Logistic_regression

March 8, 2020

[52]:
```
from IPython.display import Image
from sklearn.externals.six import StringIO
from sklearn.tree import export_graphviz
import pydotplus
import imblearn
import lightgbm
import hyperopt
```

[30]:
```
import pandas as pd
import numpy as np
import matplotlib
import matplotlib.pyplot as plt
import seaborn as sns
import statsmodels.api as sm
%matplotlib inline
import plusmodules as pm
import warnings
warnings.filterwarnings('ignore')
```

[31]:
```
df=pd.read_csv('telco_chrun_encoded (1).csv')
df.head()
```

[31]:

	gender	senior	partner	dependents	tenure	phone_service	multiple_lines	\
0	1	0	1	0	1	0	0	
1	0	0	0	0	34	1	0	
2	0	0	0	0	2	1	0	
3	0	0	0	0	45	0	0	
4	1	0	0	0	2	1	0	

	online_security	online_backup	device_protection	…	total_charges	\
0	0	1	0	…	29.85	
1	1	0	1	…	1889.50	
2	1	1	0	…	108.15	
3	1	0	1	…	1840.75	
4	0	0	0	…	151.65	

	churn	avg_monthly_charges	internet_service-fiber_optic	\

```
0       0            29.850000                           0
1       0            55.573529                           0
2       1            54.075000                           0
3       0            40.905556                           0
4       1            75.825000                           1

   internet_service-no  contract-one_year  contract-two_year  \
0                    0                  0                  0
1                    0                  1                  0
2                    0                  0                  0
3                    0                  1                  0
4                    0                  0                  0

   payment_method-credit_card_auto  payment_method-electronic_check  \
0                                0                                1
1                                0                                0
2                                0                                0
3                                0                                0
4                                0                                1

   payment_method-mailed_check
0                            0
1                            1
2                            1
3                            0
4                            0

[5 rows x 25 columns]
```

[32]:
```
df.shape
```

[32]:
```
(7032, 25)
```

[33]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 7032 entries, 0 to 7031
Data columns (total 25 columns):
 #   Column                           Non-Null Count  Dtype
---  ------                           --------------  -----
 0   gender                           7032 non-null   int64
 1   senior                           7032 non-null   int64
 2   partner                          7032 non-null   int64
 3   dependents                       7032 non-null   int64
 4   tenure                           7032 non-null   int64
 5   phone_service                    7032 non-null   int64
 6   multiple_lines                   7032 non-null   int64
```

```
 7   online_security                  7032 non-null   int64
 8   online_backup                    7032 non-null   int64
 9   device_protection                7032 non-null   int64
 10  tech_support                     7032 non-null   int64
 11  streaming_tv                     7032 non-null   int64
 12  streaming_movies                 7032 non-null   int64
 13  paperless_billing                7032 non-null   int64
 14  monthly_charges                  7032 non-null   float64
 15  total_charges                    7032 non-null   float64
 16  churn                            7032 non-null   int64
 17  avg_monthly_charges              7032 non-null   float64
 18  internet_service-fiber_optic     7032 non-null   int64
 19  internet_service-no              7032 non-null   int64
 20  contract-one_year                7032 non-null   int64
 21  contract-two_year                7032 non-null   int64
 22  payment_method-credit_card_auto  7032 non-null   int64
 23  payment_method-electronic_check  7032 non-null   int64
 24  payment_method-mailed_check      7032 non-null   int64
dtypes: float64(3), int64(22)
memory usage: 1.3 MB
```

[6]:
```
df=df.sample(frac=0.25, random_state=3)
```

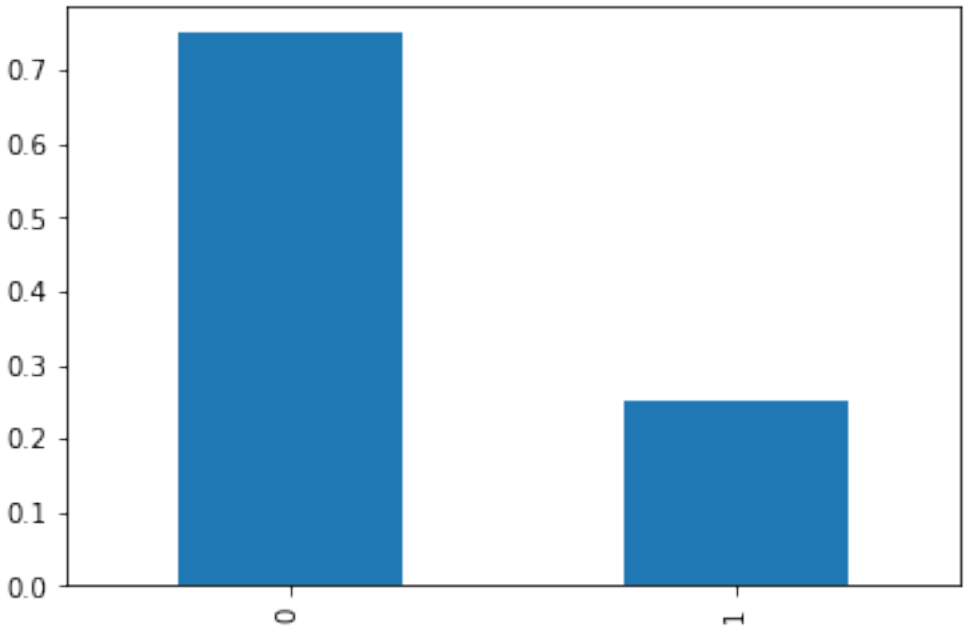
[7]:
```
y=df['churn']
x=df.drop('churn', axis=1)
```

[8]:
```
df['churn'].value_counts()
```

[8]:
```
0    1318
1     440
Name: churn, dtype: int64
```

[9]:
```
df['churn'].value_counts(normalize=True).plot.bar()
```

[9]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x29d66b51c18>
```



