience       no_enrollment        Graduate
8954  Has relevent experience       no_enrollment        Graduate

     major_discipline  experience company_size    company_type
last_new_job  \
0                STEM          15        50-99         Pvt Ltd
>4
1                STEM          21        50-99  Funded Startup
4
2                STEM          13          <10         Pvt Ltd
>4
3                STEM           7        50-99         Pvt Ltd
1
4                STEM           5    5000-9999         Pvt Ltd
1
```

```
...                ...         ...          ...              ...
...
8950              STEM           1      100-500           Pvt Ltd
1
8951              STEM           9        50-99           Pvt Ltd
1
8952              STEM          10      100-500     Public Sector
3
8953        Humanities           7       Oct-49   Funded Startup
1
8954              STEM          21        50-99           Pvt Ltd
4

      training_hours  target
0                 47       0
1                  8       0
2                 18       1
3                 46       1
4                108       0
...              ...     ...
8950              52       1
8951              36       1
8952              23       0
8953              25       0
8954              44       0

[8955 rows x 14 columns]
```

2. Feature Selection and Pre-processing

2.1. Preprocessing City

```
# Plot #of records per city so that the highest city counts are shown
in descending order
plt.figure(figsize=(14,7))
ax = sns.countplot(x = "city", data = df, order =
df["city"].value_counts().index)
ax.set(xticklabels=[])
plt.show()
```



How many rows belong to the top 5 cities in total and how many for the remaining?

```
df["city"].value_counts()
```

```
city_103    2426
city_21     1111
city_16      836
city_114     648
city_160     401
            ...
city_127       1
city_107       1
city_62        1
city_109       1
city_25        1
Name: city, Length: 116, dtype: int64
```

The top 5 cities:

```
top_cities = df["city"].value_counts().head(5)
top_cities
```

```
city_103    2426
city_21     1111
city_16      836
city_114     648
city_160     401
Name: city, dtype: int64
```

And the rest have 1 row per city

```
# Replace the city name with city_others if the city name is not
within the top 4 city names
df = df.loc[~df["city"].isin(top_cities)].rename(columns={'city' :
'city_others'})
```

```
#records have changed accordingly
df
```

```
      enrollee_id city_others  city_development_index  gender  \
0           29725     city_40                   0.776    Male
1             666    city_162                   0.767    Male
2             402     city_46                   0.762    Male
3           27107    city_103                   0.920    Male
4           23853    city_103                   0.920    Male
...           ...         ...                     ...     ...
8950        21319     city_21                   0.624    Male
8951          251    city_103                   0.920    Male
8952        32313    city_160                   0.920  Female
8953        29754    city_103                   0.920  Female
8954        24576    city_103                   0.920    Male

          relevent_experience enrolled_university education_level  \
0      No relevent experience       no_enrollment        Graduate
1     Has relevent experience       no_enrollment         Masters
2     Has relevent experience       no_enrollment        Graduate
3     Has relevent experience       no_enrollment        Graduate
4     Has relevent experience       no_enrollment        Graduate
...                       ...                 ...             ...
8950   No relevent experience    Full time course        Graduate
8951  Has relevent experience       no_enrollment         Masters
8952  Has relevent experience       no_enrollment        Graduate
8953  Has relevent experience       no_enrollment        Graduate
8954  Has relevent experience       no_enrollment        Graduate

     major_discipline  experience company_size    company_type
last_new_job  \
0                STEM          15        50-99         Pvt Ltd
>4
1                STEM          21        50-99  Funded Startup
4
2                STEM          13          <10         Pvt Ltd
>4
3                STEM           7        50-99         Pvt Ltd
1
4                STEM           5    5000-9999         Pvt Ltd
1
...               ...         ...          ...             ...
...
8950             STEM           1      100-500         Pvt Ltd
1
8951             STEM           9        50-99         Pvt Ltd
1
8952             STEM          10      100-500   Public Sector
3
8953       Humanities           7       Oct-49  Funded Startup
```

```
1
8954              STEM          21        50-99         Pvt Ltd
4

      training_hours  target
0                 47       0
1                  8       0
2                 18       1
3                 46       1
4                108       0
...              ...     ...
8950              52       1
8951              36       1
8952              23       0
8953              25       0
8954              44       0

[8955 rows x 14 columns]
```

2.2. Preprocessing Education Level

```
# unique values of education level
df["education_level"].unique()
```

```
array(['Graduate', 'Masters', 'Phd'], dtype=object)
```

```
# Replace the value of Education level column like ordinal values
# "Graduate" -> 0, Masters->1, and Phd -> 2
education_mapper = {"Graduate": 0, "Masters": 1, "Phd": 2}
df["education_level"] =
df["education_level"].replace(education_mapper)
df["education_level"]
```

```
0       0
1       1
2       0
3       0
4       0
       ..
8950    0
8951    1
8952    0
8953    0
8954    0
Name: education_level, Length: 8955, dtype: int64
```

```
# updated values of education level
df["education_level"].unique()
```

```
array([0, 1, 2], dtype=int64)
```

2.3. Preprocessing Company size

```
# unique values of the company_size column
df["company_size"].unique()

array(['50-99', '<10', '5000-9999', '1000-4999', 'Oct-49', '100-500',
       '10000+', '500-999'], dtype=object)

# Change the values of the company_size column from
# 0 to 7 where 0 is <10 and 7 is 10000+

df.loc[df.company_size == '<10', 'company_size'] = 0
df.loc[np.logical_or(df.company_size == 'Oct-49', df.company_size ==
'10-49'), "company_size"] = 1
df.loc[df.company_size == '50-99', 'company_size'] = 2
df.loc[df.company_size == '100-500', 'company_size'] = 3
df.loc[df.company_size == '500-999', 'company_size'] = 4
df.loc[df.company_size == '1000-4999', 'company_size'] = 5
df.loc[df.company_size == '5000-9999', 'company_size'] = 6
df.loc[df.company_size == '10000+', 'company_size'] = 7


df["company_size"].unique()

array([2, 0, 6, 5, 1, 3, 7, 4], dtype=object)
```

2.4 Preprocessing last new job

```
# unique values of the company_size column
df["last_new_job"].unique()

array(['>4', '4', '1', '3', '2', 'never'], dtype=object)

# Convert the values of this column
LNJ_mapper = {"never": 0, "1": 1, "2": 2, "3":3, "4":4, ">4":5}
df["last_new_job"] = df["last_new_job"].replace(LNJ_mapper)

# updated values of last_new_job
df["last_new_job"].unique()

array([5, 4, 1, 3, 2, 0], dtype=int64)
```

2.5 Remaining columns

```
# Show the unique values of
# company_type, major_descipline, enrolled_university,
# relevant_experience, gender, and updated city column
df["company_type"].unique()

array(['Pvt Ltd', 'Funded Startup', 'Early Stage Startup',
       'Public Sector', 'NGO', 'Other'], dtype=object)

df["major_discipline"].unique()

array(['STEM', 'Humanities', 'Business Degree', 'Other', 'No Major',
       'Arts'], dtype=object)
```

```python
df["enrolled_university"].unique()
```

```
array(['no_enrollment', 'Part time course', 'Full time course'],
      dtype=object)
```

```python
df["relevent_experience"].unique()
```

```
array(['No relevent experience', 'Has relevent experience'],
dtype=object)
```

