This jupyter notebook is prepared by "Patrick Ingram".

1. Load Data and perform basic EDA

1. **import libraries: pandas, numpy, matplotlib (set %matplotlib inline), matplotlib's pyplot, seaborn, missingno, scipy's stats, sklearn (1 pt)**
2. **import the data to a dataframe and show the count of rows and columns (1 pt)**
3. **Show the top 5 and last 5 rows (1 pt)**
4. **Show how many columns have null values**
5. **Plot the count of target and discuss its imbalances and probably issues and solutions**

In [1]:

```
import pandas as pd
import numpy as np
import matplotlib as mpl
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
import scipy.stats as st
from sklearn import ensemble, tree, linear_model
import missingno as msno

from sklearn.preprocessing import MinMaxScaler
from imblearn.over_sampling import SMOTE, ADASYN

from sklearn.svm import SVC
from sklearn.datasets import make_classification
from sklearn.model_selection import cross_val_score
from sklearn.model_selection import RepeatedStratifiedKFold, train_test_split, GridSearch
CV
from sklearn.pipeline import Pipeline, make_pipeline
from sklearn.decomposition import PCA
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score
from sklearn.metrics import confusion_matrix, classification_report
from sklearn.metrics import precision_score, recall_score
from sklearn.metrics import f1_score, make_scorer
from sklearn.metrics import roc_curve
from sklearn.metrics import roc_auc_score
from sklearn.metrics import precision_recall_curve
from sklearn.model_selection import cross_val_predict
from sklearn.neighbors import KNeighborsClassifier
from sklearn.naive_bayes import GaussianNB, CategoricalNB
```

In [2]:

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

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount
("/content/drive", force_remount=True).
```

In [3]:

```
hrdata = pd.read_csv('../content/drive/MyDrive/Colab Notebooks/hrdata2.csv')
```

In [4]:

```
hrdata.shape
```

Out[4]:

```
(8955, 15)
```

In [5]:

```
hrdata.describe()
```

Out[5]:

	Unnamed: 0	enrollee_id	city_development_index	experience	training_hours	target
count	8955.000000	8955.000000	8955.000000	8955.000000	8955.000000	8955.000000
mean	9527.135008	16869.638749	0.844570	11.635623	65.074930	0.165606
std	5554.606202	9963.804718	0.116178	6.545796	60.235087	0.371747
min	1.000000	2.000000	0.448000	0.000000	1.000000	0.000000
25%	4681.000000	8150.000000	0.794000	6.000000	23.000000	0.000000
50%	9488.000000	16924.000000	0.910000	10.000000	47.000000	0.000000
75%	14419.000000	25902.000000	0.920000	18.000000	88.000000	0.000000
max	19155.000000	33380.000000	0.949000	21.000000	336.000000	1.000000

In [6]:

```
hrdata.head()
```

Out[6]:

	Unnamed: 0	enrollee_id	city	city_development_index	gender	relevent_experience	enrolled_university	education_level
0	1	29725	city_40	0.776	Male	No relevent experience	no_enrollment	Graduate
1	4	666	city_162	0.767	Male	Has relevent experience	no_enrollment	Masters
2	7	402	city_46	0.762	Male	Has relevent experience	no_enrollment	Graduate
3	8	27107	city_103	0.920	Male	Has relevent experience	no_enrollment	Graduate
4	11	23853	city_103	0.920	Male	Has relevent experience	no_enrollment	Graduate

In [7]:

```
hrdata.tail()
```

Out[7]:

	Unnamed: 0	enrollee_id	city	city_development_index	gender	relevent_experience	enrolled_university	education_lev
8950	19147	21319	city_21	0.624	Male	No relevent experience	Full time course	Graduat
8951	19149	251	city_103	0.920	Male	Has relevent experience	no_enrollment	Maste
8952	19150	32313	city_160	0.920	Female	Has relevent experience	no_enrollment	Graduat
8953	19152	29754	city_103	0.920	Female	Has relevent experience	no_enrollment	Graduat
8954	19155	24576	city_103	0.920	Male	Has relevent experience	no_enrollment	Graduat

In [8]:

In [8]:

```
hrdata.isnull()
```

Out[8]:

	Unnamed: 0	enrollee_id	city	city_development_index	gender	relevent_experience	enrolled_university	education_level
0	False	False	False	False	False	False	False	False
1	False	False	False	False	False	False	False	False
2	False	False	False	False	False	False	False	False
3	False	False	False	False	False	False	False	False
4	False	False	False	False	False	False	False	False
...	...	...	...	...	...	...	...	...
8950	False	False	False	False	False	False	False	False
8951	False	False	False	False	False	False	False	False
8952	False	False	False	False	False	False	False	False
8953	False	False	False	False	False	False	False	False
8954	False	False	False	False	False	False	False	False

8955 rows × 15 columns

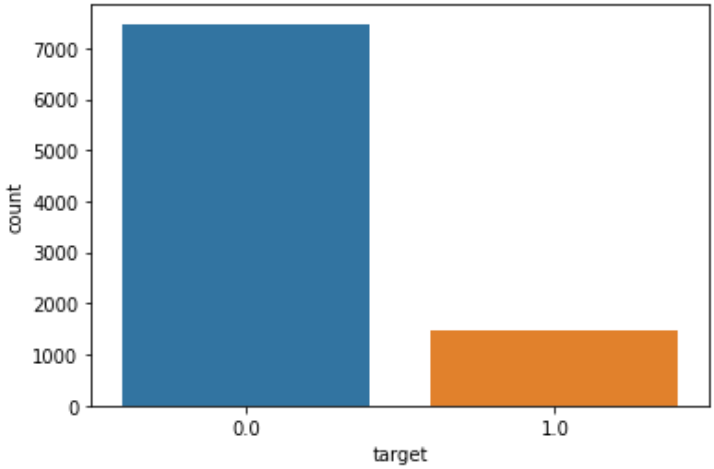
In [9]:

```
x_target = hrdata['target']
sns.countplot(x_target)
```

```
/usr/local/lib/python3.7/dist-packages/seaborn/_decorators.py:43: FutureWarning: Pass the
following variable as a keyword arg: x. From version 0.12, the only valid positional argu
ment will be `data`, and passing other arguments without an explicit keyword will result
in an error or misinterpretation.
  FutureWarning
```

Out[9]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fe9d8caa250>
```



2. Feature Selection and Pre-Processing

In [10]:

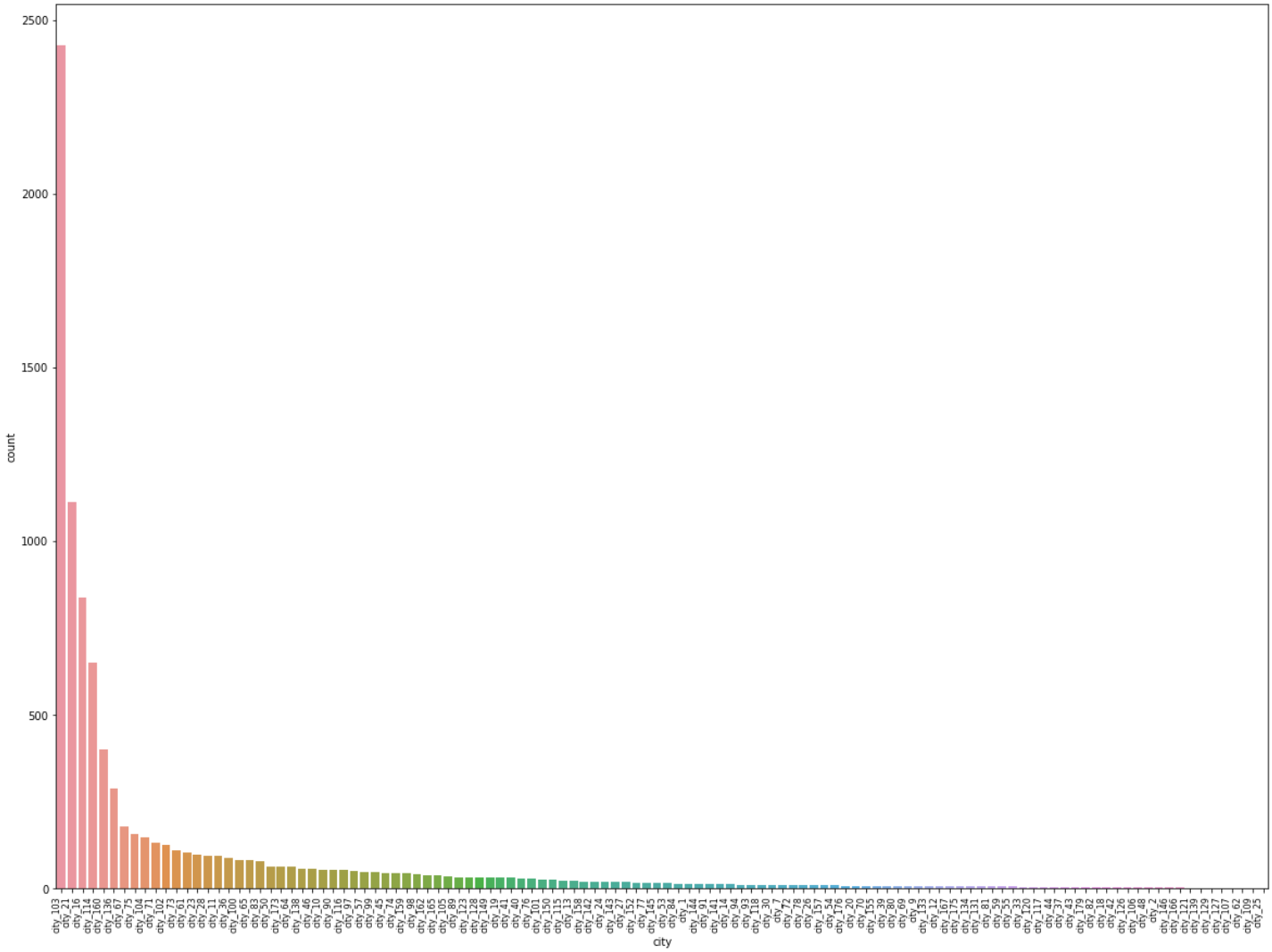
```
x = hrdata['city']
plt.figure(figsize = (20, 15))
plt.xticks(rotation=90, horizontalalignment='right', fontweight='light', fontsize=8)
sns.countplot(x, order=hrdata['city'].value_counts().index)
```

```
/usr/local/lib/python3.7/dist-packages/seaborn/_decorators.py:43: FutureWarning: Pass the
```

```
following variable as a keyword arg: x. From version 0.12, the only valid positional argu
ment will be `data`, and passing other arguments without an explicit keyword will result
in an error or misinterpretation.
  FutureWarning
```