#Building the predictive algorith using Random forest

[10]:
```
from sklearn.model_selection import train_test_split

x_train, x_test, y_train, y_test =train_test_split(x, y, test_size=0.30,␣
 ↪random_state=3)
```

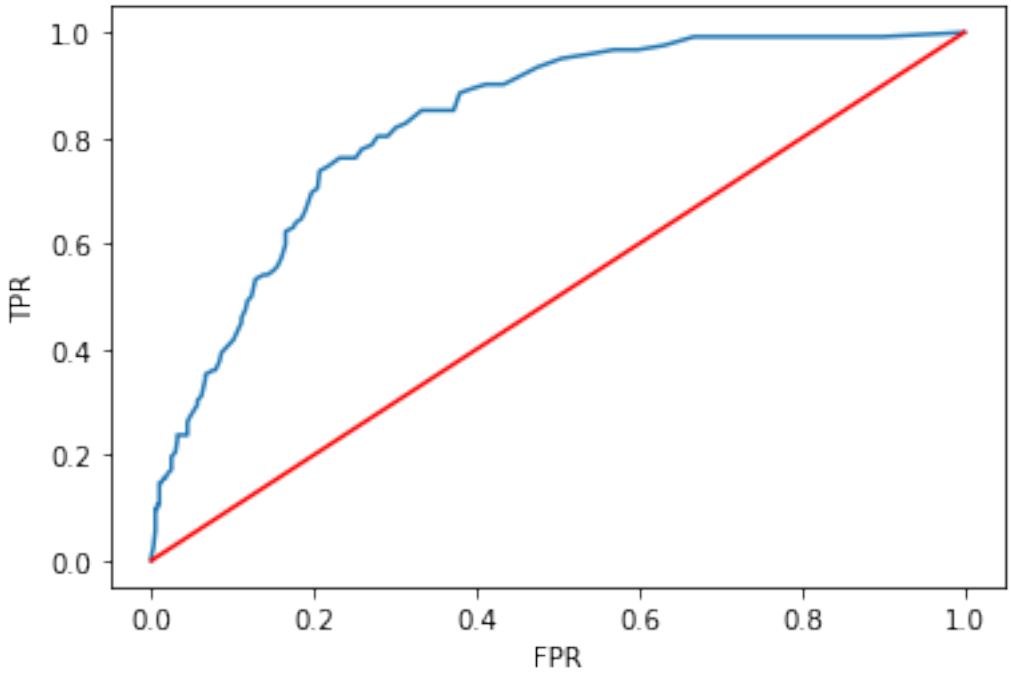
[11]:
```
from sklearn.preprocessing import StandardScaler

ss= StandardScaler()
xs=ss.fit_transform(x)

x_trains =ss.fit_transform(x_train)
x_tests =ss.transform(x_test)
```

[12]:
```
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import confusion_matrix, roc_auc_score, accuracy_score,␣
 ↪roc_curve

rfc=RandomForestClassifier(n_estimators=100)

rfc.fit(x_trains, y_train)

y_train_pred=rfc.predict(x_trains)

y_train_prob=rfc.predict_proba(x_trains)[:,1]
```

```
print('Confusion Matrix - Train: ', '\n' ,confusion_matrix(y_train,␣
↪y_train_pred))

print('Overall Accuracy - Train: ', accuracy_score(y_train, y_train_pred))

print('AUC- Train:' , roc_auc_score(y_train, y_train_prob))



y_test_pred= rfc.predict(x_tests)

y_test_prob=rfc.predict_proba(x_tests)[:,1]

print('Confusion Matrix - Test: ', '\n' ,confusion_matrix(y_test, y_test_pred))

print('Overall Accuracy - Test: ', accuracy_score(y_test, y_test_pred))

print('AUC- Test:' , roc_auc_score(y_test, y_test_prob))

fpr, tpr, thresholds =roc_curve(y_test, y_test_prob)
plt.plot(fpr, tpr)
plt.plot(fpr, fpr, 'red')
plt.xlabel('FPR')
plt.ylabel('TPR')
```

```
Confusion Matrix - Train:
 [[912   0]
 [  0 318]]
Overall Accuracy - Train:  1.0
AUC- Train: 1.0
Confusion Matrix - Test:
 [[364  42]
 [ 70  52]]
Overall Accuracy - Test:  0.7878787878787878
AUC- Test: 0.8298372769118953
```