```python
df["gender"].unique()
```

```
array(['Male', 'Female', 'Other'], dtype=object)
```

```python
df["city_others"].unique()
```

```
array(['city_40', 'city_162', 'city_46', 'city_103', 'city_61',
       'city_114', 'city_159', 'city_21', 'city_160', 'city_16',
       'city_83', 'city_64', 'city_105', 'city_104', 'city_73',
'city_75',
       'city_100', 'city_93', 'city_67', 'city_13', 'city_36',
'city_71',
       'city_57', 'city_65', 'city_11', 'city_136', 'city_97',
'city_50',
       'city_173', 'city_82', 'city_89', 'city_150', 'city_90',
'city_98',
       'city_28', 'city_115', 'city_94', 'city_165', 'city_142',
       'city_12', 'city_43', 'city_74', 'city_102', 'city_116',
'city_99',
       'city_23', 'city_138', 'city_45', 'city_41', 'city_72',
'city_19',
       'city_101', 'city_20', 'city_106', 'city_10', 'city_157',
       'city_144', 'city_91', 'city_133', 'city_145', 'city_123',
       'city_175', 'city_128', 'city_167', 'city_84', 'city_54',
       'city_126', 'city_81', 'city_176', 'city_131', 'city_149',
       'city_24', 'city_27', 'city_118', 'city_152', 'city_141',
       'city_76', 'city_70', 'city_143', 'city_78', 'city_53',
'city_158',
       'city_2', 'city_77', 'city_117', 'city_120', 'city_9',
'city_39',
       'city_80', 'city_155', 'city_179', 'city_37', 'city_30',
'city_44',
       'city_14', 'city_55', 'city_42', 'city_1', 'city_59',
'city_69',
       'city_7', 'city_109', 'city_26', 'city_62', 'city_18',
'city_127',
       'city_33', 'city_134', 'city_146', 'city_107', 'city_166',
       'city_121', 'city_129', 'city_48', 'city_139', 'city_25'],
      dtype=object)
```

```python
# function to one-hot-encode our categorical columns
def one_hot_encode(in_df, cat_cols):
```

```
    for col in cat_cols:
        temp_df = pd.get_dummies(in_df[col], prefix = col, drop_first
= True)
        in_df = in_df.drop(columns = col)

        encoded_df = pd.merge(
        left = in_df,
        right = temp_df,
        left_index = True,
        right_index = True,
        )
    if(col in encoded_df.columns):
        encoded_df = encoded_df.drop(columns = col)
    print(encoded_df)
    return encoded_df

# show all columns for one-hot encoding
pd.set_option('display.max_columns', None)
one_hot_encoded_df = one_hot_encode(df,
["company_type","major_discipline","enrolled_university","relevent_exp
erience", "gender", "city_others"] ) #pd.get_dummies(df, columns =
["company_type","major_discipline","enrolled_university","relevent_exp
erience", "gender", "city_others"], drop_first = True)
```

```
      enrollee_id  city_development_index  education_level  experience
\
0           29725                   0.776                0          15

1             666                   0.767                1          21

2             402                   0.762                0          13

3           27107                   0.920                0           7

4           23853                   0.920                0           5

...           ...                     ...              ...         ...

8950        21319                   0.624                0           1

8951          251                   0.920                1           9

8952        32313                   0.920                0          10

8953        29754                   0.920                0           7

8954        24576                   0.920                0          21
```

```
      company_size  last_new_job  training_hours  target
city_others_city_10  \
0                2             5              47       0
0
1                2             4               8       0
0
2                0             5              18       1
0
3                2             1              46       1
0
4                6             1             108       0
0
...            ...           ...             ...     ...
...
8950             3             1              52       1
0
8951             2             1              36       1
0
8952             3             3              23       0
0
8953             1             1              25       0
0
8954             2             4              44       0
0

      city_others_city_100  city_others_city_101  city_others_city_102
\
0                        0                     0                     0

1                        0                     0                     0

2                        0                     0                     0

3                        0                     0                     0

4                        0                     0                     0

...                    ...                   ...                   ...

8950                     0                     0                     0

8951                     0                     0                     0

8952                     0                     0                     0

8953                     0                     0                     0

8954                     0                     0                     0
```

	city_others_city_103	city_others_city_104	city_others_city_105
\			
0	0	0	0
1	0	0	0
2	0	0	0
3	1	0	0
4	1	0	0
...	...	...	...
8950	0	0	0
8951	1	0	0
8952	0	0	0
8953	1	0	0
8954	1	0	0

	city_others_city_106	city_others_city_107	city_others_city_109
\			
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
...	...	...	...
8950	0	0	0
8951	0	0	0
8952	0	0	0
8953	0	0	0

```
8954                        0                       0                       0

      city_others_city_11  city_others_city_114  city_others_city_115  \
0                       0                       0                       0
1                       0                       0                       0
2                       0                       0                       0
3                       0                       0                       0
4                       0                       0                       0
...                   ...                     ...                     ...
8950                    0                       0                       0
8951                    0                       0                       0
8952                    0                       0                       0
8953                    0                       0                       0
8954                    0                       0                       0

      city_others_city_116  city_others_city_117  city_others_city_118  \
0                        0                       0                       0
1                        0                       0                       0
2                        0                       0                       0
3                        0                       0                       0
4                        0                       0                       0
...                    ...                     ...                     ...
8950                     0                       0                       0
8951                     0                       0                       0
8952                     0                       0                       0
```

```
8953                        0                      0                      0

8954                        0                      0                      0

      city_others_city_12  city_others_city_120  city_others_city_121
\
0                       0                      0                      0

1                       0                      0                      0

2                       0                      0                      0

3                       0                      0                      0

4                       0                      0                      0

...                   ...                    ...                    ...

8950                    0                      0                      0

8951                    0                      0                      0

8952                    0                      0                      0

8953                    0                      0                      0

8954                    0                      0                      0

      city_others_city_123  city_others_city_126  city_others_city_127
\
0                        0                      0                      0

1                        0                      0                      0

2                        0                      0                      0

3                        0                      0                      0

4                        0                      0                      0

...                    ...                    ...                    ...

8950                     0                      0                      0

8951                     0                      0                      0
```

```
8952                    0                    0                     0

8953                    0                    0                     0

8954                    0                    0                     0

      city_others_city_128  city_others_city_129  city_others_city_13
\
0                       0                    0                    0

1                       0                    0                    0

2                       0                    0                    0

3                       0                    0                    0

4                       0                    0                    0

...                   ...                  ...                  ...

8950                    0                    0                    0

8951                    0                    0                    0

8952                    0                    0                    0

8953                    0                    0                    0

8954                    0                    0                    0

      city_others_city_131  city_others_city_133  city_others_city_134
\
0                       0                    0                     0

1                       0                    0                     0

2                       0                    0                     0

3                       0                    0                     0

4                       0                    0                     0

...                   ...                  ...                   ...

8950                    0                    0                     0
```

```
8951                        0                        0                        0

8952                        0                        0                        0

8953                        0                        0                        0

8954                        0                        0                        0

      city_others_city_136  city_others_city_138  city_others_city_139
\
0                           0                        0                        0

1                           0                        0                        0

2                           0                        0                        0

3                           0                        0                        0

4                           0                        0                        0

...                       ...                      ...                      ...

8950                        0                        0                        0

8951                        0                        0                        0

8952                        0                        0                        0

8953                        0                        0                        0

8954                        0                        0                        0

      city_others_city_14  city_others_city_141  city_others_city_142
\
0                          0                        0                        0

1                          0                        0                        0

2                          0                        0                        0

3                          0                        0                        0

4                          0                        0                        0

...                      ...                      ...                      ...
```

```
8950                       0                      0                      0
8951                       0                      0                      0
8952                       0                      0                      0
8953                       0                      0                      0
8954                       0                      0                      0

      city_others_city_143  city_others_city_144  city_others_city_145
\
0                        0                     0                     0
1                        0                     0                     0
2                        0                     0                     0
3                        0                     0                     0
4                        0                     0                     0
...                    ...                   ...                   ...
8950                     0                     0                     0
8951                     0                     0                     0
8952                     0                     0                     0
8953                     0                     0                     0
8954                     0                     0                     0

      city_others_city_146  city_others_city_149  city_others_city_150
\
0                        0                     0                     0
1                        0                     0                     0
2                        0                     0                     0
3                        0                     0                     0
4                        0                     0                     0
```

