Credit_Card

August 5, 2021

1 Dataset and XGBoost Dowload

[1]:
```
! pip install kaggle
```

```
Requirement already satisfied: kaggle in /usr/local/lib/python3.7/dist-packages
(1.5.12)
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.7/dist-
packages (from kaggle) (2.8.1)
Requirement already satisfied: requests in /usr/local/lib/python3.7/dist-
packages (from kaggle) (2.23.0)
Requirement already satisfied: six>=1.10 in /usr/local/lib/python3.7/dist-
packages (from kaggle) (1.15.0)
Requirement already satisfied: tqdm in /usr/local/lib/python3.7/dist-packages
(from kaggle) (4.41.1)
Requirement already satisfied: urllib3 in /usr/local/lib/python3.7/dist-packages
(from kaggle) (1.24.3)
Requirement already satisfied: certifi in /usr/local/lib/python3.7/dist-packages
(from kaggle) (2021.5.30)
Requirement already satisfied: python-slugify in /usr/local/lib/python3.7/dist-
packages (from kaggle) (5.0.2)
Requirement already satisfied: text-unidecode>=1.3 in /usr/local/lib/python3.7
/dist-packages (from python-slugify->kaggle) (1.3)
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.7
/dist-packages (from requests->kaggle) (3.0.4)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dist-
packages (from requests->kaggle) (2.10)
```

[2]:
```
! mkdir ~/.kaggle
```

[3]:
```
! cp kaggle.json ~/.kaggle/
```

[6]:
```
! chmod 600 ~/.kaggle/kaggle.json
```

[7]:
```
! kaggle datasets download -d mlg-ulb/creditcardfraud
```

```
Downloading creditcardfraud.zip to /content
 71% 47.0M/66.0M [00:00<00:00, 101MB/s]
100% 66.0M/66.0M [00:00<00:00, 147MB/s]
```

[8]:
```
! unzip -q creditcardfraud.zip
```

[9]:
```
! git clone --recursive https://github.com/dmlc/xgboost
! cd xgboost
! make -j4
```

```
Cloning into 'xgboost'...
remote: Enumerating objects: 46920, done.
remote: Counting objects: 100% (363/363), done.
remote: Compressing objects: 100% (279/279), done.
remote: Total 46920 (delta 140), reused 207 (delta 74), pack-reused 46557
Receiving objects: 100% (46920/46920), 20.98 MiB | 20.72 MiB/s, done.
Resolving deltas: 100% (28615/28615), done.
Submodule 'cub' (https://github.com/NVlabs/cub) registered for path 'cub'
Submodule 'dmlc-core' (https://github.com/dmlc/dmlc-core) registered for path
'dmlc-core'
Submodule 'gputreeshap' (https://github.com/rapidsai/gputreeshap.git) registered
for path 'gputreeshap'
Cloning into '/content/xgboost/cub'...
remote: Enumerating objects: 34384, done.
remote: Counting objects: 100% (653/653), done.
remote: Compressing objects: 100% (302/302), done.
remote: Total 34384 (delta 409), reused 506 (delta 349), pack-reused 33731
Receiving objects: 100% (34384/34384), 17.51 MiB | 24.83 MiB/s, done.
Resolving deltas: 100% (29778/29778), done.
Cloning into '/content/xgboost/dmlc-core'...
remote: Enumerating objects: 6193, done.
remote: Counting objects: 100% (57/57), done.
remote: Compressing objects: 100% (42/42), done.
remote: Total 6193 (delta 16), reused 27 (delta 5), pack-reused 6136
Receiving objects: 100% (6193/6193), 1.62 MiB | 19.47 MiB/s, done.
Resolving deltas: 100% (3762/3762), done.
Cloning into '/content/xgboost/gputreeshap'...
remote: Enumerating objects: 223, done.
remote: Counting objects: 100% (104/104), done.
remote: Compressing objects: 100% (62/62), done.
remote: Total 223 (delta 42), reused 67 (delta 20), pack-reused 119
Receiving objects: 100% (223/223), 100.78 KiB | 14.40 MiB/s, done.
Resolving deltas: 100% (90/90), done.
Submodule path 'cub': checked out 'af39ee264f4627608072bf54730bf3a862e56875'
Submodule path 'dmlc-core': checked out
'f00e3ec7abc9f293a1b7061157b0a4e22a735cf5'
Submodule path 'gputreeshap': checked out
'5bba198a7c2b3298dc766740965a4dffa7d8ffa4'
make: *** No targets specified and no makefile found.  Stop.
```

[13]:
```
! make -j4 --directory=xgboost
```

```
make: Entering directory '/content/xgboost'
Makefile:23: MAKE [make] - checked OK
g++ -c -DDMLC_LOG_CUSTOMIZE=1 -std=c++14 -Wall -Wno-unknown-pragmas -Iinclude
-Idmlc-core/include -Irabit/include -I/include -O3 -funroll-loops amalgamation
/xgboost-all0.cc -o amalgamation/xgboost-all0.o
make: Leaving directory '/content/xgboost'
```