[12]: Text(0, 0.5, 'TPR')



#Hyper parameter tuning for Random forest

[13]:
```
from sklearn.model_selection import RandomizedSearchCV

from scipy.stats import randint as sp_randint

rfc=RandomForestClassifier(random_state=3)

params={'n_estimators': sp_randint(50, 200),
       'max_features': sp_randint(1, 24),
       'max_depth': sp_randint(2,10),
       'min_samples_split': sp_randint(2, 20),
       'min_samples_leaf': sp_randint(1, 20),
       'criterion': ['gini', 'entropy'] }


rsearch_rfc = RandomizedSearchCV(rfc, param_distributions= params, n_iter=50,␣
↪cv=3, scoring='roc_auc',
                  random_state=3, return_train_score=True)

rsearch_rfc.fit(xs, y)
```

[13]:
```
RandomizedSearchCV(cv=3, error_score=nan,
                   estimator=RandomForestClassifier(bootstrap=True,
                                                    ccp_alpha=0.0,
```

```
                                                    class_weight=None,
                                                    criterion='gini',
                                                    max_depth=None,
                                                    max_features='auto',
                                                    max_leaf_nodes=None,
                                                    max_samples=None,
                                                    min_impurity_decrease=0.0,
                                                    min_impurity_split=None,
                                                    min_samples_leaf=1,
                                                    min_samples_split=2,
      min_weight_fraction_leaf=0.0,
                                                    n_estimators=100,
                                                    n_jobs…
                                           'min_samples_leaf':
      <scipy.stats._distn_infrastructure.rv_frozen object at 0x0000029D674FFDD8>,
                                           'min_samples_split':
      <scipy.stats._distn_infrastructure.rv_frozen object at 0x0000029D674FFA90>,
                                           'n_estimators':
      <scipy.stats._distn_infrastructure.rv_frozen object at 0x0000029D674FF5C0>},
                         pre_dispatch='2*n_jobs', random_state=3, refit=True,
                         return_train_score=True, scoring='roc_auc', verbose=0)
```

[14]:
```
rsearch_rfc.best_params_
```

[14]:
```
{'criterion': 'entropy',
 'max_depth': 8,
 'max_features': 2,
 'min_samples_leaf': 16,
 'min_samples_split': 5,
 'n_estimators': 120}
```

[15]:
```
pd.DataFrame(rsearch_rfc.cv_results_).head(2)
```

[15]:

	mean_fit_time	std_fit_time	mean_score_time	std_score_time	\
0	0.175137	0.023511	0.012330	0.001515	
1	0.815924	0.052228	0.046503	0.007779	

	param_criterion	param_max_depth	param_max_features	param_min_samples_leaf	\
0	gini	2	4	9	
1	entropy	5	11	12	

	param_min_samples_split	param_n_estimators	…	split1_test_score	\
0	2	71	…	0.830451	
1	11	188	…	0.820061	

	split2_test_score	mean_test_score	std_test_score	rank_test_score	\
0	0.848930	0.841708	0.008065	10	