```
...                       ...                      ...                      ...
8950                        0                        0                        0
8951                        0                        0                        0
8952                        0                        0                        0
8953                        0                        0                        0
8954                        0                        0                        0

      city_others_city_152  city_others_city_155  city_others_city_157
\
0                         0                        0                        0
1                         0                        0                        0
2                         0                        0                        0
3                         0                        0                        0
4                         0                        0                        0
...                       ...                      ...                      ...
8950                        0                        0                        0
8951                        0                        0                        0
8952                        0                        0                        0
8953                        0                        0                        0
8954                        0                        0                        0

      city_others_city_158  city_others_city_159  city_others_city_16
\
0                         0                        0                       0
1                         0                        0                       0
2                         0                        0                       0
3                         0                        0                       0
```

```
4                         0                     0                     0
...                     ...                   ...                   ...
8950                      0                     0                     0
8951                      0                     0                     0
8952                      0                     0                     0
8953                      0                     0                     0
8954                      0                     0                     0

      city_others_city_160  city_others_city_162  city_others_city_165  \
0                        0                     0                     0
1                        0                     1                     0
2                        0                     0                     0
3                        0                     0                     0
4                        0                     0                     0
...                    ...                   ...                   ...
8950                     0                     0                     0
8951                     0                     0                     0
8952                     1                     0                     0
8953                     0                     0                     0
8954                     0                     0                     0

      city_others_city_166  city_others_city_167  city_others_city_173  \
0                        0                     0                     0
1                        0                     0                     0
2                        0                     0                     0
```

```
3                         0                     0                     0

4                         0                     0                     0

...                     ...                   ...                   ...

8950                      0                     0                     0

8951                      0                     0                     0

8952                      0                     0                     0

8953                      0                     0                     0

8954                      0                     0                     0


      city_others_city_175  city_others_city_176  city_others_city_179
\
0                         0                     0                     0

1                         0                     0                     0

2                         0                     0                     0

3                         0                     0                     0

4                         0                     0                     0

...                     ...                   ...                   ...

8950                      0                     0                     0

8951                      0                     0                     0

8952                      0                     0                     0

8953                      0                     0                     0

8954                      0                     0                     0


      city_others_city_18  city_others_city_19  city_others_city_2  \
0                        0                    0                   0
1                        0                    0                   0
2                        0                    0                   0
3                        0                    0                   0
4                        0                    0                   0
```

```
...                   ...                   ...                  ...
8950                    0                     0                    0
8951                    0                     0                    0
8952                    0                     0                    0
8953                    0                     0                    0
8954                    0                     0                    0

      city_others_city_20  city_others_city_21  city_others_city_23  \
0                       0                     0                    0
1                       0                     0                    0
2                       0                     0                    0
3                       0                     0                    0
4                       0                     0                    0
...                   ...                   ...                  ...
8950                    0                     1                    0
8951                    0                     0                    0
8952                    0                     0                    0
8953                    0                     0                    0
8954                    0                     0                    0

      city_others_city_24  city_others_city_25  city_others_city_26  \
0                       0                     0                    0
1                       0                     0                    0
2                       0                     0                    0
3                       0                     0                    0
4                       0                     0                    0
...                   ...                   ...                  ...
8950                    0                     0                    0
8951                    0                     0                    0
8952                    0                     0                    0
8953                    0                     0                    0
8954                    0                     0                    0

      city_others_city_27  city_others_city_28  city_others_city_30  \
0                       0                     0                    0
1                       0                     0                    0
2                       0                     0                    0
3                       0                     0                    0
4                       0                     0                    0
...                   ...                   ...                  ...
8950                    0                     0                    0
8951                    0                     0                    0
8952                    0                     0                    0
8953                    0                     0                    0
8954                    0                     0                    0

      city_others_city_33  city_others_city_36  city_others_city_37  \
0                       0                     0                    0
1                       0                     0                    0
2                       0                     0                    0
```

```
3                        0                    0                    0
4                        0                    0                    0
...                    ...                  ...                  ...
8950                     0                    0                    0
8951                     0                    0                    0
8952                     0                    0                    0
8953                     0                    0                    0
8954                     0                    0                    0

      city_others_city_39  city_others_city_40  city_others_city_41  \
0                        0                    1                    0
1                        0                    0                    0
2                        0                    0                    0
3                        0                    0                    0
4                        0                    0                    0
...                    ...                  ...                  ...
8950                     0                    0                    0
8951                     0                    0                    0
8952                     0                    0                    0
8953                     0                    0                    0
8954                     0                    0                    0

      city_others_city_42  city_others_city_43  city_others_city_44  \
0                        0                    0                    0
1                        0                    0                    0
2                        0                    0                    0
3                        0                    0                    0
4                        0                    0                    0
...                    ...                  ...                  ...
8950                     0                    0                    0
8951                     0                    0                    0
8952                     0                    0                    0
8953                     0                    0                    0
8954                     0                    0                    0

      city_others_city_45  city_others_city_46  city_others_city_48  \
0                        0                    0                    0
1                        0                    0                    0
2                        0                    1                    0
3                        0                    0                    0
4                        0                    0                    0
...                    ...                  ...                  ...
8950                     0                    0                    0
8951                     0                    0                    0
8952                     0                    0                    0
8953                     0                    0                    0
8954                     0                    0                    0

      city_others_city_50  city_others_city_53  city_others_city_54  \
0                        0                    0                    0
```

```
1                       0                    0                    0
2                       0                    0                    0
3                       0                    0                    0
4                       0                    0                    0
...                   ...                  ...                  ...
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_55  city_others_city_57  city_others_city_59  \
0                       0                    0                    0
1                       0                    0                    0
2                       0                    0                    0
3                       0                    0                    0
4                       0                    0                    0
...                   ...                  ...                  ...
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_61  city_others_city_62  city_others_city_64  \
0                       0                    0                    0
1                       0                    0                    0
2                       0                    0                    0
3                       0                    0                    0
4                       0                    0                    0
...                   ...                  ...                  ...
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_65  city_others_city_67  city_others_city_69  \
0                       0                    0                    0
1                       0                    0                    0
2                       0                    0                    0
3                       0                    0                    0
4                       0                    0                    0
...                   ...                  ...                  ...
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0
```

```
      city_others_city_7  city_others_city_70  city_others_city_71  \
0                      0                    0                    0   
1                      0                    0                    0   
2                      0                    0                    0   
3                      0                    0                    0   
4                      0                    0                    0   
...                  ...                  ...                  ...   
8950                   0                    0                    0   
8951                   0                    0                    0   
8952                   0                    0                    0   
8953                   0                    0                    0   
8954                   0                    0                    0   

      city_others_city_72  city_others_city_73  city_others_city_74  \
0                       0                    0                    0   
1                       0                    0                    0   
2                       0                    0                    0   
3                       0                    0                    0   
4                       0                    0                    0   
...                   ...                  ...                  ...   
8950                    0                    0                    0   
8951                    0                    0                    0   
8952                    0                    0                    0   
8953                    0                    0                    0   
8954                    0                    0                    0   

      city_others_city_75  city_others_city_76  city_others_city_77  \
0                       0                    0                    0   
1                       0                    0                    0   
2                       0                    0                    0   
3                       0                    0                    0   
4                       0                    0                    0   
...                   ...                  ...                  ...   
8950                    0                    0                    0   
8951                    0                    0                    0   
8952                    0                    0                    0   
8953                    0                    0                    0   
8954                    0                    0                    0   

      city_others_city_78  city_others_city_80  city_others_city_81  \
0                       0                    0                    0   
1                       0                    0                    0   
2                       0                    0                    0   
3                       0                    0                    0   
4                       0                    0                    0   
...                   ...                  ...                  ...   
8950                    0                    0                    0   
8951                    0                    0                    0   
8952                    0                    0                    0   
8953                    0                    0                    0   
```