[ ]:
```
! python ./xgboost/python-package/setup.py install
```

[24]:
```
! pip install conda
! conda install libgcc
```

```
Collecting conda
  Downloading conda-4.3.16.tar.gz (299 kB)
     || 299 kB 29.7 MB/s
Collecting pycosat>=0.6.1
  Downloading pycosat-0.6.3.zip (66 kB)
     || 66 kB 5.0 MB/s
Requirement already satisfied: requests>=2.12.4 in
/usr/local/lib/python3.7/dist-packages (from conda) (2.23.0)
Collecting ruamel.yaml>=0.11.14
  Downloading ruamel.yaml-0.17.10-py3-none-any.whl (108 kB)
     || 108 kB 58.5 MB/s
Requirement already satisfied: chardet<4,>=3.0.2 in
/usr/local/lib/python3.7/dist-packages (from requests>=2.12.4->conda) (3.0.4)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dist-
packages (from requests>=2.12.4->conda) (2.10)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.7
/dist-packages (from requests>=2.12.4->conda) (2021.5.30)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in
/usr/local/lib/python3.7/dist-packages (from requests>=2.12.4->conda) (1.24.3)
Collecting ruamel.yaml.clib>=0.1.2
  Downloading ruamel.yaml.clib-0.2.6-cp37-cp37m-manylinux1_x86_64.whl (546 kB)
     || 546 kB 49.1 MB/s
Building wheels for collected packages: conda, pycosat
  Building wheel for conda (setup.py) ... done
  Created wheel for conda: filename=conda-4.3.16-py3-none-any.whl size=336960
sha256=0fbba7ede94b670238c72150e6fc2e9a0a07e346483b837c49e8833b0dfdc9e0
  Stored in directory: /root/.cache/pip/wheels/66/ec/2c/cce33d7a071720882d948fd3
364d3ff5562bac9e5638768d41
  Building wheel for pycosat (setup.py) ... done
  Created wheel for pycosat: filename=pycosat-0.6.3-cp37-cp37m-linux_x86_64.whl
size=143861
sha256=69d03dc883e4bea196b368728021f92d11e87ea8ade24d307733779e6d26963d
  Stored in directory: /root/.cache/pip/wheels/c8/29/0e/a226b7c5a4f24e246f25201c
0b1fbf6fb8f19f9cce89b02c36
Successfully built conda pycosat
Installing collected packages: ruamel.yaml.clib, ruamel.yaml, pycosat, conda
```

```
Successfully installed conda-4.3.16 pycosat-0.6.3 ruamel.yaml-0.17.10
ruamel.yaml.clib-0.2.6
ERROR: The install method you used for conda--probably either `pip install
conda`
or `easy_install conda`--is not compatible with using conda as an application.
If your intention is to install conda as a standalone application, currently
supported install methods include the Anaconda installer and the miniconda
installer.  You can download the miniconda installer from
https://conda.io/miniconda.html.
```

[25]:
```
import xgboost as xgb
```

[26]:
```
! pip install lightgbm
```

```
Requirement already satisfied: lightgbm in /usr/local/lib/python3.7/dist-
packages (2.2.3)
Requirement already satisfied: scipy in /usr/local/lib/python3.7/dist-packages
(from lightgbm) (1.4.1)
Requirement already satisfied: numpy in /usr/local/lib/python3.7/dist-packages
(from lightgbm) (1.19.5)
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.7/dist-
packages (from lightgbm) (0.22.2.post1)
Requirement already satisfied: joblib>=0.11 in /usr/local/lib/python3.7/dist-
packages (from scikit-learn->lightgbm) (1.0.1)
```

[27]:
```
! pip install fastcluster hdbscan tslearn
```

```
Collecting fastcluster
  Downloading fastcluster-1.2.3-cp37-cp37m-
manylinux_2_5_x86_64.manylinux1_x86_64.whl (155 kB)
     || 155 kB 36.4 MB/s
Collecting hdbscan
  Downloading hdbscan-0.8.27.tar.gz (6.4 MB)
     || 6.4 MB 37.9 MB/s
  Installing build dependencies ... done
  Getting requirements to build wheel ... done
    Preparing wheel metadata ... done
Collecting tslearn
  Downloading tslearn-0.5.1.0-cp37-cp37m-manylinux_2_5_x86_64.manylinux1_x86_64.
manylinux_2_12_x86_64.manylinux2010_x86_64.whl (793 kB)
     || 793 kB 31.2 MB/s
Requirement already satisfied: numpy>=1.9 in /usr/local/lib/python3.7
/dist-packages (from fastcluster) (1.19.5)
Requirement already satisfied: six in /usr/local/lib/python3.7/dist-packages
(from hdbscan) (1.15.0)
Requirement already satisfied: cython>=0.27 in /usr/local/lib/python3.7/dist-
```

```
packages (from hdbscan) (0.29.23)
Requirement already satisfied: joblib>=1.0 in /usr/local/lib/python3.7/dist-
packages (from hdbscan) (1.0.1)
Requirement already satisfied: scipy>=1.0 in /usr/local/lib/python3.7/dist-
packages (from hdbscan) (1.4.1)
Requirement already satisfied: scikit-learn>=0.20 in /usr/local/lib/python3.7
/dist-packages (from hdbscan) (0.22.2.post1)
Requirement already satisfied: numba in /usr/local/lib/python3.7/dist-packages
(from tslearn) (0.51.2)
Requirement already satisfied: setuptools in /usr/local/lib/python3.7/dist-
packages (from numba->tslearn) (57.2.0)
Requirement already satisfied: llvmlite<0.35,>=0.34.0.dev0 in
/usr/local/lib/python3.7/dist-packages (from numba->tslearn) (0.34.0)
Building wheels for collected packages: hdbscan
  Building wheel for hdbscan (PEP 517) ... done
  Created wheel for hdbscan: filename=hdbscan-0.8.27-cp37-cp37m-linux_x86_64.whl
size=2311886
sha256=c9d26a46f51587b95dbdfd3d9520d707de4127ac0cb02de3434b693b5a008bbc
  Stored in directory: /root/.cache/pip/wheels/73/5f/2f/9a259b84003b84847c259779
206acecabb25ab56f1506ee72b
Successfully built hdbscan
Installing collected packages: tslearn, hdbscan, fastcluster
Successfully installed fastcluster-1.2.3 hdbscan-0.8.27 tslearn-0.5.1.0
```

2 Credit Card Fraud Detection

[28]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import matplotlib.pyplot as plt
color = sns.color_palette()
```

[37]:
```
%matplotlib inline
'''Data Prep'''
from sklearn import preprocessing as pp
from scipy.stats import pearsonr
from sklearn.model_selection import train_test_split
from sklearn.model_selection import StratifiedKFold
from sklearn.metrics import log_loss
from sklearn.metrics import precision_recall_curve, average_precision_score
from sklearn.metrics import roc_curve, auc, roc_auc_score
from sklearn.metrics import confusion_matrix, classification_report
'''Algos'''
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
import xgboost as xgb
```