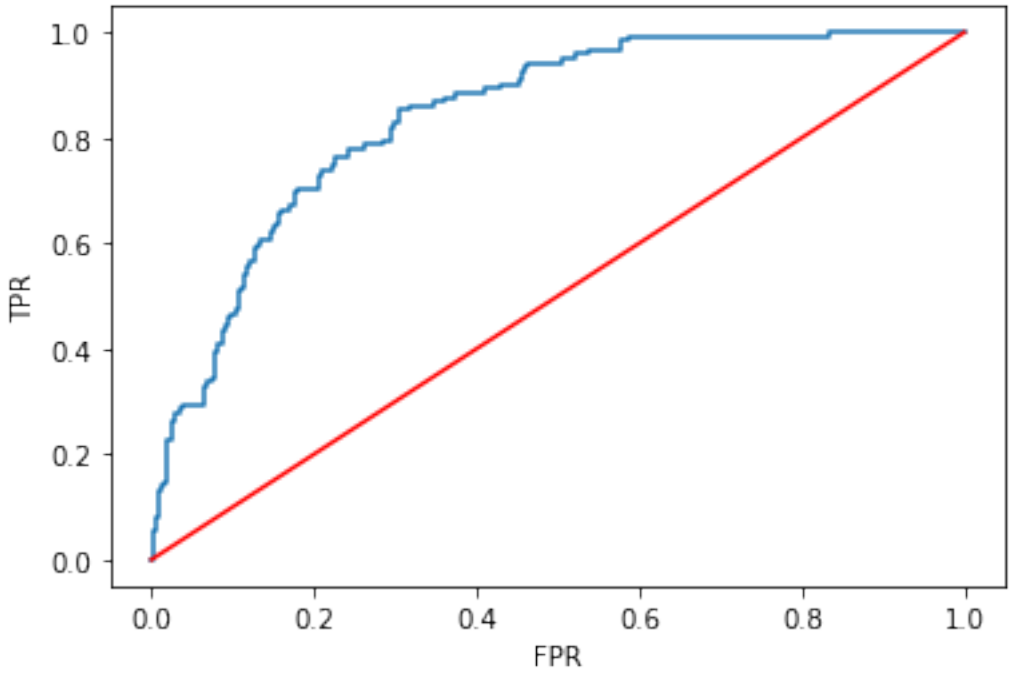
```
1           0.855198         0.841571        0.015390                11

   split0_train_score  split1_train_score  split2_train_score  \
0            0.852283            0.860699            0.848861
1            0.888735            0.896357            0.883738

   mean_train_score  std_train_score
0          0.853948         0.004974
1          0.889610         0.005189

[2 rows x 22 columns]
```

[16]:
```
# model using best params
rfc=RandomForestClassifier(**rsearch_rfc.best_params_, random_state=3)

rfc.fit(x_trains, y_train)

y_train_pred=rfc.predict(x_trains)

y_train_prob=rfc.predict_proba(x_trains)[:,1]

print('Confusion Matrix - Train: ', '\n' ,confusion_matrix(y_train,␣
 ↪y_train_pred))

print('Overall Accuracy - Train: ', accuracy_score(y_train, y_train_pred))

print('AUC- Train:' , roc_auc_score(y_train, y_train_prob))



y_test_pred= rfc.predict(x_tests)

y_test_prob=rfc.predict_proba(x_tests)[:,1]

print('Confusion Matrix - Test: ', '\n' ,confusion_matrix(y_test, y_test_pred))

print('Overall Accuracy - Test: ', accuracy_score(y_test, y_test_pred))

print('AUC- Test:' , roc_auc_score(y_test, y_test_prob))

fpr, tpr, thresholds =roc_curve(y_test, y_test_prob)
plt.plot(fpr, tpr)
plt.plot(fpr, fpr, 'red')
plt.xlabel('FPR')
plt.ylabel('TPR')
```

```
Confusion Matrix - Train:
```

```
 [[887  25]
 [193 125]]
Overall Accuracy - Train:  0.8227642276422764
AUC- Train: 0.8874510371841554
Confusion Matrix - Test:
 [[383  23]
 [ 86  36]]
Overall Accuracy - Test:  0.7935606060606061
AUC- Test: 0.8407494145199063
```

[16]:
```
Text(0, 0.5, 'TPR')
```



[17]:
```
imp = pd.DataFrame(rfc.feature_importances_, index = x.columns, columns=['imp'])

imp = imp.sort_values(by = 'imp', ascending = False)

imp

# the results says the percentage of dropping based on the features, we can use␣
 ↪this as feature selection if we remove
#the features which are having the value of 0 we can simply remove those this␣
 ↪says that the features are not having any
#impact on data
```

[17]:

	imp
tenure	0.155242
total_charges	0.119885
contract-two_year	0.092182
monthly_charges	0.085751
avg_monthly_charges	0.083130
internet_service-fiber_optic	0.077960
payment_method-electronic_check	0.076173
online_security	0.040575
internet_service-no	0.040186
contract-one_year	0.035663
dependents	0.031578
paperless_billing	0.023652
online_backup	0.023328
payment_method-credit_card_auto	0.019833
tech_support	0.019323
partner	0.014272
streaming_movies	0.010863
gender	0.008537
device_protection	0.008298
streaming_tv	0.008101
senior	0.007751
multiple_lines	0.007676
payment_method-mailed_check	0.007300
phone_service	0.002743

[18]:
```
from sklearn.neighbors import KNeighborsClassifier

from sklearn.model_selection import RandomizedSearchCV

from scipy.stats import randint as sp_randint

knn = KNeighborsClassifier()

params= {'n_neighbors': sp_randint(1,20),
        'p': sp_randint(1,5)}

rsearch_knn=RandomizedSearchCV(knn, param_distributions = params, cv=3,␣
 ↪random_state=3, n_iter=50)

rsearch_knn.fit(xs, y)
```