```
8954                    0                    0                    0

      city_others_city_82  city_others_city_83  city_others_city_84  \
0                       0                    0                    0
1                       0                    0                    0
2                       0                    0                    0
3                       0                    0                    0
4                       0                    0                    0
...                   ...                  ...                  ...
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_89  city_others_city_9  city_others_city_90  \
0                       0                   0                    0
1                       0                   0                    0
2                       0                   0                    0
3                       0                   0                    0
4                       0                   0                    0
...                   ...                 ...                  ...
8950                    0                   0                    0
8951                    0                   0                    0
8952                    0                   0                    0
8953                    0                   0                    0
8954                    0                   0                    0

      city_others_city_91  city_others_city_93  city_others_city_94  \
0                       0                    0                    0
1                       0                    0                    0
2                       0                    0                    0
3                       0                    0                    0
4                       0                    0                    0
...                   ...                  ...                  ...
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_97  city_others_city_98  city_others_city_99
0                       0                    0                    0
1                       0                    0                    0
2                       0                    0                    0
3                       0                    0                    0
4                       0                    0                    0
...                   ...                  ...                  ...
8950                    0                    0                    0
8951                    0                    0                    0
```

```
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

[8955 rows x 123 columns]
```

```
one_hot_encoded_df.head()
```

```
   enrollee_id  city_development_index  education_level  experience  \
0        29725                   0.776                0          15   
1          666                   0.767                1          21   
2          402                   0.762                0          13   
3        27107                   0.920                0           7   
4        23853                   0.920                0           5   

  company_size  last_new_job  training_hours  target  
city_others_city_10  \
0            2             5              47       0  
0  
1            2             4               8       0  
0  
2            0             5              18       1  
0  
3            2             1              46       1  
0  
4            6             1             108       0  
0  

   city_others_city_100  city_others_city_101  city_others_city_102  \
0                     0                     0                     0   
1                     0                     0                     0   
2                     0                     0                     0   
3                     0                     0                     0   
4                     0                     0                     0   

   city_others_city_103  city_others_city_104  city_others_city_105  \
0                     0                     0                     0   
1                     0                     0                     0   
2                     0                     0                     0   
3                     1                     0                     0   
4                     1                     0                     0   

   city_others_city_106  city_others_city_107  city_others_city_109  \
0                     0                     0                     0   
1                     0                     0                     0   
2                     0                     0                     0   
3                     0                     0                     0   
4                     0                     0                     0   

   city_others_city_11  city_others_city_114  city_others_city_115  \
```

```
0                    0                     0                     0
1                    0                     0                     0
2                    0                     0                     0
3                    0                     0                     0
4                    0                     0                     0

   city_others_city_116  city_others_city_117  city_others_city_118  \
0                     0                     0                     0
1                     0                     0                     0
2                     0                     0                     0
3                     0                     0                     0
4                     0                     0                     0

   city_others_city_12  city_others_city_120  city_others_city_121  \
0                    0                     0                     0
1                    0                     0                     0
2                    0                     0                     0
3                    0                     0                     0
4                    0                     0                     0

   city_others_city_123  city_others_city_126  city_others_city_127  \
0                     0                     0                     0
1                     0                     0                     0
2                     0                     0                     0
3                     0                     0                     0
4                     0                     0                     0

   city_others_city_128  city_others_city_129  city_others_city_13  \
0                     0                     0                    0
1                     0                     0                    0
2                     0                     0                    0
3                     0                     0                    0
4                     0                     0                    0

   city_others_city_131  city_others_city_133  city_others_city_134  \
0                     0                     0                     0
1                     0                     0                     0
2                     0                     0                     0
3                     0                     0                     0
4                     0                     0                     0

   city_others_city_136  city_others_city_138  city_others_city_139  \
0                     0                     0                     0
1                     0                     0                     0
2                     0                     0                     0
3                     0                     0                     0
4                     0                     0                     0

   city_others_city_14  city_others_city_141  city_others_city_142  \
```

```
0                    0                    0                    0  
1                    0                    0                    0  
2                    0                    0                    0  
3                    0                    0                    0  
4                    0                    0                    0  

   city_others_city_143  city_others_city_144  city_others_city_145  \
0                     0                     0                     0   
1                     0                     0                     0   
2                     0                     0                     0   
3                     0                     0                     0   
4                     0                     0                     0   

   city_others_city_146  city_others_city_149  city_others_city_150  \
0                     0                     0                     0   
1                     0                     0                     0   
2                     0                     0                     0   
3                     0                     0                     0   
4                     0                     0                     0   

   city_others_city_152  city_others_city_155  city_others_city_157  \
0                     0                     0                     0   
1                     0                     0                     0   
2                     0                     0                     0   
3                     0                     0                     0   
4                     0                     0                     0   

   city_others_city_158  city_others_city_159  city_others_city_16  \
0                     0                     0                    0   
1                     0                     0                    0   
2                     0                     0                    0   
3                     0                     0                    0   
4                     0                     0                    0   

   city_others_city_160  city_others_city_162  city_others_city_165  \
0                     0                     0                     0   
1                     0                     1                     0   
2                     0                     0                     0   
3                     0                     0                     0   
4                     0                     0                     0   

   city_others_city_166  city_others_city_167  city_others_city_173  \
0                     0                     0                     0   
1                     0                     0                     0   
2                     0                     0                     0   
3                     0                     0                     0   
4                     0                     0                     0   

   city_others_city_175  city_others_city_176  city_others_city_179  \
```

```
0                     0                     0                     0
1                     0                     0                     0
2                     0                     0                     0
3                     0                     0                     0
4                     0                     0                     0

   city_others_city_18  city_others_city_19  city_others_city_2  \
0                    0                    0                   0
1                    0                    0                   0
2                    0                    0                   0
3                    0                    0                   0
4                    0                    0                   0

   city_others_city_20  city_others_city_21  city_others_city_23  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_24  city_others_city_25  city_others_city_26  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_27  city_others_city_28  city_others_city_30  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_33  city_others_city_36  city_others_city_37  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_39  city_others_city_40  city_others_city_41  \
0                    0                    1                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_42  city_others_city_43  city_others_city_44  \
```

```
0                  0                  0                  0
1                  0                  0                  0
2                  0                  0                  0
3                  0                  0                  0
4                  0                  0                  0

   city_others_city_45  city_others_city_46  city_others_city_48  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    1                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_50  city_others_city_53  city_others_city_54  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_55  city_others_city_57  city_others_city_59  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_61  city_others_city_62  city_others_city_64  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_65  city_others_city_67  city_others_city_69  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_7  city_others_city_70  city_others_city_71  \
0                   0                    0                    0
1                   0                    0                    0
2                   0                    0                    0
3                   0                    0                    0
4                   0                    0                    0

   city_others_city_72  city_others_city_73  city_others_city_74  \
```

```
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_75  city_others_city_76  city_others_city_77  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_78  city_others_city_80  city_others_city_81  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_82  city_others_city_83  city_others_city_84  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_89  city_others_city_9  city_others_city_90  \
0                    0                   0                    0
1                    0                   0                    0
2                    0                   0                    0
3                    0                   0                    0
4                    0                   0                    0

   city_others_city_91  city_others_city_93  city_others_city_94  \
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0

   city_others_city_97  city_others_city_98  city_others_city_99
0                    0                    0                    0
1                    0                    0                    0
2                    0                    0                    0
3                    0                    0                    0
4                    0                    0                    0
```

```
one_hot_encoded_df.tail()
```

```
      enrollee_id  city_development_index  education_level  experience  \
8950        21319                   0.624                0           1

8951          251                   0.920                1           9

8952        32313                   0.920                0          10

8953        29754                   0.920                0           7

8954        24576                   0.920                0          21


     company_size  last_new_job  training_hours  target
city_others_city_10  \
8950            3             1              52       1
0
8951            2             1              36       1
0
8952            3             3              23       0
0
8953            1             1              25       0
0
8954            2             4              44       0
0

      city_others_city_100  city_others_city_101  city_others_city_102
\
8950                     0                     0                     0

8951                     0                     0                     0

8952                     0                     0                     0

8953                     0                     0                     0

8954                     0                     0                     0


      city_others_city_103  city_others_city_104  city_others_city_105
\
8950                     0                     0                     0