```
import lightgbm as lgb
import os
```

[40]:
```
curr_path = os.getcwd()
file = '/creditcard.csv'
data = pd.read_csv(curr_path + file)
```

[41]:
```
data.head(15)
```

[41]:

	Time	V1	V2	V3	...	V27	V28	Amount	Class
0	0.0	-1.359807	-0.072781	2.536347	...	0.133558	-0.021053	149.62	0
1	0.0	1.191857	0.266151	0.166480	...	-0.008983	0.014724	2.69	0
2	1.0	-1.358354	-1.340163	1.773209	...	-0.055353	-0.059752	378.66	0
3	1.0	-0.966272	-0.185226	1.792993	...	0.062723	0.061458	123.50	0
4	2.0	-1.158233	0.877737	1.548718	...	0.219422	0.215153	69.99	0
5	2.0	-0.425966	0.960523	1.141109	...	0.253844	0.081080	3.67	0
6	4.0	1.229658	0.141004	0.045371	...	0.034507	0.005168	4.99	0
7	7.0	-0.644269	1.417964	1.074380	...	-1.206921	-1.085339	40.80	0
8	7.0	-0.894286	0.286157	-0.113192	...	0.011747	0.142404	93.20	0
9	9.0	-0.338262	1.119593	1.044367	...	0.246219	0.083076	3.68	0
10	10.0	1.449044	-1.176339	0.913860	...	0.042850	0.016253	7.80	0
11	10.0	0.384978	0.616109	-0.874300	...	0.042472	-0.054337	9.99	0
12	10.0	1.249999	-1.221637	0.383930	...	0.026416	0.042422	121.50	0
13	11.0	1.069374	0.287722	0.828613	...	0.021491	0.021293	27.50	0
14	12.0	-2.791855	-0.327771	1.641750	...	-0.164778	-0.030154	58.80	0

[15 rows x 31 columns]

[42]:
```
data.describe()
```

[42]:

	Time	V1	...	Amount	Class
count	284807.000000	2.848070e+05	...	284807.000000	284807.000000
mean	94813.859575	3.919560e-15	...	88.349619	0.001727
std	47488.145955	1.958696e+00	...	250.120109	0.041527
min	0.000000	-5.640751e+01	...	0.000000	0.000000
25%	54201.500000	-9.203734e-01	...	5.600000	0.000000
50%	84692.000000	1.810880e-02	...	22.000000	0.000000
75%	139320.500000	1.315642e+00	...	77.165000	0.000000
max	172792.000000	2.454930e+00	...	25691.160000	1.000000

[8 rows x 31 columns]

[43]:
```
data.columns
```

[43]:
```
Index(['Time', 'V1', 'V2', 'V3', 'V4', 'V5', 'V6', 'V7', 'V8', 'V9', 'V10',
       'V11', 'V12', 'V13', 'V14', 'V15', 'V16', 'V17', 'V18', 'V19', 'V20',
       'V21', 'V22', 'V23', 'V24', 'V25', 'V26', 'V27', 'V28', 'Amount',
       'Class'],
      dtype='object')
```

[44]:
```
data["Class"].sum()
```

[44]:
```
492
```

[46]:
```
nanCounter = np.isnan(data).sum()
nanCounter
```

[46]:
```
Time      0
V1        0
V2        0
V3        0
V4        0
V5        0
V6        0
V7        0
V8        0
V9        0
V10       0
V11       0
V12       0
V13       0
V14       0
V15       0
V16       0
V17       0
V18       0
V19       0
V20       0
V21       0
V22       0
V23       0
V24       0
V25       0
V26       0
V27       0
V28       0
Amount    0
Class     0
dtype: int64
```

[48]:
```
distinctCounter = data.apply(lambda x: len(x.unique()))
distinctCounter
```

[48]:
```
Time      124592
V1        275663
V2        275663
V3        275663
V4        275663
V5        275663
V6        275663
V7        275663
```

```
V8        275663
V9        275663
V10       275663
V11       275663
V12       275663
V13       275663
V14       275663
V15       275663
V16       275663
V17       275663
V18       275663
V19       275663
V20       275663
V21       275663
V22       275663
V23       275663
V24       275663
V25       275663
V26       275663
V27       275663
V28       275663
Amount     32767
Class          2
dtype: int64
```

[49]:
```
dataX = data.copy().drop(["Class"], axis=1)
dataY = data["Class"].copy()
```

[50]:
```
featuresToScale = dataX.drop(["Time"], axis=1).columns
sX = pp.StandardScaler(copy=True)
dataX.loc[:,featuresToScale] = sX.fit_transform(dataX[featuresToScale])
```

[51]:
```
dataX.describe()
```

[51]:

	Time	V1	...	V28	Amount
count	284807.000000	2.848070e+05	...	2.848070e+05	2.848070e+05
mean	94813.859575	-8.157366e-16	...	5.401572e-17	3.202236e-16
std	47488.145955	1.000002e+00	...	1.000002e+00	1.000002e+00
min	0.000000	-2.879855e+01	...	-4.674612e+01	-3.532294e-01
25%	54201.500000	-4.698918e-01	...	-1.604440e-01	-3.308401e-01
50%	84692.000000	9.245351e-03	...	3.406368e-02	-2.652715e-01
75%	139320.500000	6.716939e-01	...	2.371526e-01	-4.471707e-02
max	172792.000000	1.253351e+00	...	1.025434e+02	1.023622e+02

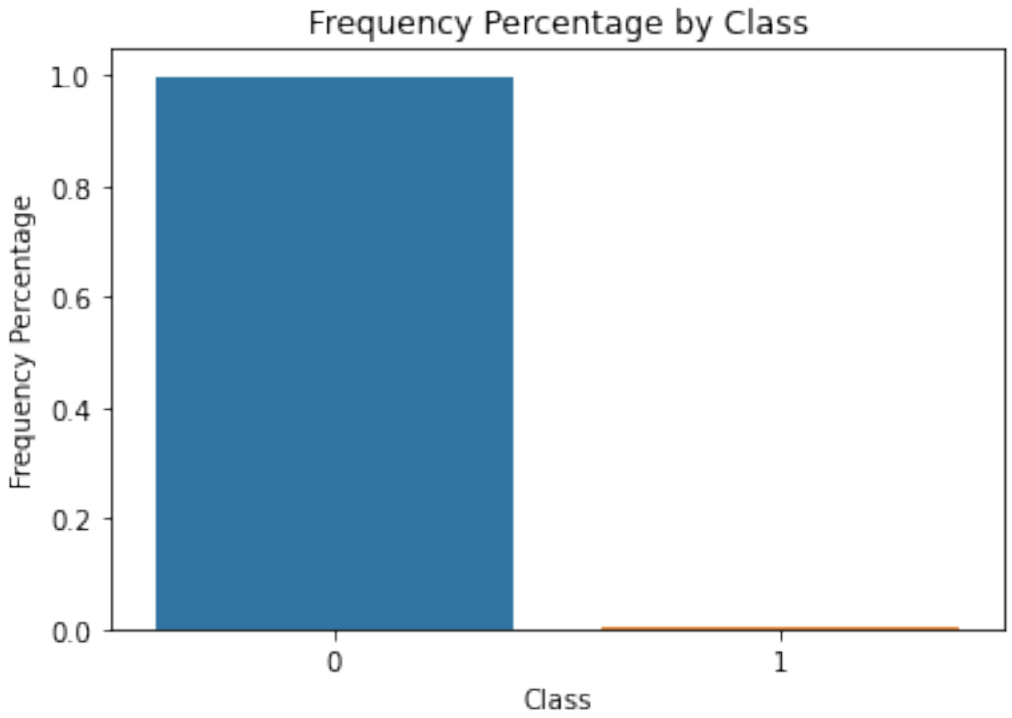
[8 rows x 30 columns]

[52]:
```
correlationMatrix = pd.DataFrame(data=[],index=dataX.columns,
columns=dataX.columns)
for i in dataX.columns:
```