[18]:
```
RandomizedSearchCV(cv=3, error_score=nan,
                   estimator=KNeighborsClassifier(algorithm='auto',
                                                  leaf_size=30,
                                                  metric='minkowski',
                                                  metric_params=None,
```

```
                                                   n_jobs=None, n_neighbors=5,
                                                   p=2, weights='uniform'),
                   iid='deprecated', n_iter=50, n_jobs=None,
                   param_distributions={'n_neighbors':
<scipy.stats._distn_infrastructure.rv_frozen object at 0x0000029D685FE1D0>,
                                        'p':
<scipy.stats._distn_infrastructure.rv_frozen object at 0x0000029D685FE198>},
                   pre_dispatch='2*n_jobs', random_state=3, refit=True,
                   return_train_score=False, scoring=None, verbose=0)
```

[19]:
```
rsearch_knn.best_params_
```

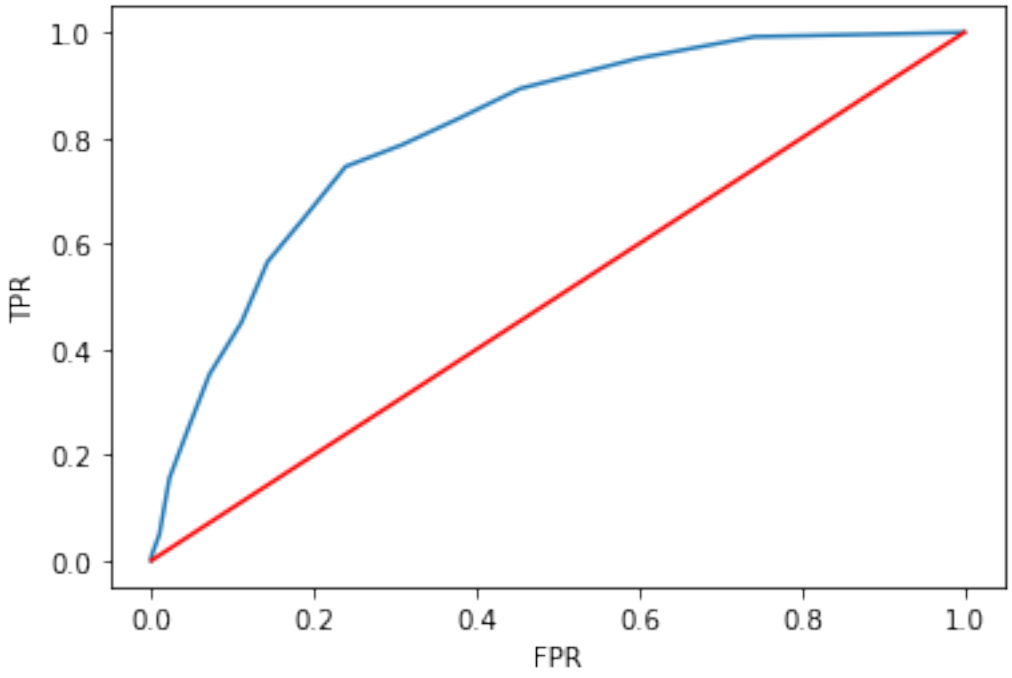
[19]:
```
{'n_neighbors': 15, 'p': 1}
```

[20]:
```
knn = KNeighborsClassifier(** rsearch_knn.best_params_)
from sklearn.metrics import confusion_matrix, roc_auc_score, accuracy_score,␣
 ↪roc_curve, classification_report

knn.fit(x_trains, y_train)

y_train_pred=knn.predict(x_trains)

y_train_prob=knn.predict_proba(x_trains)[:,1]

print('Confusion Matrix - Train: ', '\n' ,confusion_matrix(y_train,␣
 ↪y_train_pred))

print('Overall Accuracy - Train: ', accuracy_score(y_train, y_train_pred))

print('Classification Report - Test', classification_report(y_test,␣
 ↪y_test_pred))

print('AUC- Train:' , roc_auc_score(y_train, y_train_prob))



y_test_pred= knn.predict(x_tests)

y_test_prob=knn.predict_proba(x_tests)[:,1]

print('Confusion Matrix - Test: ', '\n' ,confusion_matrix(y_test, y_test_pred))

print('Overall Accuracy - Test: ', accuracy_score(y_test, y_test_pred))

print('AUC- Test:' , roc_auc_score(y_test, y_test_prob))

fpr, tpr, thresholds =roc_curve(y_test, y_test_prob)
```

```
plt.plot(fpr, tpr)
plt.plot(fpr, fpr, 'red')
plt.xlabel('FPR')
plt.ylabel('TPR')
```

```
Confusion Matrix - Train:
 [[804 108]
 [113 205]]
Overall Accuracy - Train:  0.8203252032520325
Classification Report - Test                precision    recall  f1-score
support

           0       0.82      0.94      0.88       406
           1       0.61      0.30      0.40       122

    accuracy                           0.79       528
   macro avg       0.71      0.62      0.64       528
weighted avg       0.77      0.79      0.77       528

AUC- Train: 0.8661487642061128
Confusion Matrix - Test:
 [[348  58]
 [ 53  69]]
Overall Accuracy - Test:  0.7897727272727273
AUC- Test: 0.8143018654607121
```