8951                     1                     0                     0

8952                     0                     0                     0

8953                     1                     0                     0
```

```
8954                    1                    0                    0

     city_others_city_106  city_others_city_107  city_others_city_109  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

     city_others_city_11  city_others_city_114  city_others_city_115  \
8950                   0                    0                    0
8951                   0                    0                    0
8952                   0                    0                    0
8953                   0                    0                    0
8954                   0                    0                    0

     city_others_city_116  city_others_city_117  city_others_city_118  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

     city_others_city_12  city_others_city_120  city_others_city_121  \
8950                   0                    0                    0
8951                   0                    0                    0
```

```
8952                    0                    0                   0
8953                    0                    0                   0
8954                    0                    0                   0

      city_others_city_123  city_others_city_126  city_others_city_127  \
8950                     0                     0                     0
8951                     0                     0                     0
8952                     0                     0                     0
8953                     0                     0                     0
8954                     0                     0                     0

      city_others_city_128  city_others_city_129  city_others_city_13  \
8950                     0                     0                    0
8951                     0                     0                    0
8952                     0                     0                    0
8953                     0                     0                    0
8954                     0                     0                    0

      city_others_city_131  city_others_city_133  city_others_city_134  \
8950                     0                     0                     0
8951                     0                     0                     0
8952                     0                     0                     0
8953                     0                     0                     0
8954                     0                     0                     0

      city_others_city_136  city_others_city_138  city_others_city_139
```

```
\
8950                    0                     0                     0

8951                    0                     0                     0

8952                    0                     0                     0

8953                    0                     0                     0

8954                    0                     0                     0

      city_others_city_14  city_others_city_141  city_others_city_142
\
8950                   0                     0                     0

8951                   0                     0                     0

8952                   0                     0                     0

8953                   0                     0                     0

8954                   0                     0                     0

      city_others_city_143  city_others_city_144  city_others_city_145
\
8950                    0                     0                     0

8951                    0                     0                     0

8952                    0                     0                     0

8953                    0                     0                     0

8954                    0                     0                     0

      city_others_city_146  city_others_city_149  city_others_city_150
\
8950                    0                     0                     0

8951                    0                     0                     0

8952                    0                     0                     0

8953                    0                     0                     0
```

```
8954                    0                    0                    0

      city_others_city_152  city_others_city_155  city_others_city_157  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_158  city_others_city_159  city_others_city_16  \
8950                    0                    0                   0
8951                    0                    0                   0
8952                    0                    0                   0
8953                    0                    0                   0
8954                    0                    0                   0

      city_others_city_160  city_others_city_162  city_others_city_165  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    1                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_166  city_others_city_167  city_others_city_173  \
8950                    0                    0                    0
8951                    0                    0                    0
```

```
8952                    0                    0                    0

8953                    0                    0                    0

8954                    0                    0                    0


      city_others_city_175  city_others_city_176  city_others_city_179
\
8950                    0                    0                    0

8951                    0                    0                    0

8952                    0                    0                    0

8953                    0                    0                    0

8954                    0                    0                    0


      city_others_city_18  city_others_city_19  city_others_city_2  \
8950                   0                    0                   0
8951                   0                    0                   0
8952                   0                    0                   0
8953                   0                    0                   0
8954                   0                    0                   0

      city_others_city_20  city_others_city_21  city_others_city_23  \
8950                   0                    1                    0
8951                   0                    0                    0
8952                   0                    0                    0
8953                   0                    0                    0
8954                   0                    0                    0

      city_others_city_24  city_others_city_25  city_others_city_26  \
8950                   0                    0                    0
8951                   0                    0                    0
8952                   0                    0                    0
8953                   0                    0                    0
8954                   0                    0                    0

      city_others_city_27  city_others_city_28  city_others_city_30  \
8950                   0                    0                    0
8951                   0                    0                    0
8952                   0                    0                    0
8953                   0                    0                    0
8954                   0                    0                    0

      city_others_city_33  city_others_city_36  city_others_city_37  \
```

```
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_39  city_others_city_40  city_others_city_41  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_42  city_others_city_43  city_others_city_44  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_45  city_others_city_46  city_others_city_48  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_50  city_others_city_53  city_others_city_54  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_55  city_others_city_57  city_others_city_59  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_61  city_others_city_62  city_others_city_64  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_65  city_others_city_67  city_others_city_69  \
```

```
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_7  city_others_city_70  city_others_city_71  \
8950                   0                    0                    0
8951                   0                    0                    0
8952                   0                    0                    0
8953                   0                    0                    0
8954                   0                    0                    0

      city_others_city_72  city_others_city_73  city_others_city_74  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_75  city_others_city_76  city_others_city_77  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_78  city_others_city_80  city_others_city_81  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_82  city_others_city_83  city_others_city_84  \
8950                    0                    0                    0
8951                    0                    0                    0
8952                    0                    0                    0
8953                    0                    0                    0
8954                    0                    0                    0

      city_others_city_89  city_others_city_9  city_others_city_90  \
8950                    0                   0                    0
8951                    0                   0                    0
8952                    0                   0                    0
8953                    0                   0                    0
8954                    0                   0                    0

      city_others_city_91  city_others_city_93  city_others_city_94  \
```

```
8950                      0                     0                     0
8951                      0                     0                     0
8952                      0                     0                     0
8953                      0                     0                     0
8954                      0                     0                     0

      city_others_city_97  city_others_city_98  city_others_city_99
8950                      0                     0                     0
8951                      0                     0                     0
8952                      0                     0                     0
8953                      0                     0                     0
8954                      0                     0                     0
```

```
one_hot_encoded_df.shape
```

```
(8955, 123)
```

3. X/Y and Training/Test Split with stratified sampling and SMOTE

```
# Copy all the features into X and the target to Y
X = one_hot_encoded_df.drop(columns = "target")
y = one_hot_encoded_df["target"]

# function to calculate ratio of 1 to 0 in column
def cal_ratio(x):
    n_1 = sum(x['target'].values == 1)
    n_0 = sum(x['target'].values == 0)
    return '{:}/{:}'.format(n_1, n_0)

# apply above function to get 1:0 ratio for target
y.value_counts()
```

```
0    7472
1    1483
Name: target, dtype: int64
```

```
print("1:0 ratio of y = " + str(y.value_counts()[1]/y.value_counts()
[0]))
```

```
1:0 ratio of y = 0.19847430406852248
```

```
# split data into train and test sets with 30% of records in test.
stratify to Y
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(X,y,test_size =
.3, random_state=0, stratify = y)

y_train.value_counts()
```

```
0    5230
1    1038
Name: target, dtype: int64
```

```
# 1:0 ratios for y_train (should have 50% each class)
print("1:0 ratio of y_train = " + str(y_train.value_counts()
[1]/y_train.value_counts()[0]))
```

```
1:0 ratio of y_train = 0.19847036328871892
```

We need to use SMOTE to balance it!