```
  for j in dataX.columns:
    correlationMatrix.loc[i,j] = np.round(pearsonr(dataX.loc[:,i],
     dataX.loc[:,j])[0],2)
```

[55]:
```
count_classes = pd.value_counts(data['Class'],sort=True).sort_index()
ax = sns.barplot(x=count_classes.index, y=np.array(tuple(count_classes/
 ↪len(data))))
ax.set_title('Frequency Percentage by Class')
ax.set_xlabel('Class')
ax.set_ylabel('Frequency Percentage')
```

[55]:
```
Text(0, 0.5, 'Frequency Percentage')
```



[56]:
```
X_train, X_test, y_train, y_test = train_test_split(dataX,
dataY, test_size=0.33,
random_state=2018, stratify=dataY)
```

[57]:
```
k_fold = StratifiedKFold(n_splits=5, shuffle=True, random_state=2018)
```

2.1 Logistic Regression

[67]:
```
penalty = 'l2'
C = 1.0
class_weight = 'balanced'
random_state = 2018
```

```
solver = 'liblinear'
logReg = LogisticRegression(penalty=penalty, C=C,
class_weight=class_weight, random_state=random_state,
solver=solver)
```

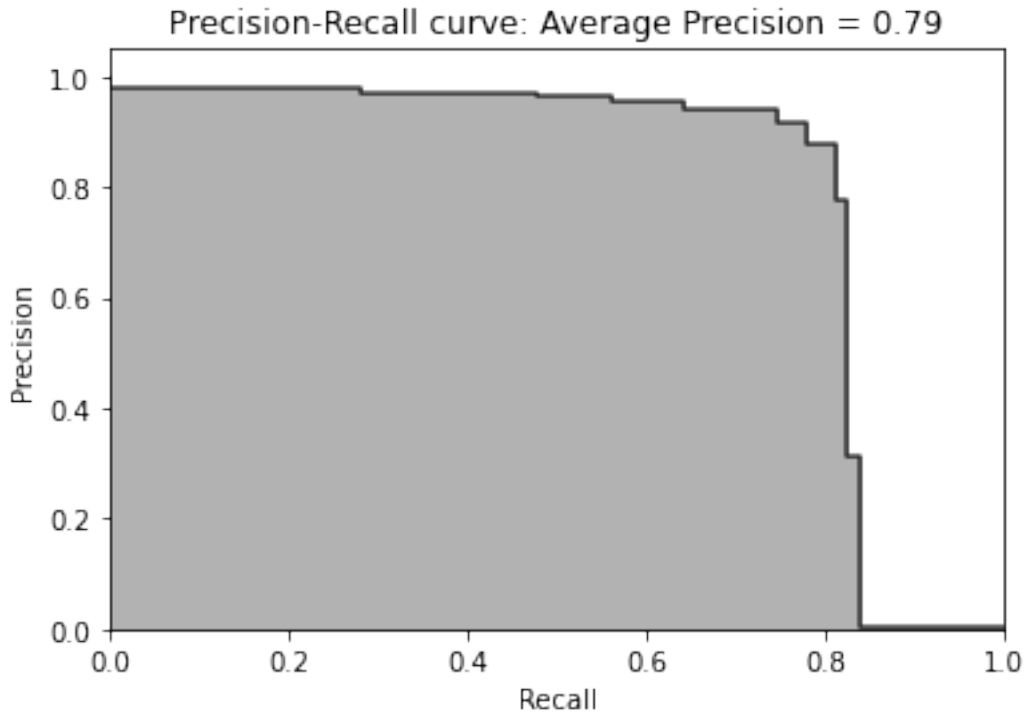
[68]:
```
trainingScores = []
cvScores = []
predictionsBasedOnKFolds = pd.DataFrame(data=[],index=y_train.index,␣
 ↪columns=[0,1])
model = logReg
for train_index, cv_index in k_fold.split(np.zeros(len(X_train)), y_train.
 ↪ravel()):
  X_train_fold, X_cv_fold = X_train.iloc[train_index,:], X_train.iloc[cv_index,:
 ↪]
  y_train_fold, y_cv_fold = y_train.iloc[train_index], y_train.iloc[cv_index]

  model.fit(X_train_fold, y_train_fold)
  logLossTraining = log_loss(y_train_fold, model.predict_proba(X_train_fold)[:
 ↪,1])
  trainingScores.append(logLossTraining)
  predictionsBasedOnKFolds.loc[X_cv_fold.index, :] = model.
 ↪predict_proba(X_cv_fold)
  logLossCv = log_loss(y_cv_fold,
                       predictionsBasedOnKFolds.loc[X_cv_fold.index, 1])
  cvScores.append(logLossCv)
  print('Training Log Loss: ', logLossTraining)
  print('CV Log Loss: ', logLossCv)
loglossLogisticRegression = log_loss(y_train,
  predictionsBasedOnKFolds.loc[:,1])
print('Logistic Regression Log Loss: ', loglossLogisticRegression)
```