[20]: Text(0, 0.5, 'TPR')



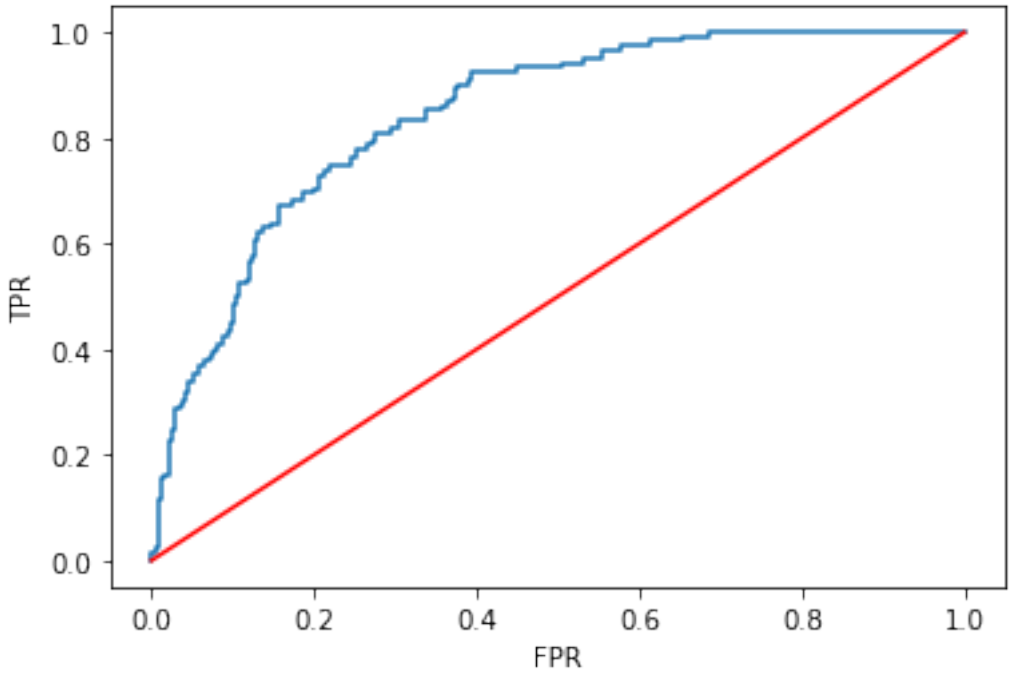
1 stacking results of 3 learners (random forest, knn, logistic regression)

[21]:
```
from sklearn.linear_model import LogisticRegression
lr= LogisticRegression(solver= 'liblinear')


lr.fit(x_trains, y_train)

y_train_pred=lr.predict(x_trains)

y_train_prob=lr.predict_proba(x_trains)[:,1]

print('Confusion Matrix - Train: ', '\n' ,confusion_matrix(y_train,␣
 ↪y_train_pred))

print('Overall Accuracy - Train: ', accuracy_score(y_train, y_train_pred))

print('Classification Report - Test', classification_report(y_test,␣
 ↪y_test_pred))

print('AUC- Train:' , roc_auc_score(y_train, y_train_prob))



y_test_pred= lr.predict(x_tests)

y_test_prob=.predict_proba(x_tests)[:,1]

print('Confusion Matrix - Test: ', '\n' ,confusion_matrix(y_test, y_test_pred))

print('Overall Accuracy - Test: ', accuracy_score(y_test, y_test_pred))

print('AUC- Test:' , roc_auc_score(y_test, y_test_prob))

fpr, tpr, thresholds =roc_curve(y_test, y_test_prob)
plt.plot(fpr, tpr)
plt.plot(fpr, fpr, 'red')
plt.xlabel('FPR')
plt.ylabel('TPR')
```

```
Confusion Matrix - Train:
 [[826  86]
```

```
 [146 172]]
Overall Accuracy - Train:  0.8113821138211382
Classification Report - Test               precision    recall  f1-score
support

           0       0.87      0.86      0.86       406
           1       0.54      0.57      0.55       122

    accuracy                           0.79       528
   macro avg       0.71      0.71      0.71       528
weighted avg       0.79      0.79      0.79       528

AUC- Train: 0.8558320920225091
Confusion Matrix - Test:
 [[359  47]
 [ 57  65]]
Overall Accuracy - Test:  0.803030303030303
AUC- Test: 0.843111523863361
```