```
from imblearn.over_sampling import SMOTE, ADASYN

# convert text data in x to numeric before applying SMOTE
from sklearn.feature_extraction.text import CountVectorizer
vectorizer = CountVectorizer(lowercase = False)

X_train_res, y_train_res = SMOTE().fit_resample(X_train, y_train)

y_train_res.value_counts()
```

```
0    5230
1    5230
Name: target, dtype: int64
```

```
print("1:0 ratio of y_train = " + str(y_train_res.value_counts()
[1]/y_train_res.value_counts()[0]))
```

```
1:0 ratio of y_train = 1.0
```

4. PCA and Logistic Regression

```
# Principal Component Analysis and Boxplot

from numpy import mean
from sklearn.datasets import make_classification
from sklearn.linear_model import LogisticRegression
from sklearn.decomposition import PCA
from sklearn.pipeline import Pipeline
from sklearn.model_selection import RepeatedStratifiedKFold
from sklearn.model_selection import cross_val_score

X_train_res.shape
```

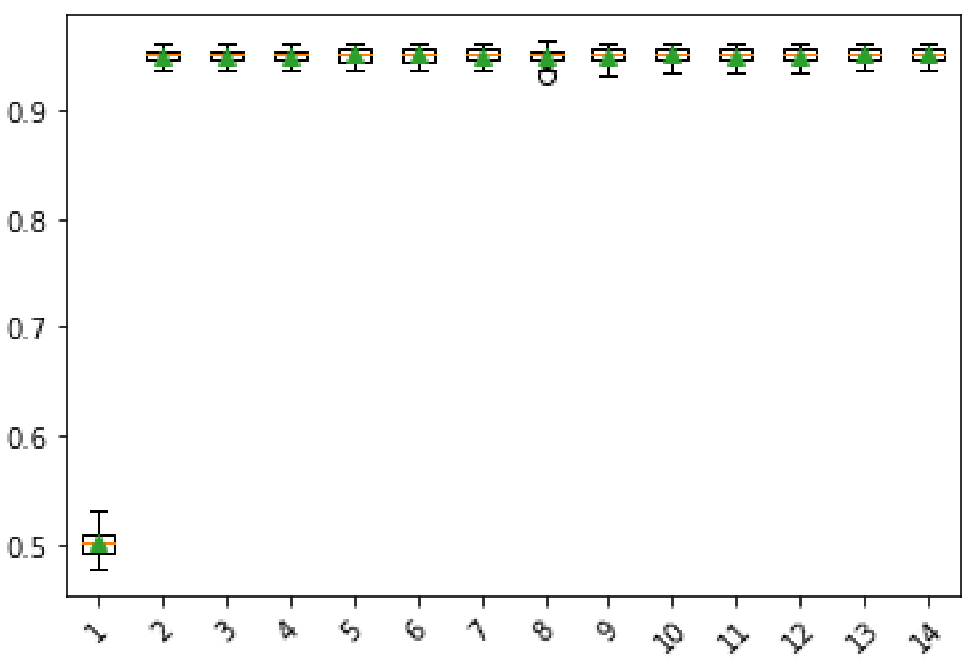
```
(10460, 122)
```

```
y_train_res.shape
```

```
(10460,)
```

```
def get_dataset():
    X, y = make_classification(n_samples = 10460, n_features = 15,
random_state = 7)
    return X,y

def get_models():
    models = dict()
    for i in range(1,15):
```

```
        steps = [('pca', PCA(n_components = i)), ('m',
LogisticRegression())]
        models[str(i)] = Pipeline(steps = steps)
    return models

def evaluate_model(model, X, y):
    cv = RepeatedStratifiedKFold(n_splits = 10, n_repeats = 3,
random_state = 1)
    scores = cross_val_score(model,X,y,scoring='accuracy', cv=cv,
n_jobs = -1, error_score = 'raise')
    return scores

X,y = get_dataset()
models = get_models()
results, names = list(), list()
for name, model in models.items():
    scores = evaluate_model(model,X,y)
    results.append(scores)
    names.append(name)


plt.boxplot(results, labels = names, showmeans= True)
plt.xticks(rotation = 45)
plt.show()
```




```
# evaluate the model for accuracy

steps = [('pca', PCA(n_components = 15)), ('m', LogisticRegression())]

model = Pipeline(steps=steps)
```

```
%%capture --no-stdout
model.fit(X_train_res,y_train_res);
y_pred = model.predict(X_test);
```

```
print("Predicted Class: %d" % y_pred[0])
```

```
Predicted Class: 1
```

```
# accuracy score of PCA model
cross_val_score(model, X_train_res, y_train_res, cv = 3, scoring =
'accuracy')
```

```
array([0.70490393, 0.64009177, 0.73580034])
```

```
# create confusion matrix
from sklearn.metrics import confusion_matrix
confusion_matrix(y_test,y_pred)
```

```
array([[1642,  600],
       [ 161,  284]], dtype=int64)
```

Interpretation:

```
# precision, recall and F1 score for test set and predicted values
from sklearn.metrics import precision_score, recall_score, f1_score
precision_score(y_test, y_pred)
```

```
0.3212669683257919
```

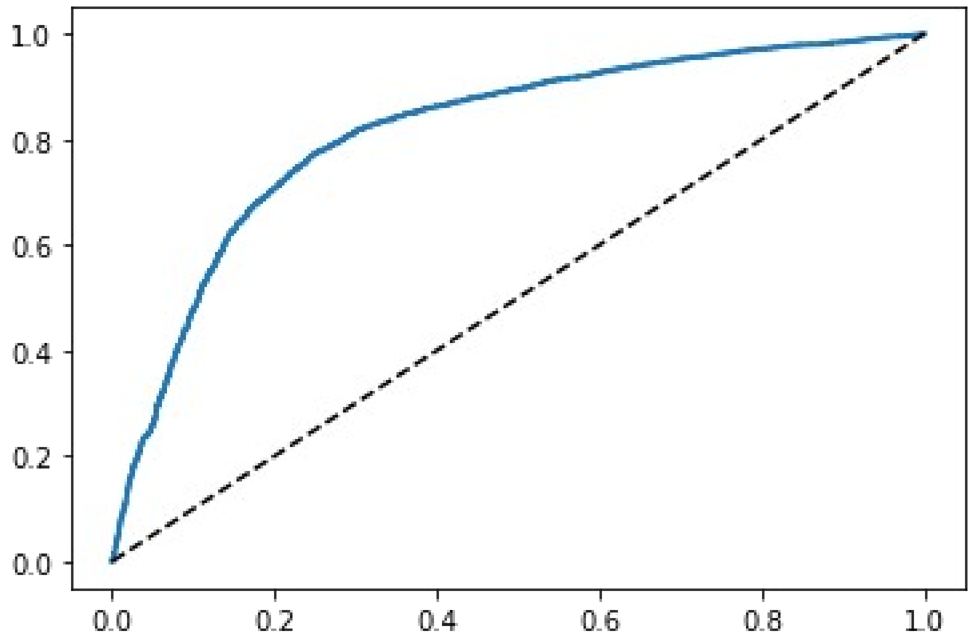
```
recall_score(y_test,y_pred)
```

```
0.6382022471910113
```

```
f1_score(y_test,y_pred)
```

```
0.4273890142964635
```

```
# plot ROC curve
from sklearn.metrics import roc_curve
y_scores = model.decision_function(X_train_res)
fpr, tpr, thresholds = roc_curve(y_train_res, y_scores)
def plot_roc_curve(fpr,tpr, label = None):
    plt.plot(fpr,tpr, linewidth = 2, label = label)
    plt.plot([0,1],[0,1], 'k--')

plot_roc_curve(fpr,tpr)
```



5. Softmax Regression

How is softmax regression related to logistic regression? What library can you use for softmax?

Both are used for classification tasks. Softmax can be used for multiclass classification (assuming the classes are mutually exclusive) and logistic regression can be used on binary classes.

While there are specific libraries for softmax regression (keras and tensorflow), we can also use scikit learn's logistic regression class for softmax by setting the multi-class parameter to "multinomial"

6. KNN

```
# Use sklearn's KNNN to train and predict based on unbalanced training
set
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import classification_report
knn = KNeighborsClassifier(n_neighbors = 10)
knn.fit(X_train,y_train)
y_pred = knn.predict(X_test)

from sklearn import metrics
print("Accuracy: " , metrics.accuracy_score(y_test,y_pred))
```

```
Accuracy:  0.8299218459248232
```

```
# confusion matrix
confusion_matrix(y_test,y_pred)
```

```
array([[2226,   16],
       [ 441,    4]], dtype=int64)
```

```
#classification report
print(classification_report(y_test,y_pred))
```

```
              precision    recall  f1-score   support

           0       0.83      0.99      0.91      2242
           1       0.20      0.01      0.02       445

    accuracy                           0.83      2687
   macro avg       0.52      0.50      0.46      2687
weighted avg       0.73      0.83      0.76      2687
```