Out[10]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fe9d8b44310>
```



In [11]:

```
#getting top 4 cities

city_top = hrdata[hrdata.city == 'city_103'].shape[0] + hrdata[hrdata.city == 'city_21']
.shape[0] + hrdata[hrdata.city == 'city_16'].shape[0] + hrdata[hrdata.city == 'city_114'
].shape[0]
city_top
```

Out[11]:

```
5021
```

In [12]:

```
#Remaining rows

print(hrdata['city'].shape[0] - city_top)
```

```
3934
```

In [13]:

```
#Replacing with city_others

newSet = set(hrdata['city'])
```

```
newSet.remove('city_114')
newSet.remove('city_21')
newSet.remove('city_16')
newSet.remove('city_103')

hrdata.loc[hrdata['city'].isin(newSet), 'city'] = 'city_others'
newSet
```

Out[13]:

```
{'city_1',
 'city_10',
 'city_100',
 'city_101',
 'city_102',
 'city_104',
 'city_105',
 'city_106',
 'city_107',
 'city_109',
 'city_11',
 'city_115',
 'city_116',
 'city_117',
 'city_118',
 'city_12',
 'city_120',
 'city_121',
 'city_123',
 'city_126',
 'city_127',
 'city_128',
 'city_129',
 'city_13',
 'city_131',
 'city_133',
 'city_134',
 'city_136',
 'city_138',
 'city_139',
 'city_14',
 'city_141',
 'city_142',
 'city_143',
 'city_144',
 'city_145',
 'city_146',
 'city_149',
 'city_150',
 'city_152',
 'city_155',
 'city_157',
 'city_158',
 'city_159',
 'city_160',
 'city_162',
 'city_165',
 'city_166',
 'city_167',
 'city_173',
 'city_175',
 'city_176',
 'city_179',
 'city_18',
 'city_19',
 'city_2',
 'city_20',
 'city_23',
 'city_24',
 'city_25',
 'city_26',
 'city_27',
 'city_28',
```

```
 'city_30',
 'city_33',
 'city_36',
 'city_37',
 'city_39',
 'city_40',
 'city_41',
 'city_42',
 'city_43',
 'city_44',
 'city_45',
 'city_46',
 'city_48',
 'city_50',
 'city_53',
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 'city_71',
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 'city_75',
 'city_76',
 'city_77',
 'city_78',
 'city_80',
 'city_81',
 'city_82',
 'city_83',
 'city_84',
 'city_89',
 'city_9',
 'city_90',
 'city_91',
 'city_93',
 'city_94',
 'city_97',
 'city_98',
 'city_99'}
```
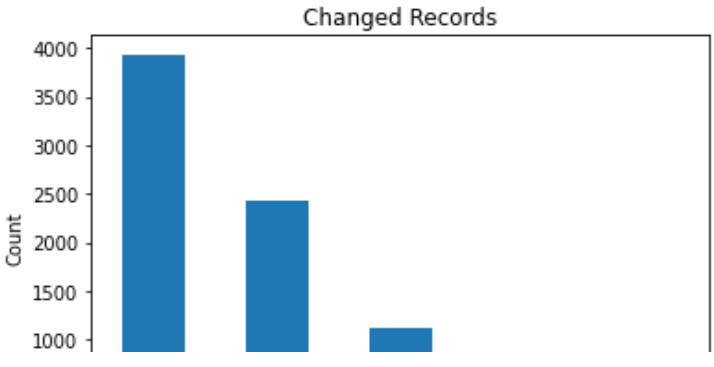
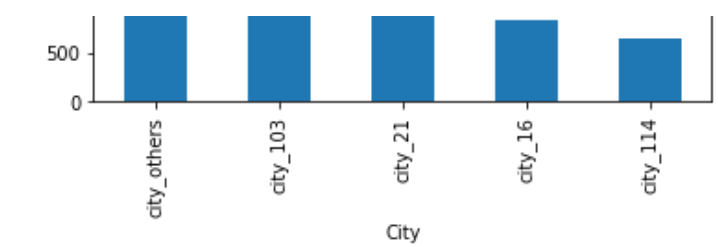

In [14]:

```
#plotting sample data for changed records

hrdata['city'].value_counts().plot(kind='bar')
plt.title('Changed Records')
plt.xlabel('City')
plt.ylabel('Count')
plt.show()
```





In [15]:

```
#Education Level

unq = set()

for i in hrdata['education_level']:
    unq.add(i)
unq
```

Out[15]:

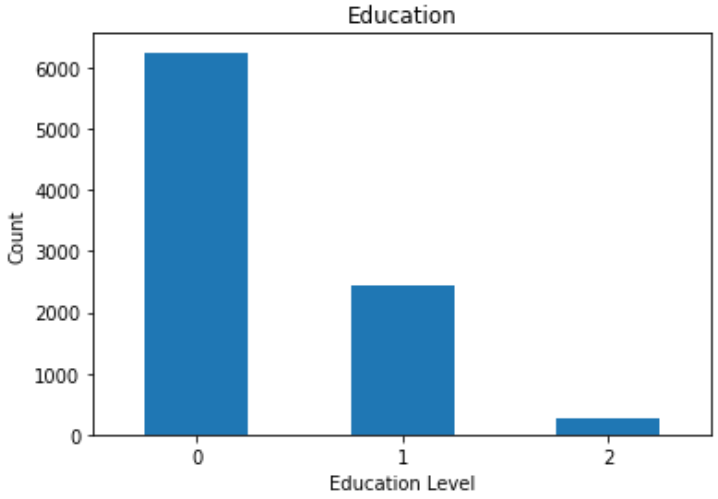
```
{'Graduate', 'Masters', 'Phd'}
```

In [16]:

```
#Replacing edu level with Ordinal Values

level = {
    'Graduate': 0,
    'Masters' : 1,
    'Phd' : 2
}

convEdu = hrdata.replace({'education_level': level})
hrdata = convEdu
```

In [17]:

```
#Show changes

hrdata['education_level'].value_counts().plot(kind='bar')
plt.xticks(rotation=0, fontweight='light')
plt.title('Education')
plt.xlabel('Education Level')
plt.ylabel('Count')
plt.show()
```



In [18]:

```
#Company Size

unq = set()

for i in hrdata['company_size']:
```

```
    unq.add(i)
unq
```

Out[18]:

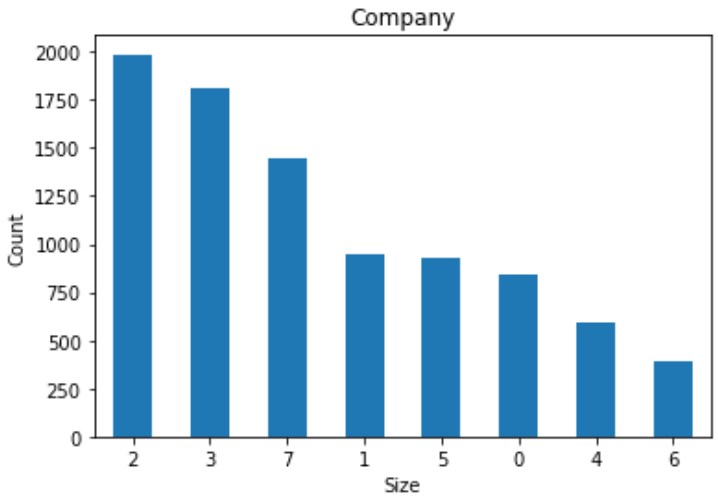
```
{'10/49',
 '100-500',
 '1000-4999',
 '10000+',
 '50-99',
 '500-999',
 '5000-9999',
 '<10'}
```

In [19]:

```
order = {'<10': 0, '10/49': 1, '50-99' : 2,'100-500':3, '500-999': 4,'1000-4999':5, '5000-9999':6, '10000+':7}
newSize = hrdata.replace({'company_size': order})
hrdata = newSize
```

In [20]:

```
#Show Changes

hrdata['company_size'].value_counts().plot(kind='bar')
plt.xticks(rotation=0, fontweight='light')
plt.title('Company')
plt.xlabel('Size')
plt.ylabel('Count')
plt.show()
```



In [21]:

```
unq = set()

for i in hrdata['last_new_job']:
    unq.add(i)
unq
```

Out[21]:

```
{'1', '2', '3', '4', '>4', 'never'}
```

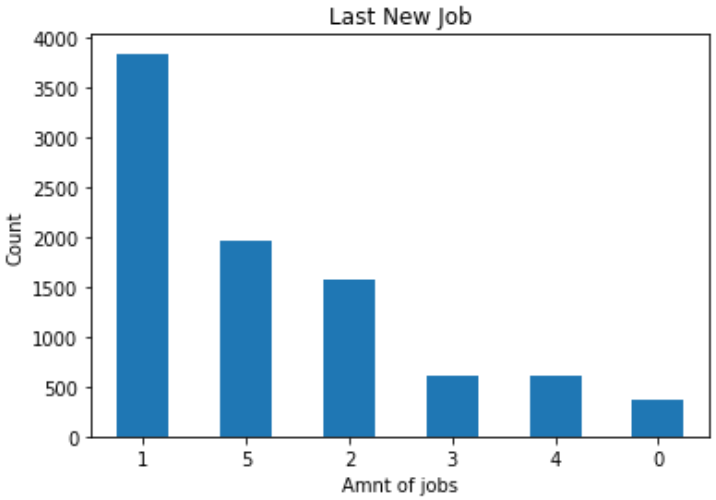
In [22]:

```
jobMap = {'never': 0, '1': 1, '2' : 2,'3':3, '4': 4,'>4':5}

lastNew = hrdata.replace({'last_new_job': jobMap})
hrdata = lastNew
```

In [23]:

```
hrdata['last_new_job'].value_counts().plot(kind='bar')
```

```
plt.xticks(rotation=0, fontweight='light')
plt.title('Last New Job')
plt.xlabel('Amnt of jobs')
plt.ylabel('Count')
plt.show()
```



In [24]:

```
#Rest of columns

comp = set()
gen = set()
ci = set()
relexp = set()
enruni = set()
mjdisc = set()

for i in hrdata['company_type']:
    comp.add(i)

for i in hrdata['gender']:
    gen.add(i)

for i in hrdata['city']:
    ci.add(i)

for i in hrdata['relevent_experience']:
    relexp.add(i)

for i in hrdata['enrolled_university']:
    enruni.add(i)

for i in hrdata['major_discipline']:
    mjdisc.add(i)

print(comp)
print(gen)
print(ci)
print(relexp)
print(enruni)
print(mjdisc)
```

```
{'Funded Startup', 'NGO', 'Other', 'Pvt Ltd', 'Public Sector', 'Early Stage Startup'}
{'Female', 'Male', 'Other'}
{'city_114', 'city_others', 'city_16', 'city_103', 'city_21'}
{'No relevent experience', 'Has relevent experience'}
{'Full time course', 'Part time course', 'no_enrollment'}
{'Other', 'Arts', 'STEM', 'Humanities', 'Business Degree', 'No Major'}
```

In [25]:

```
#get_dummies for binary columns

hrdata = pd.get_dummies(data=hrdata, columns=['company_type', 'gender', 'city', 'releven
```

```
t_experience', 'enrolled_university', 'major_discipline'])
```

In [26]:

```
#Show top and last 5
hrdata.head()
```

Out[26]:

	Unnamed: 0	enrollee_id	city_development_index	education_level	experience	company_size	last_new_job	training_hours	ta
0	1	29725	0.776	0	15.0	2	5	47	
1	4	666	0.767	1	21.0	2	4	8	
2	7	402	0.762	0	13.0	0	5	18	
3	8	27107	0.920	0	7.0	2	1	46	
4	11	23853	0.920	0	5.0	6	1	108	

5 rows × 34 columns

In [27]:

```
hrdata.tail()
```

Out[27]:

	Unnamed: 0	enrollee_id	city_development_index	education_level	experience	company_size	last_new_job	training_hours
8950	19147	21319	0.624	0	1.0	3	1	52
8951	19149	251	0.920	1	9.0	2	1	36
8952	19150	32313	0.920	0	10.0	3	3	23
8953	19152	29754	0.920	0	7.0	1	1	25
8954	19155	24576	0.920	0	21.0	2	4	44

5 rows × 34 columns

In [28]:

```
#Show the shape of the new table

hrdata.shape
```

Out[28]:

```
(8955, 34)
```

In [29]:

```
#Drop Enrollee ID and duplicates

hrdata = hrdata.drop('enrollee_id', axis=1)
```

In [30]:

```
#Feature Scaling
scaler = MinMaxScaler()
col = hrdata.columns
data_scale = scaler.fit_transform(hrdata.to_numpy())
data_scale = pd.DataFrame(data_scale, columns = col)

data_scale.head()
```

Out[30]:

	Unnamed: 0	city_development_index	education_level	experience	company_size	last_new_job	training_hours	target	compa
0	0.000000	0.654691	0.0	0.714286	0.285714	1.0	0.137313	0.0	
1	0.000157	0.636727	0.5	1.000000	0.285714	0.8	0.020896	0.0	
2	0.000313	0.626747	0.0	0.619048	0.000000	1.0	0.050746	1.0	
3	0.000365	0.942116	0.0	0.333333	0.285714	0.2	0.134328	1.0	
4	0.000522	0.942116	0.0	0.238095	0.857143	0.2	0.319403	0.0	

5 rows × 33 columns

In [31]:

```
#Move target to last column

data_scale = data_scale.loc[:, data_scale.columns != 'target']
data_scale['target'] = hrdata['target']
data_scale.head()
```

Out[31]:

	Unnamed: 0	city_development_index	education_level	experience	company_size	last_new_job	training_hours	company_type Stage S
0	0.000000	0.654691	0.0	0.714286	0.285714	1.0	0.137313	
1	0.000157	0.636727	0.5	1.000000	0.285714	0.8	0.020896	
2	0.000313	0.626747	0.0	0.619048	0.000000	1.0	0.050746	
3	0.000365	0.942116	0.0	0.333333	0.285714	0.2	0.134328	
4	0.000522	0.942116	0.0	0.238095	0.857143	0.2	0.319403	

5 rows × 33 columns

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

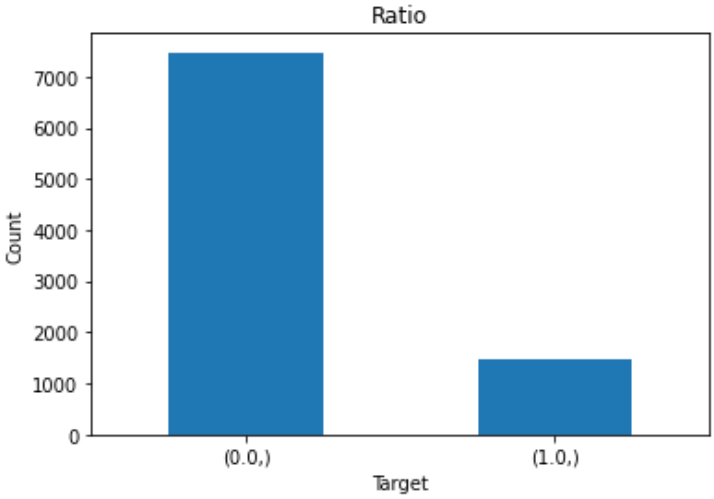
In [32]:

```
#Copy all features into X and target into Y

X = hrdata[['city_development_index', 'education_level', 'experience',
'company_size', 'last_new_job', 'training_hours',
'company_type_Early Stage Startup', 'company_type_Funded Startup',
'company_type_NGO', 'company_type_Other', 'company_type_Public Sector',
'company_type_Pvt Ltd', 'major_discipline_Arts',
'major_discipline_Business Degree', 'major_discipline_Humanities',
'major_discipline_No Major', 'major_discipline_Other',
'major_discipline_STEM', 'enrolled_university_Full time course',
'enrolled_university_Part time course',
'enrolled_university_no_enrollment',
'relevent_experience_Has relevent experience',
'relevent_experience_No relevent experience', 'gender_Female',
'gender_Male', 'gender_Other', 'city_city_103', 'city_city_114',
'city_city_16', 'city_city_21', 'city_city_others']]

Y = hrdata[['target']]
```

In [33]:

```
#Show the ratio of 1 and 0 in Y
```

```
Y.value_counts().plot(kind='bar')
plt.title('Ratio')
plt.xticks(rotation=0, fontweight='light')
plt.xlabel('Target')
plt.ylabel('Count')
plt.show()
```

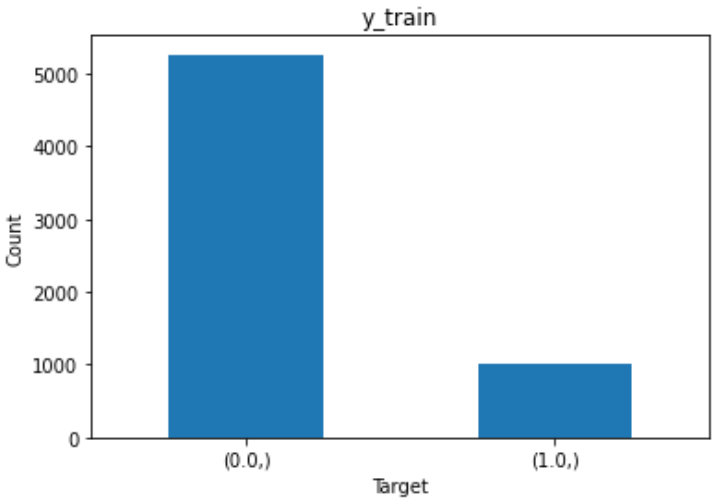


In [34]:

```
#Use sklearn's train_test_split to split the data set into training and test sets. There should be 30% records in the test set.
X_train, X_test, y_train, y_test = train_test_split(X, Y, test_size = .30, random_state = 0)
```

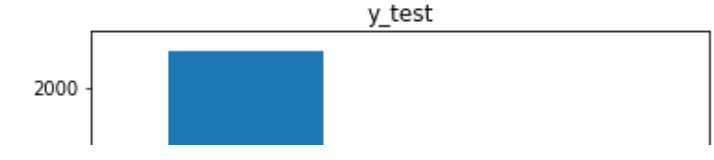
In [35]:

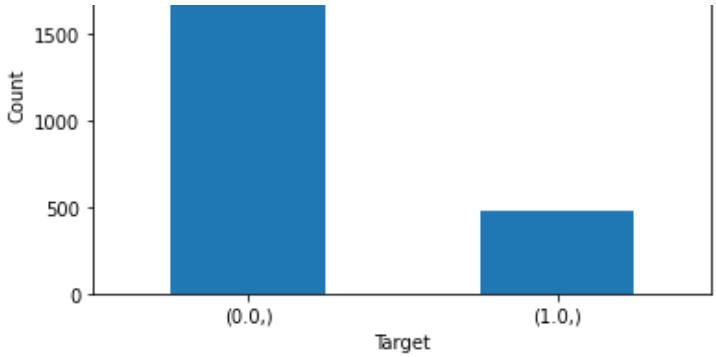
```
y_train.value_counts().plot(kind='bar')
plt.xticks(rotation=0, fontweight='light')
plt.title('y_train')
plt.xlabel('Target')
plt.ylabel('Count')
plt.show()
```



In [36]:

```
y_test.value_counts().plot(kind='bar')
plt.xticks(rotation=0, fontweight='light')
plt.title('y_test')
plt.xlabel('Target')
plt.ylabel('Count')
plt.show()
```



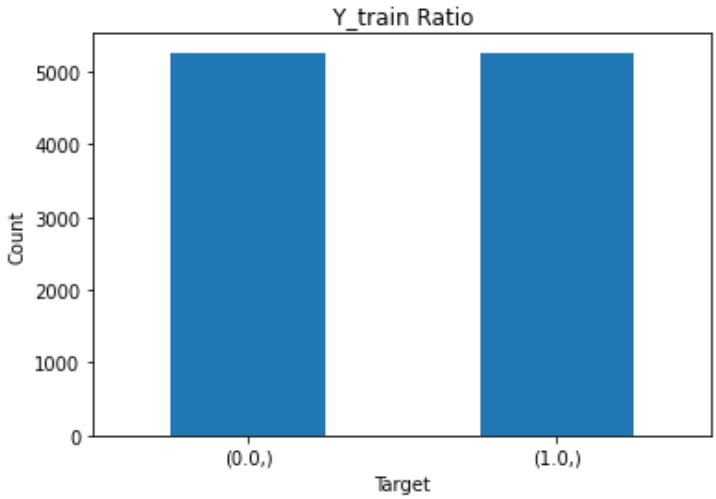


In [37]:

```
X_scaled, y_scaled = SMOTE().fit_resample(X_train, y_train)
```

In [38]:

```
y_scaled.value_counts().plot(kind='bar')
plt.xticks(rotation=0, fontweight='light')
plt.title('Y_train Ratio')
plt.xlabel('Target')
plt.ylabel('Count')
plt.show()
```



4. PCA and Logistic Regression

In [39]:

```
#Logistical Regression Model with Make_Pipeline

features = list(range(1,X.shape[1]+1))
model_s = []
for i in features:
  step = make_pipeline(PCA(n_components=i), LogisticRegression())
  RS = RepeatedStratifiedKFold(n_splits=10, n_repeats=3)
  scores = cross_val_score(step, X_scaled, y_scaled, scoring='accuracy', cv=RS, n_jobs=-
1)
  model_s.append(scores)

plt.boxplot(model_s, showmeans=True)
```

Out[39]:

```
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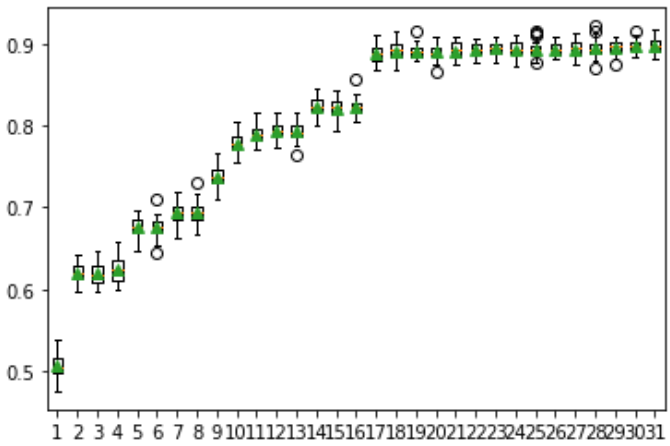


In [40]:

```
#PCA and Logistic Regression

steps = [('pca', PCA(n_components=19)), ('m', LogisticRegression())]
model = Pipeline(steps=steps)
model.fit(X_scaled, y_scaled)
y_pred = model.predict(X_test)
accuracy_score(y_test, y_pred, normalize=True, sample_weight=None)
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:993: DataConversionWar
ning: A column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.7/dist-packages/sklearn/linear_model/_logistic.py:818: Convergence
Warning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG,
```

Out[40]:

```
0.84108671380722
```

In [41]:

```
confusion_matrix(y_test, y_pred)
```

Out[41]:

```
array([[2062,  150],
       [ 277,  198]])
```

In [42]:

```
precision_score(y_test, y_pred)
```

Out[42]:

```
0.5689655172413793
```

In [43]:

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

Out[43]:

```
0.4168421052631579
```

In [44]:

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

Out[44]:

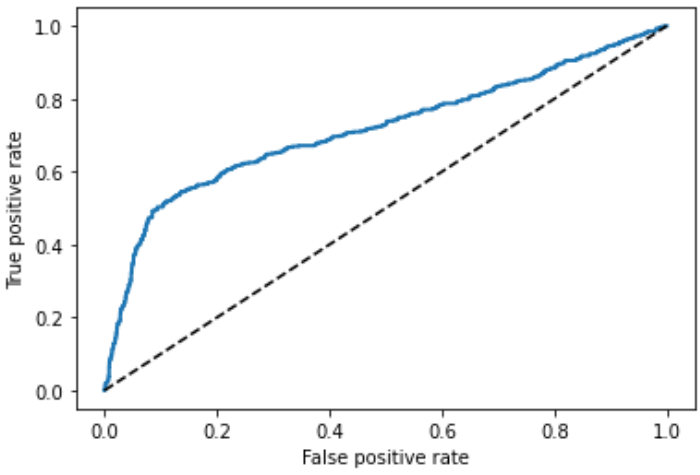
```
0.48116646415552855
```

In [45]:

```
y_pred = model.decision_function(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [46]:

```
#Show ROC Score
roc_auc_score(y_test, y_pred)
```

Out[46]:

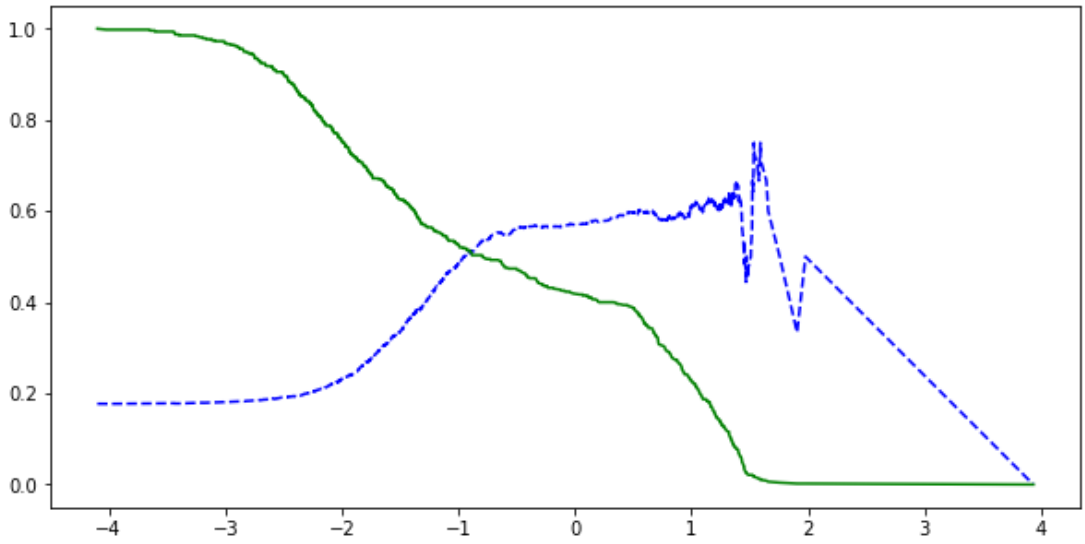
```
0.7164047777672028
```

In [47]:

```
#Precision Recall Curve Plot
precisions, recalls, thresholds = precision_recall_curve(y_test, y_pred)
```