[21]:
```
Text(0, 0.5, 'TPR')
```



[22]:
```
from sklearn.ensemble import VotingClassifier

lr = LogisticRegression(solver='liblinear')
knn = KNeighborsClassifier(**rsearch_knn.best_params_)
```

```
rfc = RandomForestClassifier(**rsearch_rfc.best_params_)
```

2 HARD VOTING

[24]:
```
clf = VotingClassifier(estimators=[('lr', lr), ('knn', knn), ('rfc', rfc)],␣
 ↪voting='hard')

clf.fit(x_trains, y_train)

y_train_pred = clf.predict(x_trains)
y_test_pred = clf.predict(x_tests)

print('Accuracy score - Train', accuracy_score(y_train, y_train_pred))
print('Accuracy score - Test', accuracy_score(y_test, y_test_pred))
```

```
Accuracy score - Train 0.8195121951219512
Accuracy score - Test 0.8011363636363636
```

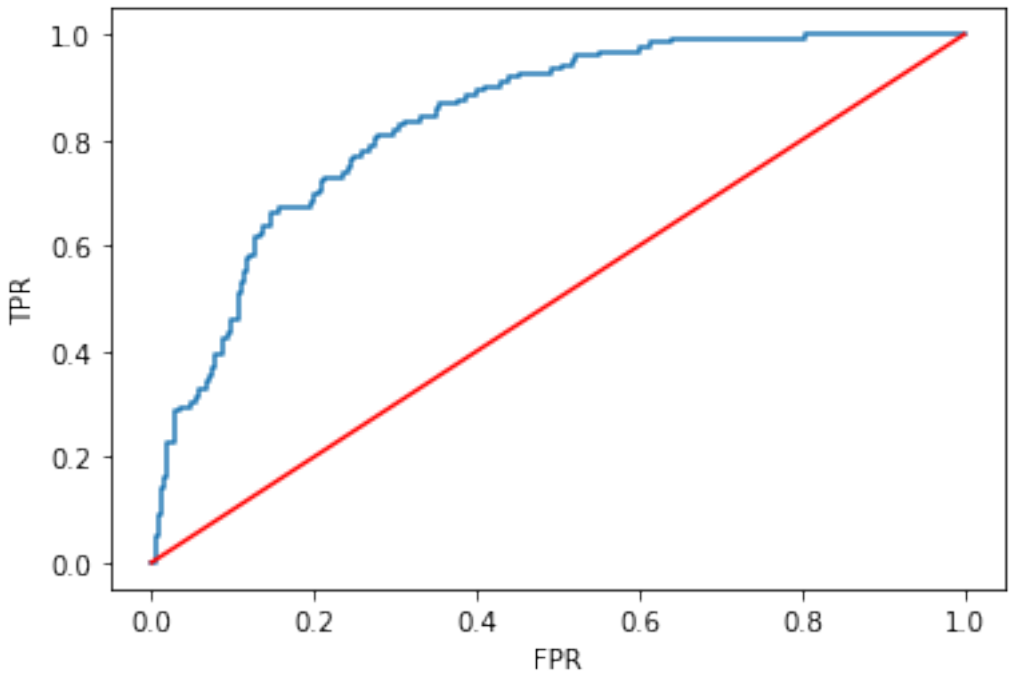
3 SOFT VOTING - Equal weightages

[25]:
```
clf = VotingClassifier(estimators=[('lr', lr), ('knn', knn), ('rfc', rfc)],␣
 ↪voting='soft')

clf.fit(x_trains, y_train)

y_train_pred=clf.predict(x_trains)

y_train_prob=clf.predict_proba(x_trains)[:,1]

print('Confusion Matrix - Train: ', '\n' ,confusion_matrix(y_train,␣
 ↪y_train_pred))

print('Overall Accuracy - Train: ', accuracy_score(y_train, y_train_pred))

print('Classification Report - Test', classification_report(y_test,␣
 ↪y_test_pred))

print('AUC- Train:' , roc_auc_score(y_train, y_train_prob))



y_test_pred= clf.predict(x_tests)

y_test_prob=clf.predict_proba(x_tests)[:,1]
```

```
print('Confusion Matrix - Test: ', '\n' ,confusion_matrix(y_test, y_test_pred))

print('Overall Accuracy - Test: ', accuracy_score(y_test, y_test_pred))

print('AUC- Test:' , roc_auc_score(y_test, y_test_prob))

fpr, tpr, thresholds =roc_curve(y_test, y_test_prob)
plt.plot(fpr, tpr)
plt.plot(fpr, fpr, 'red')
plt.xlabel('FPR')
plt.ylabel('TPR')
```

```
Confusion Matrix - Train:
 [[837  75]
 [147 171]]
Overall Accuracy - Train:  0.8195121951219512
Classification Report - Test               precision    recall  f1-score
support

           0       0.85      0.90      0.87       406
           1       0.59      0.47      0.52       122

    accuracy                           0.80       528
   macro avg       0.72      0.68      0.70       528
weighted avg       0.79      0.80      0.79       528

AUC- Train: 0.8763516495641621
Confusion Matrix - Test:
 [[365  41]
 [ 66  56]]
Overall Accuracy - Test:  0.7973484848484849
AUC- Test: 0.8382459823952193
```