```
#KNN with balanced set
knn = KNeighborsClassifier(n_neighbors = 10)
knn.fit(X_train_res,y_train_res)
y_pred = knn.predict(X_test)
```

```
print("Accuracy: " , metrics.accuracy_score(y_test,y_pred))
```

```
Accuracy:  0.6270934127279494
```

```
# confusion matrix
confusion_matrix(y_test,y_pred)
```

```
array([[1501,  741],
       [ 261,  184]], dtype=int64)
```

```
#classification report
print(classification_report(y_test,y_pred))
```

```
              precision    recall  f1-score   support

           0       0.85      0.67      0.75      2242
           1       0.20      0.41      0.27       445

    accuracy                           0.63      2687
   macro avg       0.53      0.54      0.51      2687
weighted avg       0.74      0.63      0.67      2687
```

tune KNN hyperparameters using GridSearch

from sklearn.model_selection import GridSearchCV knn_params = { "n_neighbors": range(1,20,2), "weights": ["uniform","distance"], "metric": ["euclidean", "manhattan", "minkowski"] } cv = RepeatedStratifiedKFold(n_splits = 10, n_repeats = 3, random_state = 101) grid_search = GridSearchCV(estimator = knn, param_grid = knn_params, n_jobs = 1, cv=cv, scoring= "accuracy", error_score = 0) grid_results = grid_search.fit(X_train_res, y_train_res)

best params

print(grid_results.best_params_)

train and test model using new parameters

final_model = knn.set_params(**grid_results.best_params) final_model.fit(X_train_res, y_train_res) y_pred = final_model.predict(X_test)

confusion_matrix(y_test, y_pred)

classification_report(y_test,y_pred)

plot ROC curve

from sklearn.metrics import roc_curve y_scores = grid_search.decision_function(X_train_res) fpr, tpr, thresholds = roc_curve(y_train_res, y_scores) def plot_roc_curve(fpr,tpr, label = None): plt.plot(fpr,tpr, linewidth = 2, label = label) plt.plot([0,1],[0,1], 'k--')

plot_roc_curve(fpr,tpr)

7. Naive Bayes

```
# train and test a model with GaussianNB
from sklearn.naive_bayes import GaussianNB
clf = GaussianNB()
clf.fit(X_train_res,y_train_res)
y_pred = clf.predict(X_test)
```

```
# confusion matrix
confusion_matrix(y_test,y_pred)
```

```
array([[ 939, 1303],
       [  79,  366]], dtype=int64)
```

```
print("Accuracy: " , metrics.accuracy_score(y_test,y_pred))
```

```
Accuracy:  0.4856717528842575
```

```
# classification report
print(classification_report(y_test,y_pred))
```

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

```
              0       0.92      0.42      0.58      2242
              1       0.22      0.82      0.35       445

       accuracy                           0.49      2687
      macro avg       0.57      0.62      0.46      2687
   weighted avg       0.81      0.49      0.54      2687
```

```
# number of misclassifications
print("Number of misclassifications out of %d points: %d"
     % (X_test.shape[0], (y_test != y_pred).sum()))
```

```
Number of misclassifications out of 2687 points: 1382
```

Categorical NB

```
# train and test a model with CategoricalNB
from sklearn.naive_bayes import CategoricalNB
clf = CategoricalNB()
clf.fit(X_train_res,y_train_res)
y_pred = clf.predict(X_test[2:3])
```

```
# confusion matrix
confusion_matrix(y_test[2:3],y_pred)
```

```
array([[1]], dtype=int64)
```

```
# classification report
print(classification_report(y_test[2:3],y_pred))
```

```
              precision    recall  f1-score   support

              0       1.00      1.00      1.00         1

       accuracy                           1.00         1
      macro avg       1.00      1.00      1.00         1
   weighted avg       1.00      1.00      1.00         1
```

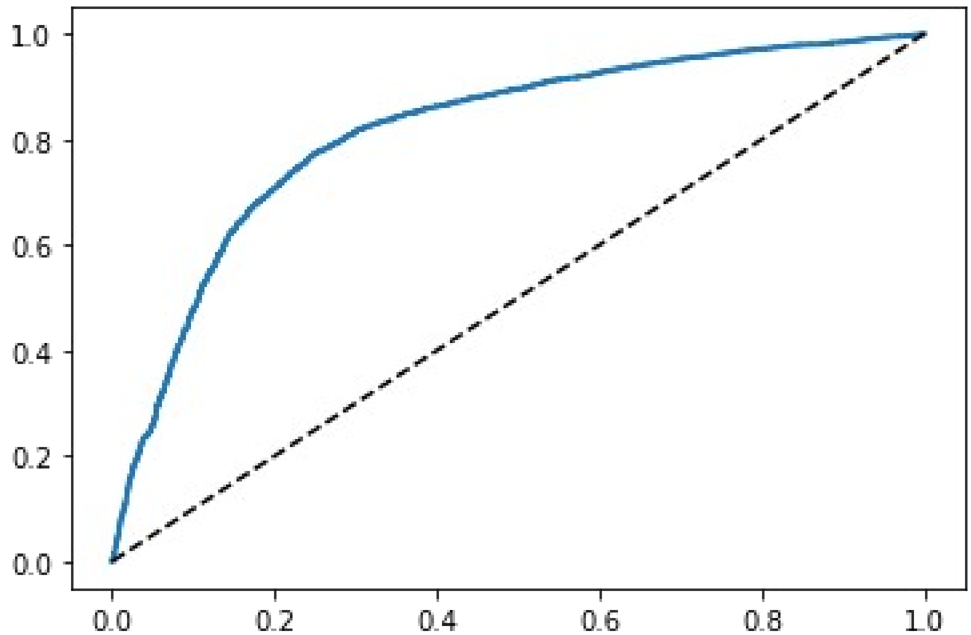
```
# number of misclassifications
print("Number of misclassifications out of %d points: %d"
     % (X_test.shape[0], (y_test[2:3] != y_pred).sum()))
```

```
Number of misclassifications out of 2687 points: 0
```

8. Support Vector Machines

```
from sklearn.pipeline import make_pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.svm import SVC
# train using SVC
clf = make_pipeline(StandardScaler(), SVC(gamma = "auto"))
clf.fit(X_train_res,y_train_res)
```

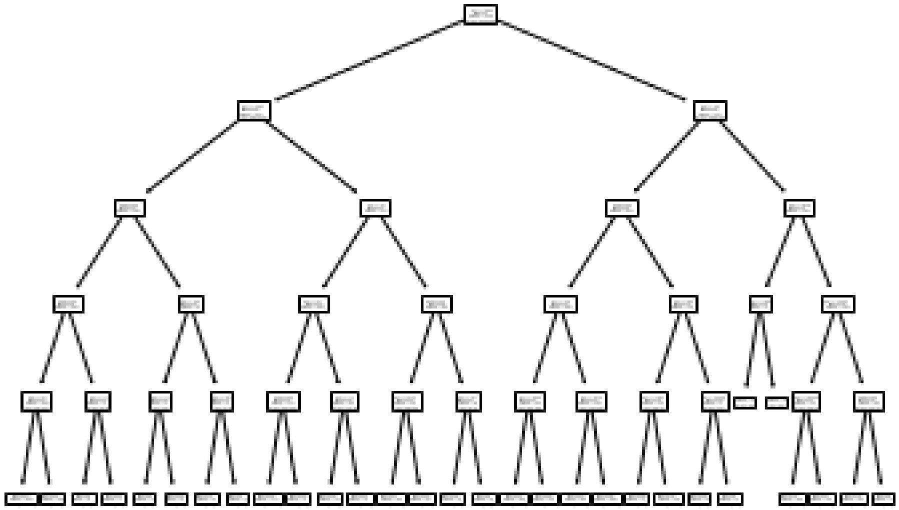
```
# test model
y_pred = clf.predict(X_test)

confusion_matrix(y_test,y_pred)

array([[2057,  185],
       [ 210,  235]], dtype=int64)

print(classification_report(y_test,y_pred))

              precision    recall  f1-score   support

           0       0.91      0.92      0.91      2242
           1       0.56      0.53      0.54       445

    accuracy                           0.85      2687
   macro avg       0.73      0.72      0.73      2687
weighted avg       0.85      0.85      0.85      2687