```
Training Log Loss:  0.10966450675373615
CV Log Loss:  0.10878937377819534
Training Log Loss:  0.10456253075352834
CV Log Loss:  0.10403949182025926
Training Log Loss:  0.1153865429073515
CV Log Loss:  0.11764573298351307
Training Log Loss:  0.11558015904920611
CV Log Loss:  0.11816691615677673
Training Log Loss:  0.09709819816667246
CV Log Loss:  0.09697807129012978
Logistic Regression Log Loss:  0.10912391720577486
```

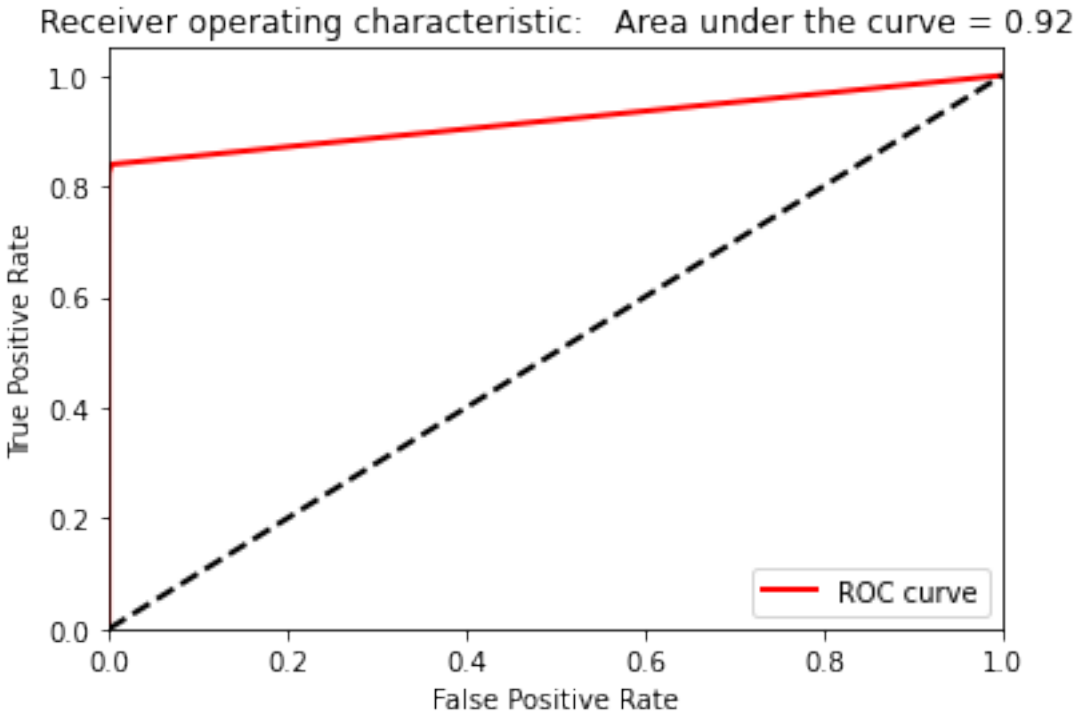
[82]:
```
def getPreds(y_train, predictionsBasedOnKFolds):
  preds = pd.concat([y_train, predictionsBasedOnKFolds.loc[:,1]], axis=1)
  preds.columns = ["trueLabel", 'prediction']
  return preds
```

```
preds = getPreds(y_train, predictionsBasedOnKFolds)
predictionsBasedOnKFoldsLogistic = preds.copy()
def prCurve(preds):
  precision, recall, thresholds = precision_recall_curve(preds['trueLabel'],
                                                          preds['prediction'])
  average_precision = average_precision_score(preds['trueLabel'],
                                              preds['prediction'])
  plt.step(recall, precision, color="k",alpha=0.7, where='post')
  plt.fill_between(recall, precision,step="post", alpha=0.3, color="k")
  plt.xlabel('Recall')
  plt.ylabel('Precision')
  plt.ylim([0.0, 1.05])
  plt.xlim([0.0, 1.0])
  plt.title('Precision-Recall curve: Average Precision = {0:0.2f}'.format(
  average_precision))
prCurve(preds)
```



[83]:
```
def rocCurve(preds):
  fpr, tpr, thresholds = roc_curve(preds['trueLabel'],preds['prediction'])
  areaUnderROC = auc(fpr, tpr)
  plt.figure()
  plt.plot(fpr, tpr, color='r', lw=2, label='ROC curve')
  plt.plot([0, 1], [0, 1], color='k', lw=2, linestyle='--')
```