[25]: Text(0, 0.5, 'TPR')

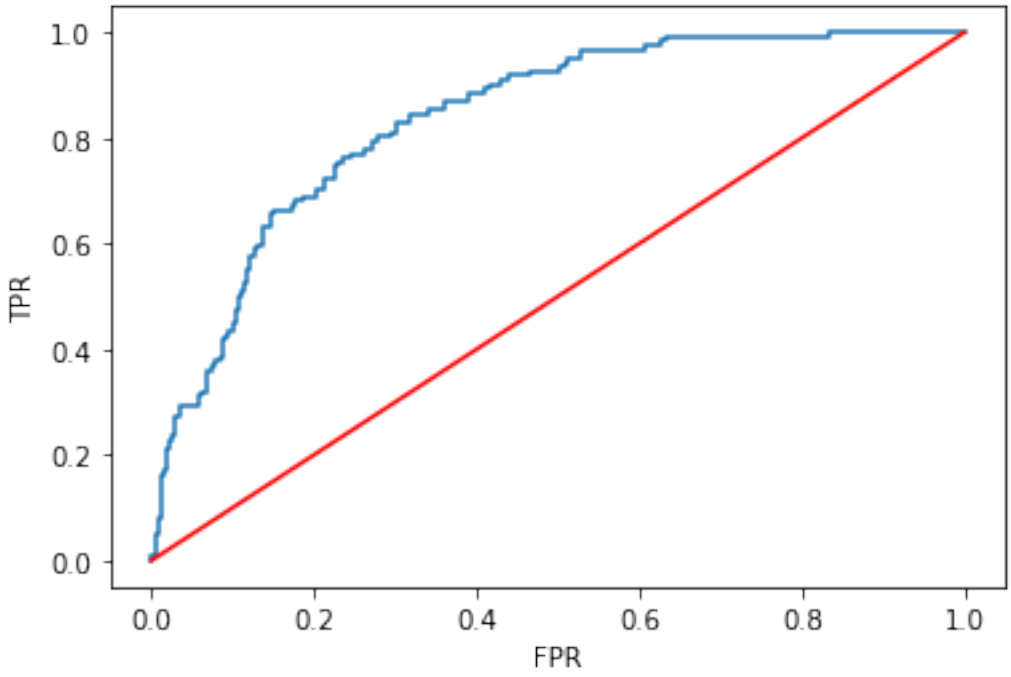


[26]:
```
clf = VotingClassifier(estimators=[('lr', lr), ('knn', knn), ('rfc', rfc)],␣
↪weights=[1,2,3] ,voting='soft')

clf.fit(x_trains, y_train)

y_train_pred=clf.predict(x_trains)

y_train_prob=clf.predict_proba(x_trains)[:,1]

print('Confusion Matrix - Train: ', '\n' ,confusion_matrix(y_train,␣
↪y_train_pred))

print('Overall Accuracy - Train: ', accuracy_score(y_train, y_train_pred))

print('Classification Report - Test', classification_report(y_test,␣
↪y_test_pred))

print('AUC- Train:' , roc_auc_score(y_train, y_train_prob))



y_test_pred= clf.predict(x_tests)

y_test_prob=clf.predict_proba(x_tests)[:,1]
```

```
print('Confusion Matrix - Test: ', '\n' ,confusion_matrix(y_test, y_test_pred))

print('Overall Accuracy - Test: ', accuracy_score(y_test, y_test_pred))

print('AUC- Test:' , roc_auc_score(y_test, y_test_prob))

fpr, tpr, thresholds =roc_curve(y_test, y_test_prob)
plt.plot(fpr, tpr)
plt.plot(fpr, fpr, 'red')
plt.xlabel('FPR')
plt.ylabel('TPR')
```

```
Confusion Matrix - Train:
 [[849  63]
 [153 165]]
Overall Accuracy - Train:  0.824390243902439
Classification Report - Test               precision    recall  f1-score
support

           0       0.85      0.90      0.87       406
           1       0.58      0.46      0.51       122

    accuracy                           0.80       528
   macro avg       0.71      0.68      0.69       528
weighted avg       0.78      0.80      0.79       528

AUC- Train: 0.8806307238221339
Confusion Matrix - Test:
 [[365  41]
 [ 69  53]]
Overall Accuracy - Test:  0.7916666666666666
AUC- Test: 0.8369538883953807
```

[26]: Text(0, 0.5, 'TPR')


1.0
0.8
0.6
0.4
0.2
0.0
TPR
0.0
0.2
0.4
0.6
0.8
1.0
FPR