```
def plot_precision_recall_vs_threshold(precisions, recalls, thresholds):
  plt.plot(thresholds, precisions[:-1], "b--", label="Precision")
  plt.plot(thresholds, recalls[:-1], "g-", label="Recall")

plt.figure(figsize=(10,5))
plot_precision_recall_vs_threshold(precisions, recalls, thresholds)
plt.show()
```



5. Softmaxt regression:

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

Softmax Regression is a generalization of Logistic Regression and uses k dimensionality to summarize a vector of arbitrary values bounded in a binary range.

We can use TensorFlow for softmax regression

6. KNN (Always use rebalanced training set for training, if it is not specified which training set to use)

1. **Use sklearn's KNN classifier to train (with k= 10) and predict the model based on the unbalanced training set (the training set before rebalancing) and test it and show the confusion matrix and classification report**
2. **Use sklearn's KNN classifier to train (with k= 10) and predict the model based on the rebalanced training set and test it and show the confusion matrix and classification report**
3. **Use grid search to tune the following hyperparameters of KNN: number of neighbors (between 1 and 20), weights (uniform or distance), and metrics (Euclidean, Manhattan, or Minkowski)istance) to use for KNN. While creating an instance of GridSearchCV, use multiple evaluation metrics such as AUC and accuracy based on the example available at Link to Sklearn Link to sklearn (Links to an external site.). Also some helpful links and codes: GitHub Example and Youtube Video**
4. **The above grid search process can take a couple of minutes. After completing the process, print the best_params_**
5. **Based on the result from grid search, use the parameters to train a model, test it with test set, and then print the confusion matrix and classification report. Also, show the AUC of ROC.**
6. **Use PCA and based on that train model, test it and then print the confusion matrix and classification report. Also, show the AUC of ROC.**
7. **A short discussion on the 4 models and their differences.**

In [48]:

```
#KNN based on unbalanced set
```

```
classifier = KNeighborsClassifier(n_neighbors=10)
classifier.fit(X_train, y_train)
y_pred = classifier.predict(X_test)
print(y_pred)
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/neighbors/_classification.py:198: DataConv
ersionWarning: A column-vector y was passed when a 1d array was expected. Please change t
he shape of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```

```
[0. 0. 0. ... 0. 0. 0.]
```

In [49]:

```
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
[[2197   15]
 [ 466    9]]
              precision    recall  f1-score   support

         0.0       0.83      0.99      0.90      2212
         1.0       0.38      0.02      0.04       475

    accuracy                           0.82      2687
   macro avg       0.60      0.51      0.47      2687
weighted avg       0.75      0.82      0.75      2687
```

In [50]:

```
# KNN based on balanced set

classifier = KNeighborsClassifier(n_neighbors=10)
classifier.fit(X_scaled, y_scaled)
y_pred = classifier.predict(X_test)
print(y_pred)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/neighbors/_classification.py:198: DataConv
ersionWarning: A column-vector y was passed when a 1d array was expected. Please change t
he shape of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```

```
[0. 0. 0. ... 1. 0. 0.]
[[1455  757]
 [ 253  222]]
              precision    recall  f1-score   support

         0.0       0.85      0.66      0.74      2212
         1.0       0.23      0.47      0.31       475

    accuracy                           0.62      2687
   macro avg       0.54      0.56      0.52      2687
weighted avg       0.74      0.62      0.67      2687
```

In [51]:

```
#Using Grid Search

knn_params = {
"n_neighbors": range(1, 10),
"weights": ["uniform", "distance"],
"metric": ["euclidean", "manhattan", "minkowski"]
}
scoring = {"AUC": "roc_auc", "Accuracy": make_scorer(accuracy_score)}
knn = KNeighborsClassifier()
grid_search = GridSearchCV(estimator=knn, param_grid=knn_params, n_jobs=-1, cv=3, scorin
g=scoring, refit="AUC", return_train_score=True)
```

```
grid_results = grid_search.fit(X_scaled, y_scaled)
final_model = knn.set_params(**grid_results.best_params_)
final_model.fit(X_scaled, y_scaled)
y_pred = final_model.predict(X_test)
print(classification_report(y_test, y_pred))
print(confusion_matrix(y_test, y_pred))
print(grid_results.best_params_)
```

```
/usr/local/lib/python3.7/dist-packages/joblib/externals/loky/process_executor.py:705: Use
rWarning: A worker stopped while some jobs were given to the executor. This can be caused
by a too short worker timeout or by a memory leak.
  "timeout or by a memory leak.", UserWarning
/usr/local/lib/python3.7/dist-packages/sklearn/neighbors/_classification.py:198: DataConv
ersionWarning: A column-vector y was passed when a 1d array was expected. Please change t
he shape of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
/usr/local/lib/python3.7/dist-packages/sklearn/neighbors/_classification.py:198: DataConv
ersionWarning: A column-vector y was passed when a 1d array was expected. Please change t
he shape of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```

```
              precision    recall  f1-score   support

         0.0       0.86      0.70      0.77      2212
         1.0       0.26      0.49      0.34       475

    accuracy                           0.66      2687
   macro avg       0.56      0.59      0.55      2687
weighted avg       0.76      0.66      0.69      2687

[[1541  671]
 [ 242  233]]
{'metric': 'manhattan', 'n_neighbors': 7, 'weights': 'distance'}
```

In [52]:

```
#After Grid Search
print(grid_results.best_params_)
```

```
{'metric': 'manhattan', 'n_neighbors': 7, 'weights': 'distance'}
```

In [53]:

```
#Train the model after grid search

classifier = KNeighborsClassifier(n_neighbors=9, weights='uniform', metric='manhattan')
classifier.fit(X_scaled, y_scaled)
y_pred = classifier.predict(X_test)
print(y_pred)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/neighbors/_classification.py:198: DataConv
ersionWarning: A column-vector y was passed when a 1d array was expected. Please change t
he shape of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```

```
[1. 0. 0. ... 1. 1. 0.]
[[1481  731]
 [ 220  255]]
              precision    recall  f1-score   support

         0.0       0.87      0.67      0.76      2212
         1.0       0.26      0.54      0.35       475

    accuracy                           0.65      2687
   macro avg       0.56      0.60      0.55      2687
weighted avg       0.76      0.65      0.68      2687
```

In [54]:

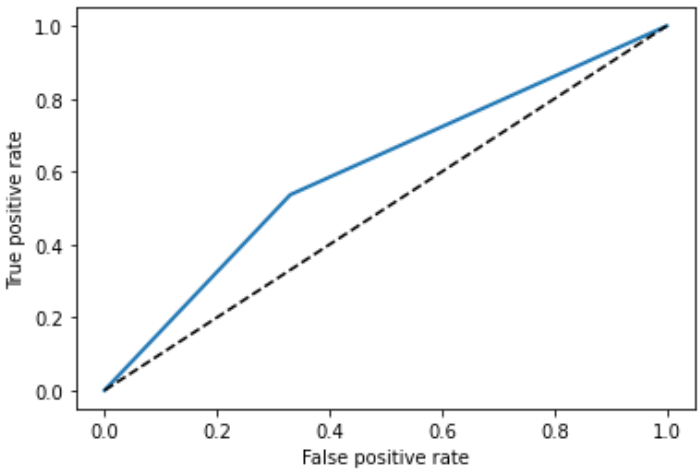
```
#plotting ROC curve
```

```
#plotting ROC curve

fpr, tpr, threshold = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [55]:

```
roc_auc_score(y_test, y_pred)
```

Out[55]:

```
0.603185971257257
```

In [56]:

```
#using PCA to train model

pca = KNeighborsClassifier()
pca.fit(X_scaled, y_scaled)
y_pred = pca.predict(X_test)
print(y_pred)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/neighbors/_classification.py:198: DataConv
ersionWarning: A column-vector y was passed when a 1d array was expected. Please change t
he shape of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```

```
[0. 0. 0. ... 1. 1. 0.]
[[1452  760]
 [ 258  217]]
              precision    recall  f1-score   support

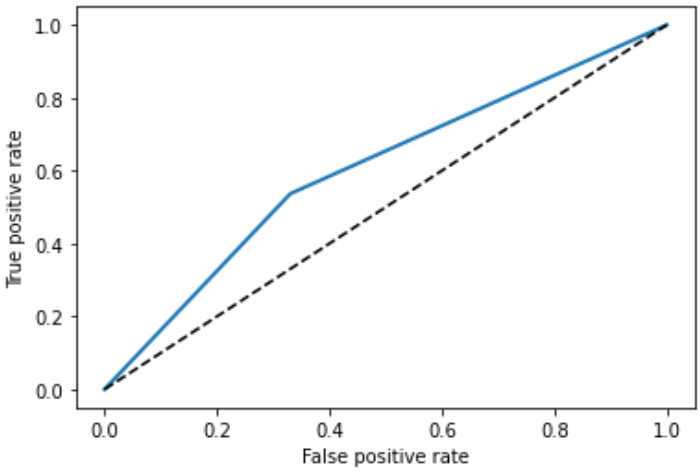
         0.0       0.85      0.66      0.74      2212
         1.0       0.22      0.46      0.30       475

    accuracy                           0.62      2687
   macro avg       0.54      0.56      0.52      2687
weighted avg       0.74      0.62      0.66      2687
```

In [57]:

```
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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [58]:

```
roc_auc_score(y_test, y_pred)
```