```
  plt.xlim([0.0, 1.0])
  plt.ylim([0.0, 1.05])
  plt.xlabel('False Positive Rate')
  plt.ylabel('True Positive Rate')
  plt.title('Receiver operating characteristic: \
  Area under the curve = {0:0.2f}'.format(areaUnderROC))
  plt.legend(loc="lower right")
  plt.show()
rocCurve(preds)
```



2.2 Random Forest Classifier

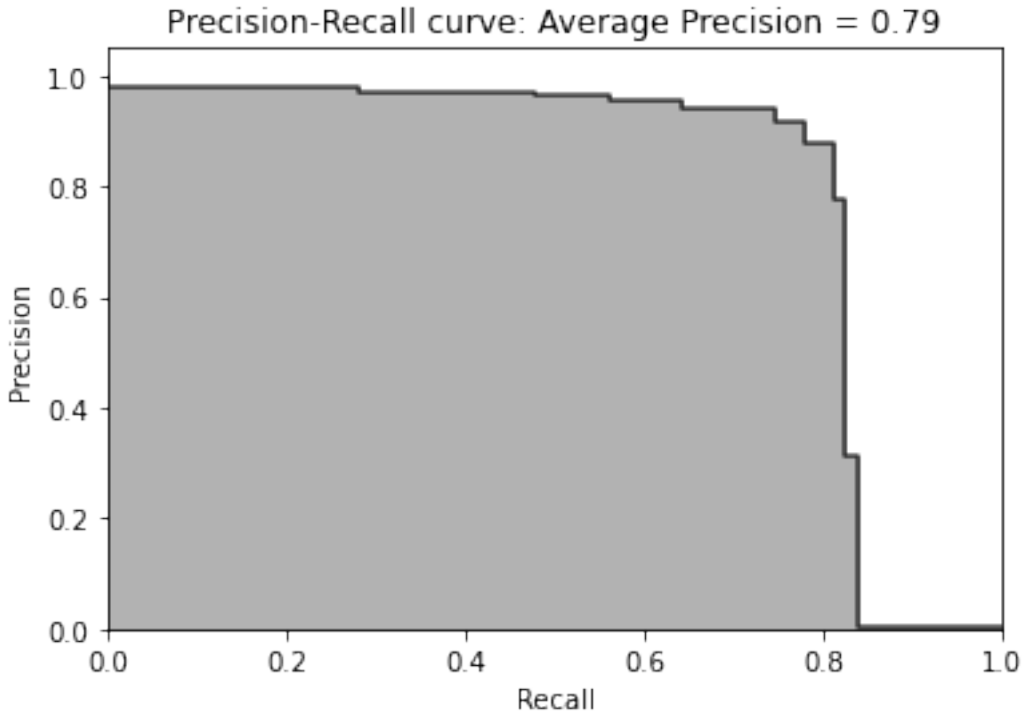
[84]:
```
n_estimators = 10
max_features = 'auto'
max_depth = None
min_samples_split = 2
min_samples_leaf = 1
min_weight_fraction_leaf = 0.0
max_leaf_nodes = None
bootstrap = True
oob_score = False
n_jobs = -1
random_state = 2018
```

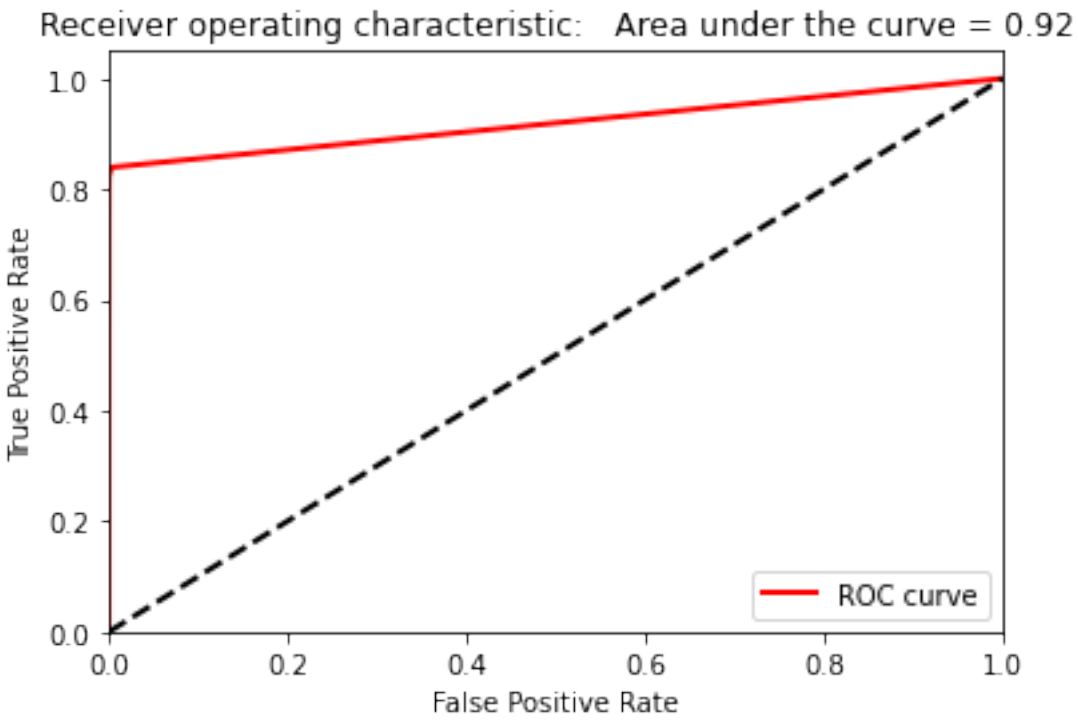
```
class_weight = 'balanced'
RFC = RandomForestClassifier(n_estimators=n_estimators,
max_features=max_features, max_depth=max_depth,
min_samples_split=min_samples_split, min_samples_leaf=min_samples_leaf,
min_weight_fraction_leaf=min_weight_fraction_leaf,
max_leaf_nodes=max_leaf_nodes, bootstrap=bootstrap,
oob_score=oob_score, n_jobs=n_jobs, random_state=random_state,
class_weight=class_weight)
```

[85]:
```
trainingScores = []
cvScores = []
predictionsBasedOnKFolds = pd.DataFrame(data=[],
index=y_train.index,columns=[0,1])
model = RFC
for train_index, cv_index in k_fold.split(np.zeros(len(X_train)),
  y_train.ravel()):
  X_train_fold, X_cv_fold = X_train.iloc[train_index,:], \
  X_train.iloc[cv_index,:]
  y_train_fold, y_cv_fold = y_train.iloc[train_index], \
  y_train.iloc[cv_index]
  model.fit(X_train_fold, y_train_fold)
  loglossTraining = log_loss(y_train_fold, \
  model.predict_proba(X_train_fold)[:,1])
  trainingScores.append(loglossTraining)
  predictionsBasedOnKFolds.loc[X_cv_fold.index,:] = \
  model.predict_proba(X_cv_fold)
  loglossCV = log_loss(y_cv_fold, \
  predictionsBasedOnKFolds.loc[X_cv_fold.index,1])
  cvScores.append(loglossCV)
  print('Training Log Loss: ', loglossTraining)
  print('CV Log Loss: ', loglossCV)
loglossRandomForestsClassifier = log_loss(y_train,
predictionsBasedOnKFolds.loc[:,1])
print('Random Forests Log Loss: ', loglossRandomForestsClassifier)
```