# number of misclassifications
print("Number of misclassifications out of %d points: %d"
     % (X_test.shape[0], (y_test != y_pred).sum()))

Number of misclassifications out of 2687 points: 395

# plot ROC curve
from sklearn.metrics import roc_curve
y_scores = model.decision_function(X_train_res)
fpr, tpr, thresholds = roc_curve(y_train_res, y_scores)
def plot_roc_curve(fpr,tpr, label = None):
    plt.plot(fpr,tpr, linewidth = 2, label = label)
    plt.plot([0,1],[0,1], 'k--')

plot_roc_curve(fpr,tpr)
```



9. Decision Tree

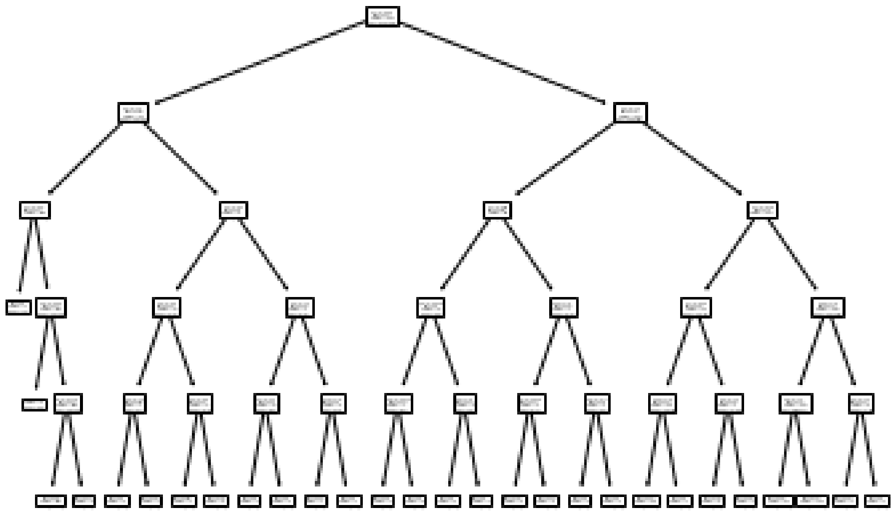
```
from sklearn.tree import DecisionTreeClassifier
# train and predict w/ Decision Tree on balanced training set
clf = DecisionTreeClassifier(random_state = 0, max_depth = 5)
clf.fit(X_train_res,y_train_res)
y_pred = clf.predict(X_test)

# plot decision tree
from sklearn import tree
tree.plot_tree(clf)
%%capture
```

```
UsageError: Line magic function `%%capture` not found.
```



```
# confusion matrix
confusion_matrix(y_test,y_pred)

# classification report
print(classification_report(y_test,y_pred))

# plot ROC curve
from sklearn.metrics import roc_curve
y_scores = clf.decision_function(X_train_res)
fpr, tpr, thresholds = roc_curve(y_train_res, y_scores)

plot_roc_curve(fpr,tpr)


# repeat w/ unbalanced training set
clf = DecisionTreeClassifier(random_state = 0, max_depth = 5)
clf.fit(X_train,y_train)
y_pred = clf.predict(X_test)

# plot decision tree
tree.plot_tree(clf)
%%capture
```

```
UsageError: Line magic function `%%capture` not found.
```



```
# confusion matrix
confusion_matrix(y_test,y_pred)
```

```
array([[2078,  164],
       [ 223,  222]], dtype=int64)
```

```
# classification report
print(classification_report(y_test,y_pred))
```

```
              precision    recall  f1-score   support

           0       0.90      0.93      0.91      2242
           1       0.58      0.50      0.53       445

    accuracy                           0.86      2687
   macro avg       0.74      0.71      0.72      2687
weighted avg       0.85      0.86      0.85      2687
```

```
# plot ROC curve
from sklearn.metrics import roc_curve
y_scores = clf.decision_function(X_train_res)
fpr, tpr, thresholds = roc_curve(y_train_res, y_scores)
plot_roc_curve(fpr,tpr)
```

```
----------------------------------------------------------------------
-----
AttributeError                            Traceback (most recent call
last)
~\AppData\Local\Temp/ipykernel_13024/300530386.py in <module>
      1 # plot ROC curve
      2 from sklearn.metrics import roc_curve
```

```
----> 3 y_scores = clf.decision_function(X_train_res)
      4 fpr, tpr, thresholds = roc_curve(y_train_res, y_scores)
      5 plot_roc_curve(fpr,tpr)

AttributeError: 'DecisionTreeClassifier' object has no attribute
'decision_function'
```

Differences between balanced and unbalanced training sets:

- Interestingly enough, the unbalanced training set yielded more accurate predictions (8% increase) The first decision tree seems more skewed to the right

10. Random Forest

```
# use grid search to tune max_depth, min_samples_leaf, n_estimators
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import GridSearchCV

rf_clf = RandomForestClassifier(random_state = 42, n_jobs = -1,
max_depth = 5, n_estimators = 100, oob_score = True)
rf_clf.fit(X_train_res,y_train_res)

params = {
    'max_depth' : [2,3,5,10,20],
    'min_samples_leaf': [5,10,20,50,100,200],
    'n_estimators' : [10,25,30,50,100,200]
}
grid_search = GridSearchCV(estimator = rf_clf, param_grid = params, cv
= 4, n_jobs = -1, verbose = 1, scoring = "accuracy")

%%time
grid_search.fit(X_train_res,y_train_res)

Fitting 4 folds for each of 180 candidates, totalling 720 fits

grid_search.best_score

rf_best = grid_search.best_estimator_
rf_best

# plot ROC curve
from sklearn.metrics import roc_curve
y_scores = rf_clf.decision_function(X_train_res)
fpr, tpr, thresholds = roc_curve(y_train_res, y_scores)
def plot_roc_curve(fpr,tpr, label = None):
    plt.plot(fpr,tpr, linewidth = 2, label = label)
    plt.plot([0,1],[0,1], 'k--')

plot_roc_curve(fpr,tpr)
```

11. Boosting Algorithms

Gradient boosting

```
# use Gradient boosting classifier to train
from sklearn.ensemble import GradientBoostingClassifier

gbc = GradientBoostingClassifier(n_estimators = 500, learning_rate =
.05, random_state = 100, max_features = 15)
gbc.fit(X_train_res, y_train_res)

# predict using gradient boost
gbc.predict(X_test)

# gradient boost confusion matrix
confusion_matrix(y_test,y_pred)

# gradient boost classification report
print(classification_report(y_test,y_pred))

# gradient boost's misclassfications
print("Number of misclassifications out of %d points: %d"
     % (X_test.shape[0], (y_test != y_pred).sum()))
```

Adaboost

```
from sklearn.ensemble import AdaBoostClassifier
from sklearn.tree import DecisionTreeClassifier
# Train adaboost with Decision tree classifier
dt = DecisionTreeClassifier()
clf = AdaBoostClassifier(n_estimators = 100, base_estimator = dt,
learning_rate = 1)
clf.fit(X_train_res, y_train_res)

# predict using adaboost
y_pred = clf.predict(X_test)

# adaboost confusion matrix
confusion_matrix(y_test,y_pred)

# ada boost classification report
print(classification_report(y_test,y_pred))

# ada boost's misclassfications
print("Number of misclassifications out of %d points: %d"
     % (X_test.shape[0], (y_test != y_pred).sum()))
```

12. Discussion

Based on accuracy, KNN and Naive Bayes were the highest contenders for an ideal classification model. In the future, I could work on hyperparameter tuning and resampling/scaling data specifically for each of these models.