Out[58]:

```
0.5566308175502047
```

7. Naive Bayes

In [59]:

```
#Training a model with GaussianNB

gnb = GaussianNB()
gnb.fit(X_scaled, y_scaled)
y_pred= gnb.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
[[1151 1061]
 [ 155  320]]
              precision    recall  f1-score   support

         0.0       0.88      0.52      0.65      2212
         1.0       0.23      0.67      0.34       475

    accuracy                           0.55      2687
   macro avg       0.56      0.60      0.50      2687
weighted avg       0.77      0.55      0.60      2687
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:993: DataConversionWar
ning: A column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

In [60]:

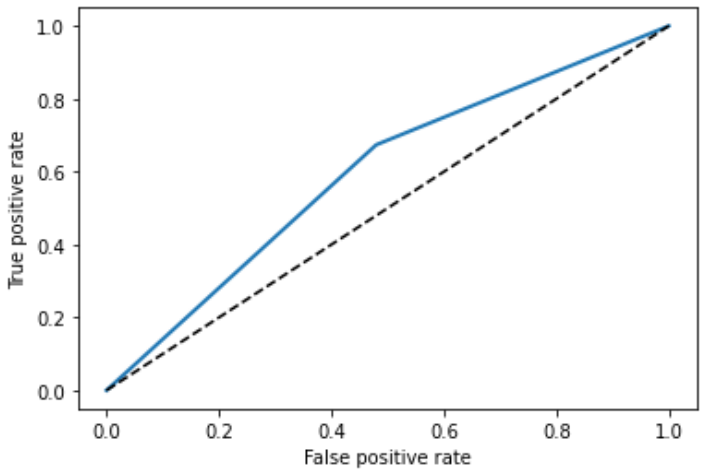
```
#Plotting and printing ROC Curve

y_pred = gnb.predict(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
```

```
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [61]:

```
roc_auc_score(y_test, y_pred)
```

Out[61]:

```
0.5970138954982392
```

In [62]:

```
# counting misclassification
y_pred = gnb.predict(X_test)
y_new=np.ravel(y_test)
p = (y_new)!= (y_pred)
print(p.sum())
```

```
1216
```

In [63]:

```
#Train with CategoricalNB

cnb = CategoricalNB()
cnb.fit(X_scaled, y_scaled)
y_pred= cnb.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
[[1968  244]
 [ 254  221]]
              precision    recall  f1-score   support

         0.0       0.89      0.89      0.89      2212
         1.0       0.48      0.47      0.47       475

    accuracy                           0.81      2687
   macro avg       0.68      0.68      0.68      2687
weighted avg       0.81      0.81      0.81      2687
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:993: DataConversionWarning: A column-vector y was passed when a 1d array was expected. Please change the shape of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

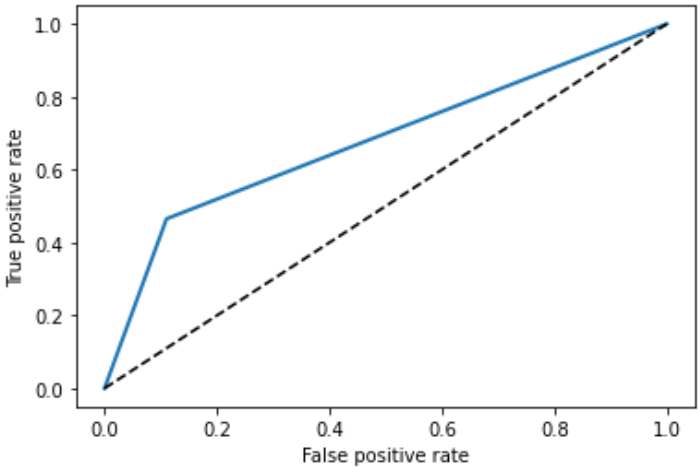
In [64]:

```
y_pred = cnb.predict(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [65]:

```
roc_auc_score(y_test, y_pred)
```

Out[65]:

```
0.6774778718949271
```

In [66]:

```
# counting misclassification
y_pred = gnb.predict(X_test)
y_new=np.ravel(y_test)
p = (y_new)!= (y_pred)
print(p.sum())
```

```
1216
```

8. Support Vector Machine

In [69]:

```
#Building support vector machine using SVC and Grid Search

model = SVC(kernel = 'sigmoid')
param_grid = {'C': [0.1,1, 10, 100]}
grid = GridSearchCV(SVC(probability=True, random_state=1), param_grid, n_jobs=-1, refit=
True, verbose=1)
grid.fit(X_scaled,y_scaled)
```

```
Fitting 5 folds for each of 4 candidates, totalling 20 fits
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:993: DataConversionWar
ning: A column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

Out[69]:

```
GridSearchCV(estimator=SVC(probability=True, random_state=1), n_jobs=-1,
             param_grid={'C': [0.1, 1, 10, 100]}, verbose=1)
```

In [70]:

```
,grid.best_params_
```

Out[70]:

{'C': 100}

In [71]:

```
#Testing the model

model = SVC(kernel = 'rbf', C=100)
model.fit(X_scaled, y_scaled)
y_pred= model.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:993: DataConversionWar
ning: A column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

```
[[2080  132]
 [ 277  198]]
              precision    recall  f1-score   support

         0.0       0.88      0.94      0.91      2212
         1.0       0.60      0.42      0.49       475

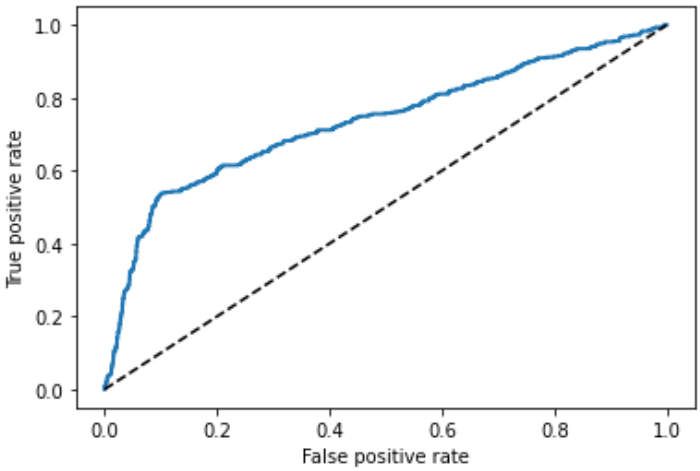
    accuracy                           0.85      2687
   macro avg       0.74      0.68      0.70      2687
weighted avg       0.83      0.85      0.84      2687
```

In [72]:

```
y_pred = model.decision_function(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [73]:

```
roc_auc_score(y_test, y_pred)
```

Out[73]:

```
0.7344670219853431
```

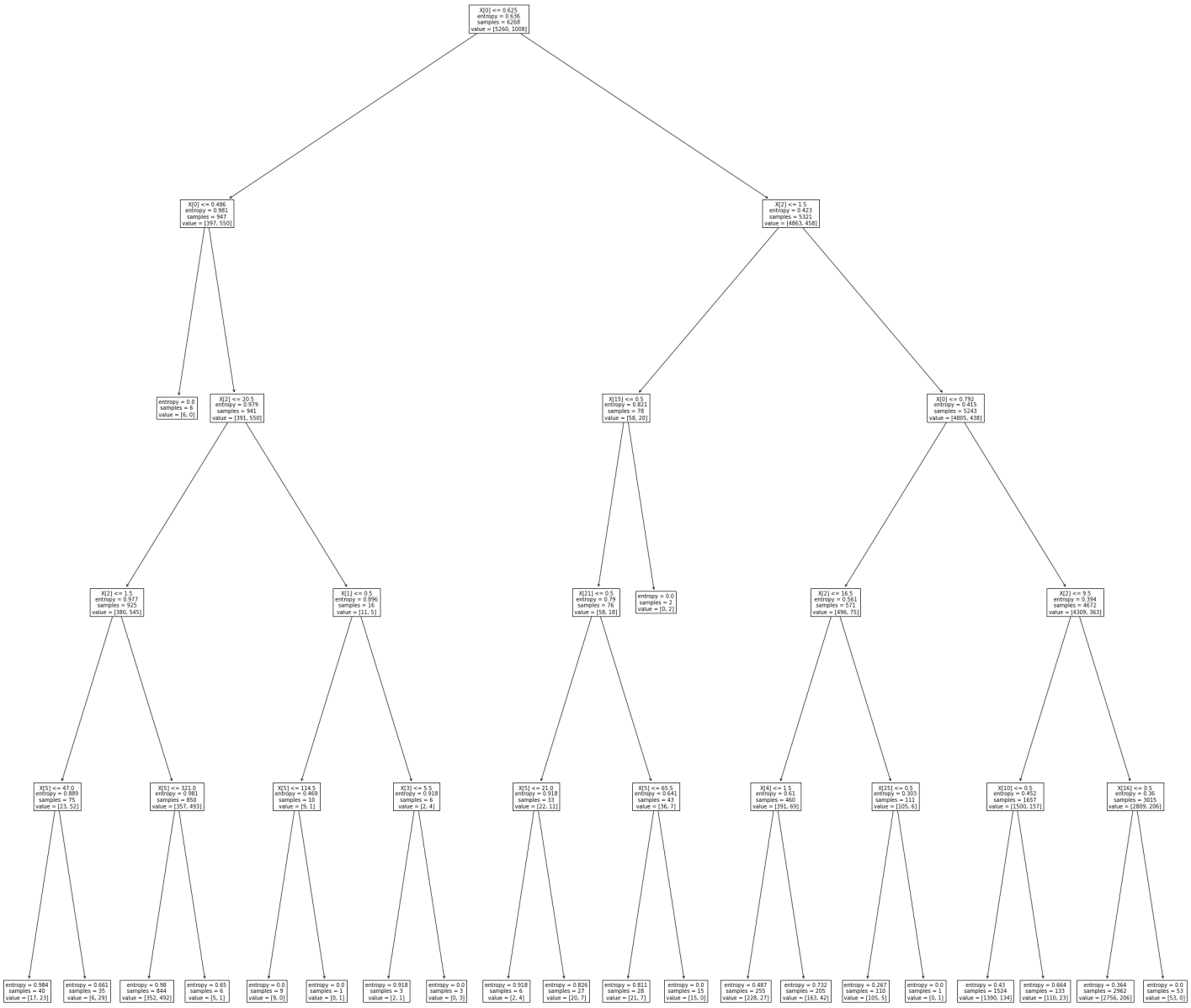
9. Decision Tree

1. **Build a decision tree model using sklearns DecisionTreeClassifier. Use the unbalanced training set, entropy as the criterion. Try with different max_depth (or use grid search). After building model, test it and print the confusion matrix and classification report. Also, plot ROC curve and show the AUC of ROC, and the count of the number of misclassification. Show the decision tree. (you can simply import tree from sklearn and call tree.plot_tree with your model and the call plt.show. At the beginning of this process, use plt.figure to change the figsize)**
2. **Perform the same tasks as 9.1 with the balanced training set**
3. **Discuss any difference and also discuss part of the tree of 9.2**

In [74]:

```
#Decision tree model with DecisionTreeClassifier
from sklearn.tree import DecisionTreeClassifier

tree_clf = DecisionTreeClassifier(max_depth=5, min_samples_leaf=1, criterion="entropy")
tree_clf.fit(X_train, y_train)
plt.figure(figsize = (40,40))
tree.plot_tree(tree_clf)
plt.show()
```



In [75]:

```
y_pred= tree_clf.predict(X_test)
```

```
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
[[2045  167]
 [ 228  247]]
              precision    recall  f1-score   support

         0.0       0.90      0.92      0.91      2212
         1.0       0.60      0.52      0.56       475

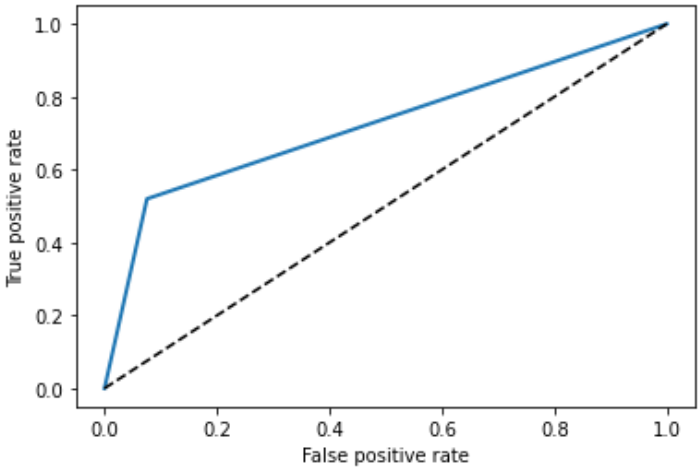
    accuracy                           0.85      2687
   macro avg       0.75      0.72      0.73      2687
weighted avg       0.85      0.85      0.85      2687
```

In [76]:

```
y_pred = tree_clf.predict(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [77]:

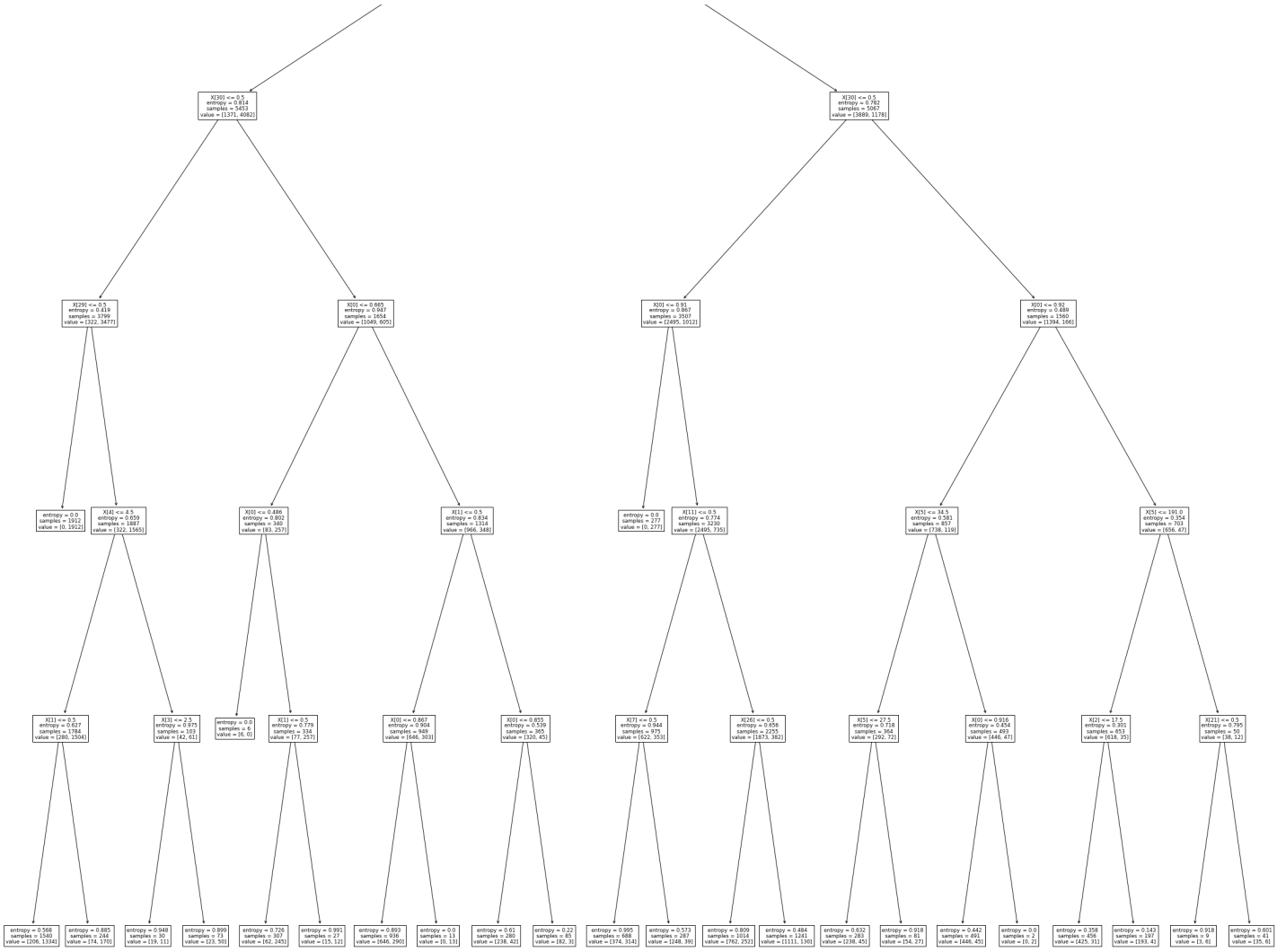
```
roc_auc_score(y_test, y_pred)
y_new=np.ravel(y_test)
p = (y_new)!= (y_pred)
print(p.sum())
```

```
395
```

In [78]:

```
#Now with balanced dataset

tree_clf = DecisionTreeClassifier(max_depth=5, min_samples_leaf=1, criterion='entropy')
tree_clf.fit(X_scaled, y_scaled)
plt.figure(figsize = (40,40))
tree.plot_tree(tree_clf)
plt.show()
```



In [79]:

```
y_pred= tree_clf.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
[[2054  158]
 [ 236  239]]
              precision    recall  f1-score   support

         0.0       0.90      0.93      0.91      2212
         1.0       0.60      0.50      0.55       475

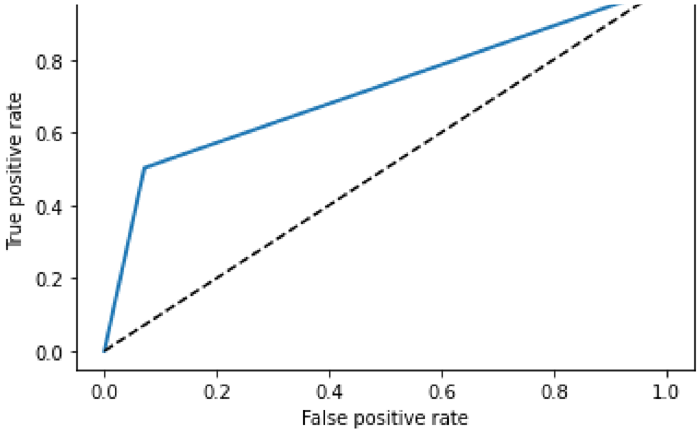
    accuracy                           0.85      2687
   macro avg       0.75      0.72      0.73      2687
weighted avg       0.84      0.85      0.85      2687
```

In [80]:

```
y_pred = tree_clf.predict(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [81]:

```
roc_auc_score(y_test, y_pred)
```

Out[81]:

```
0.7158646616541354
```

In [82]:

```
y_new=np.ravel(y_test)
p = (y_new)!= (y_pred)
print(p.sum())
```

```
394
```

Discuss any difference and also discuss part of the tree of 9.2

AUC is different between trees used. Also the balanced dataset seems to make the tree look more even.

10. Random Forest

In [92]:

```
# Grid Search with RandomForestClassifier
from sklearn.ensemble import RandomForestClassifier

rf = RandomForestClassifier(random_state=42, n_jobs=-1)
param = {
    'max_depth': [2, 3, 5, 10, 20],
    'min_samples_leaf': [5, 10, 20, 50, 100, 200],
    'n_estimators': [10, 25, 30, 50, 100, 200]
}

gridSearch = GridSearchCV(estimator=rf, param_grid=param)
gridSearch.fit(X_scaled, y_scaled)
gridSearch.best_estimator_
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_validation.py:680: DataCo
nversionWarning: A column-vector y was passed when a 1d array was expected. Please change
the shape of y to (n_samples,), for example using ravel().
  estimator.fit(X_train, y_train, **fit_params)
/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_validation.py:680: DataCo
nversionWarning: A column-vector y was passed when a 1d array was expected. Please change
the shape of y to (n_samples,), for example using ravel().
  estimator.fit(X_train, y_train, **fit_params)
/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_validation.py:680: DataCo
nversionWarning: A column-vector y was passed when a 1d array was expected. Please change
the shape of y to (n_samples,), for example using ravel().
  estimator.fit(X_train, y_train, **fit_params)
/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_validation.py:680: DataCo
nversionWarning: A column-vector y was passed when a 1d array was expected. Please change
```

```
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/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_validation.py:680: DataCo
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```
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  estimator.fit(X_train, y_train, **fit_params)
/usr/local/lib/python3.7/dist-packages/sklearn/model_selection/_search.py:926: DataConver
sionWarning: A column-vector y was passed when a 1d array was expected. Please change the
shape of y to (n_samples,), for example using ravel().
  self.best_estimator_.fit(X, y, **fit_params)
```

Out[92]:

```
RandomForestClassifier(max_depth=20, min_samples_leaf=10, n_jobs=-1,
                       random_state=42)
```

In [98]:

```
rf = RandomForestClassifier(random_state=42, max_depth=20, min_samples_leaf=5, n_estimat
ors=100, n_jobs=-1)
```

```
rf.fit(X_scaled, y_scaled)
y_pred= rf.predict(X_test)
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:2: DataConversionWarning: A
column-vector y was passed when a 1d array was expected. Please change the shape of y to
(n_samples,), for example using ravel().
```

In [97]:

```
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
[[2055  157]
 [ 235  240]]
              precision    recall  f1-score   support

         0.0       0.90      0.93      0.91      2212
         1.0       0.60      0.51      0.55       475

    accuracy                           0.85      2687
   macro avg       0.75      0.72      0.73      2687
weighted avg       0.85      0.85      0.85      2687
```

In [100]:

```
roc_auc_score(y_test, y_pred)
```

Out[100]:

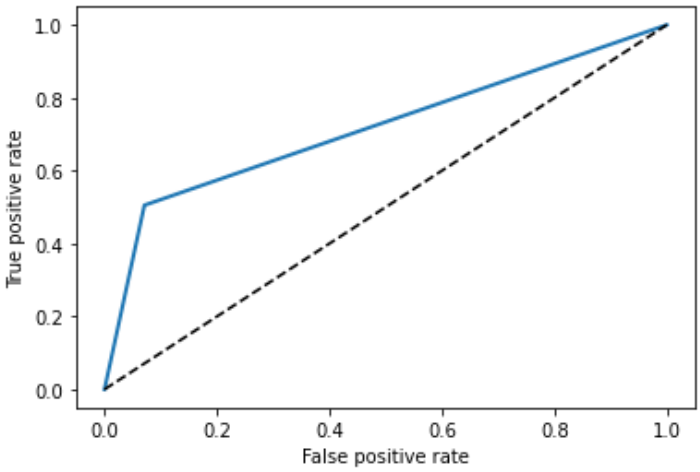
```
0.7171433330160845
```

In [102]:

```
y_pred = rf.predict(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



11. Boosting Algorithms

In [104]:

```
#Train an AdaBoostClassifier model with some manual/grid search-based parameters and then
test it and then print the confusion matrix and classification report.
#Also, plot ROC curve and show the AUC of ROC, and the count of the number of misclassifi
```

```
cation.
from sklearn.ensemble import AdaBoostClassifier

ada = AdaBoostClassifier(random_state=42)
param = {
    'learning_rate': [.01, 0.2, 0.5, 0.7, 0.9, 1.0, 1.5],
    'n_estimators': [10, 25, 30, 50, 100, 200]
}

gSearch = GridSearchCV(estimator=ada, param_grid=param, cv=3, n_jobs=-1, verbose=1, scor
ing='accuracy')
gSearch.fit(X_scaled, y_scaled)
grid_search.best_estimator_
```

```
Fitting 3 folds for each of 42 candidates, totalling 126 fits
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:993: DataConversionWar
ning: A column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

Out[104]:

```
KNeighborsClassifier(metric='manhattan', n_neighbors=7, weights='distance')
```

In [108]:

```
ada = AdaBoostClassifier(random_state=42, learning_rate=0.5, n_estimators=200)
ada.fit(X_scaled, y_scaled)
y_pred= ada.predict(X_test)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/utils/validation.py:993: DataConversionWar
ning: A column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

```
[[2053  159]
 [ 228  247]]
              precision    recall  f1-score   support

         0.0       0.90      0.93      0.91      2212
         1.0       0.61      0.52      0.56       475

    accuracy                           0.86      2687
   macro avg       0.75      0.72      0.74      2687
weighted avg       0.85      0.86      0.85      2687
```

In [110]:

```
roc_auc_score(y_test, y_pred)
```

Out[110]:

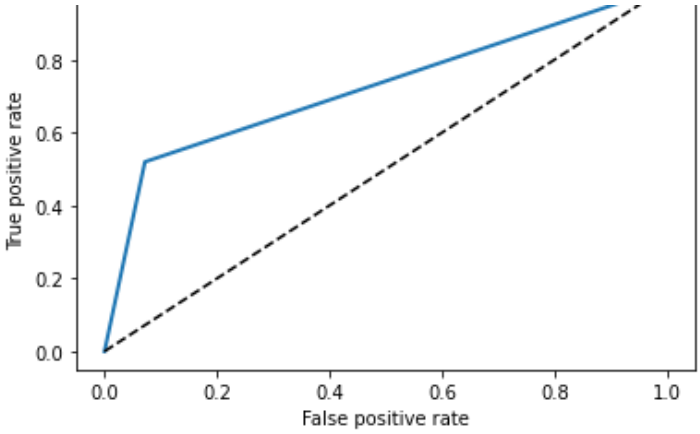
```
0.7240596745027125
```

In [111]:

```
y_pred = ada.predict(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [113]:

```
y_new = np.ravel(y_test)
p = (y_new) != (y_pred)
print(p.sum())
```

```
387
```

In [116]:

```
#Gradient BoostingClassifier
from sklearn.ensemble import GradientBoostingClassifier

grad = GradientBoostingClassifier(random_state=42)
param = {
    'learning_rate': [0.01, 0.025, 0.05, 0.075, 0.1, 0.15, 0.2],
    'n_estimators' : [10, 25, 30, 50, 100, 200],
    'max_depth'    : [3, 5, 7]
}

gSearch = GridSearchCV(estimator = grad, cv = 3, param_grid = param, n_jobs=-1, scoring=
'accuracy')
gSearch.fit(X_scaled, y_scaled)
gSearch.best_estimator_
```

```
/usr/local/lib/python3.7/dist-packages/sklearn/ensemble/_gb.py:494: DataConversionWarning
: A column-vector y was passed when a 1d array was expected. Please change the shape of y
to (n_samples, ), for example using ravel().
  y = column_or_1d(y, warn=True)
```

Out[116]:

```
GradientBoostingClassifier(learning_rate=0.075, max_depth=7, random_state=42)
```

In [117]:

```
roc_auc_score(y_test, y_pred)
```

Out[117]:

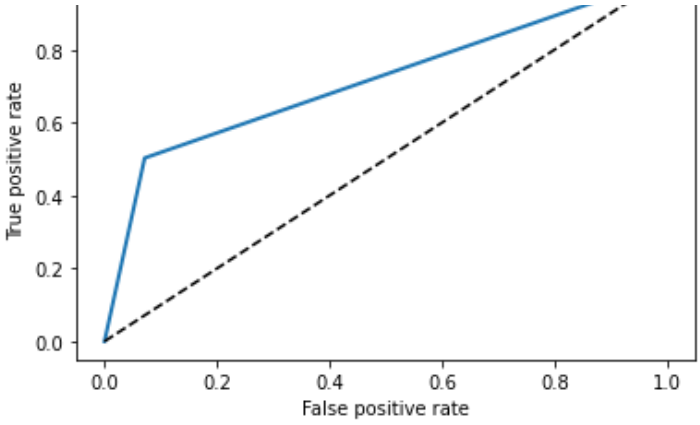
```
0.7240596745027125
```

In [118]:

```
y_pred = tree_clf.predict(X_test)
fpr, tpr, thresholds = roc_curve(y_test, y_pred)

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)
plt.xlabel("False positive rate")
plt.ylabel("True positive rate")
plt.show()
```



In [119]:

```
y_new = np.ravel(y_test)
p = (y_new) != (y_pred)
print(p.sum())
```

394

12. Final Discussion

Finally, briefly discuss your finding such as which model could be most suitable for this given scenario and what could be your future work based on this experiment.

A Decision Tree could be pretty useful in both visualizing and determining a set of variables which could lead to scenarios where an employee might look for a new job.