```
Training Log Loss:  0.0004717456539906082
CV Log Loss:  0.009958407581679842
Training Log Loss:  0.00039391696555908875
CV Log Loss:  0.012614958898596576
Training Log Loss:  0.0003955086800568252
CV Log Loss:  0.008311598856605153
Training Log Loss:  0.0004174848852259459
CV Log Loss:  0.009209166975528824
Training Log Loss:  0.00042710655140527107
CV Log Loss:  0.014292100977712807
Random Forests Log Loss:  0.01087724665802464
```

[86]:
```
preds = getPreds(y_train, predictionsBasedOnKFolds)
predictionsBasedOnKFoldsRF = preds.copy()
prCurve(preds)
rocCurve(preds)
```





2.3 XGBoost

[87]:
```
params_xGB = {
    'nthread':16,
    'learning_rate':0.3,
    'gamma':0,
    'max_depth': 6,
    'min_child_weight':1,
    'max_delta_step':0,
    'subsample':1.0,
    'colsample_bytree':1.0,
    'objective': 'binary:logistic',
    'num_class':1,
    'eval_metric':'logloss',
    'seed': 2018,
    'silent':1
}
```

[89]:
```
trainingScores = []
cvScores = []
predictionsBasedOnKFolds = pd.DataFrame(data=[],
index=y_train.index,columns=['prediction'])
for train_index, cv_index in k_fold.split(np.zeros(len(X_train)),
  y_train.ravel()):
```

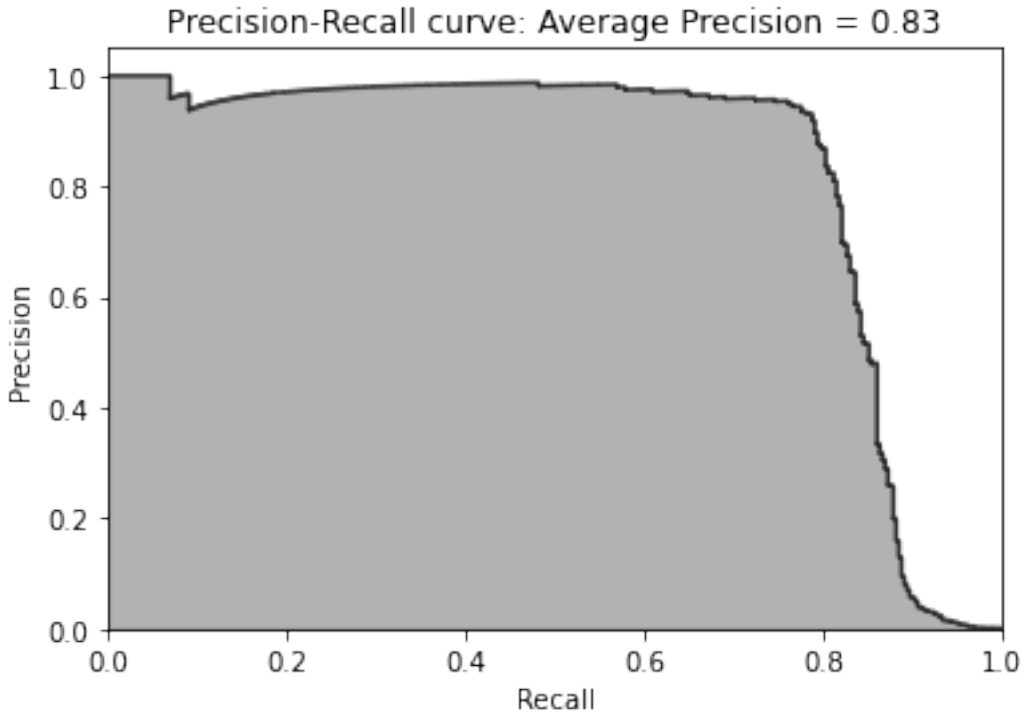
```
  X_train_fold, X_cv_fold = X_train.iloc[train_index,:], \
  X_train.iloc[cv_index,:]
  y_train_fold, y_cv_fold = y_train.iloc[train_index], \
  y_train.iloc[cv_index]
  dtrain = xgb.DMatrix(data=X_train_fold, label=y_train_fold)
  dCV = xgb.DMatrix(data=X_cv_fold)
  bst = xgb.cv(params_xGB, dtrain, num_boost_round=2000,
  nfold=5, early_stopping_rounds=200, verbose_eval=50)
  best_rounds = np.argmin(bst['test-logloss-mean'])
  bst = xgb.train(params_xGB, dtrain, best_rounds)
  loglossTraining = log_loss(y_train_fold, bst.predict(dtrain))
  trainingScores.append(loglossTraining)
  predictionsBasedOnKFolds.loc[X_cv_fold.index,'prediction'] = \
  bst.predict(dCV)
  loglossCV = log_loss(y_cv_fold, \
  predictionsBasedOnKFolds.loc[X_cv_fold.index,'prediction'])
  cvScores.append(loglossCV)
  print('Training Log Loss: ', loglossTraining)
  print('CV Log Loss: ', loglossCV)
loglossXGBoostGradientBoosting = \
log_loss(y_train, predictionsBasedOnKFolds.loc[:,'prediction'])
print('XGBoost Gradient Boosting Log Loss: ', loglossXGBoostGradientBoosting)
```

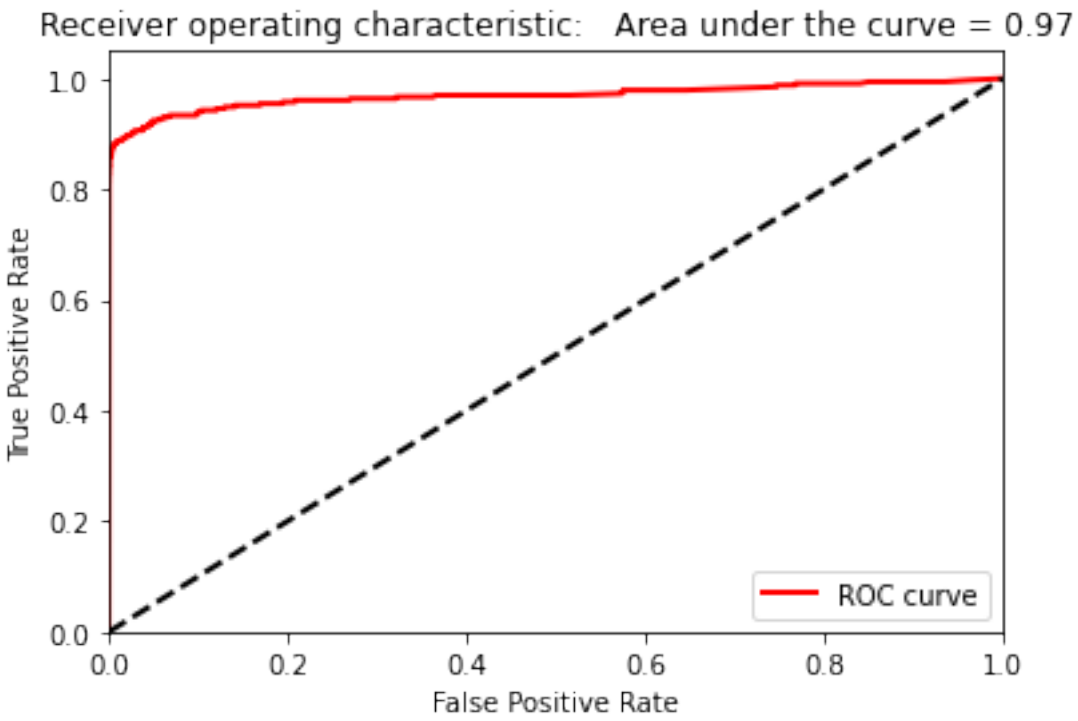
```
[0]     train-logloss:0.437929+5.24382e-05      test-
logloss:0.438071+4.12534e-05
[50]    train-logloss:0.0001446+5.4626e-06      test-
logloss:0.0032646+0.000441828
[100]   train-logloss:5.82e-05+7.48331e-07      test-
logloss:0.0035686+0.00049924
[150]   train-logloss:4.26e-05+4.89898e-07      test-
logloss:0.003685+0.000546123
[200]   train-logloss:3.64e-05+4.89898e-07      test-
logloss:0.0037592+0.00055965
Training Log Loss:  0.0009698748139954727
CV Log Loss:  0.0023983441021560694
[0]     train-logloss:0.437907+5.28674e-05      test-logloss:0.438001+5.7763e-05
[50]    train-logloss:0.000132+4.42719e-06      test-
logloss:0.003126+0.000311441
[100]   train-logloss:5.6e-05+1.78885e-06       test-
logloss:0.0034084+0.000386347
[150]   train-logloss:4.1e-05+8.94427e-07       test-
logloss:0.0035036+0.000418524
[200]   train-logloss:3.52e-05+9.79796e-07      test-
logloss:0.0035732+0.000425153
Training Log Loss:  0.000872351723518117
CV Log Loss:  0.0031189630212641204
[0]     train-logloss:0.437982+4.83802e-05      test-
```

```
logloss:0.438069+7.20017e-05
[50]    train-logloss:0.0001456+9.85089e-06     test-
logloss:0.0033342+0.000837381
[100]   train-logloss:5.96e-05+2.87054e-06      test-
logloss:0.0036202+0.000979771
[150]   train-logloss:4.4e-05+1.67332e-06       test-
logloss:0.0037264+0.00102694
[200]   train-logloss:3.7e-05+1.26491e-06       test-
logloss:0.0037872+0.00105215
Training Log Loss:  0.0007123358367720159
CV Log Loss:  0.0022997797311887728
[0]     train-logloss:0.438004+1.71231e-05      test-
logloss:0.438058+4.12485e-05
[50]    train-logloss:0.0001506+1.03073e-05     test-
logloss:0.0034172+0.000528353
[100]   train-logloss:5.96e-05+2.72764e-06      test-
logloss:0.0037104+0.000620109
[150]   train-logloss:4.4e-05+1.41421e-06       test-
logloss:0.0038264+0.000654994
[200]   train-logloss:3.68e-05+7.48331e-07      test-
logloss:0.0038916+0.000658993
Training Log Loss:  0.0009144685956787081
CV Log Loss:  0.0026294304116278163
[0]     train-logloss:0.437896+2.21323e-05      test-
logloss:0.438055+9.10573e-05
[50]    train-logloss:0.000125+8.6487e-06       test-
logloss:0.0028162+0.000828017
[100]   train-logloss:5.36e-05+2.24499e-06      test-
logloss:0.0030314+0.000934211
[150]   train-logloss:4.02e-05+7.48331e-07      test-
logloss:0.0031026+0.000949287
[200]   train-logloss:3.42e-05+7.48331e-07      test-logloss:0.00315+0.000982203
Training Log Loss:  0.0005772056222738951
CV Log Loss:  0.0036862243093052187
XGBoost Gradient Boosting Log Loss:  0.0028265483151084
[0]     train-logloss:0.437929+5.24382e-05      test-
logloss:0.438071+4.12534e-05
[50]    train-logloss:0.0001446+5.4626e-06      test-
logloss:0.0032646+0.000441828
[100]   train-logloss:5.82e-05+7.48331e-07      test-
logloss:0.0035686+0.00049924
[150]   train-logloss:4.26e-05+4.89898e-07      test-
logloss:0.003685+0.000546123
[200]   train-logloss:3.64e-05+4.89898e-07      test-
logloss:0.0037592+0.00055965
Training Log Loss:  0.0009698748139954727
CV Log Loss:  0.0023983441021560694
[0]     train-logloss:0.437907+5.28674e-05      test-logloss:0.438001+5.7763e-05
```

```
[50]    train-logloss:0.000132+4.42719e-06      test-
logloss:0.003126+0.000311441
[100]   train-logloss:5.6e-05+1.78885e-06       test-
logloss:0.0034084+0.000386347
[150]   train-logloss:4.1e-05+8.94427e-07       test-
logloss:0.0035036+0.000418524
[200]   train-logloss:3.52e-05+9.79796e-07      test-
logloss:0.0035732+0.000425153
Training Log Loss:  0.000872351723518117
CV Log Loss:  0.0031189630212641204
[0]     train-logloss:0.437982+4.83802e-05      test-logloss:0.438069+7.2015e-05
[50]    train-logloss:0.0001456+9.85089e-06     test-
logloss:0.0033342+0.000837381
[100]   train-logloss:5.96e-05+2.87054e-06      test-
logloss:0.0036202+0.000979771
[150]   train-logloss:4.4e-05+1.67332e-06       test-
logloss:0.0037264+0.00102694
[200]   train-logloss:3.7e-05+1.26491e-06       test-
logloss:0.0037872+0.00105215
Training Log Loss:  0.0007123358367720159
CV Log Loss:  0.0022997797311887728
[0]     train-logloss:0.438004+1.71231e-05      test-
logloss:0.438058+4.12485e-05
[50]    train-logloss:0.0001506+1.03073e-05     test-
logloss:0.0034172+0.000528353
[100]   train-logloss:5.96e-05+2.72764e-06      test-
logloss:0.0037104+0.000620109
[150]   train-logloss:4.4e-05+1.41421e-06       test-
logloss:0.0038264+0.000654994
[200]   train-logloss:3.68e-05+7.48331e-07      test-
logloss:0.0038916+0.000658993
Training Log Loss:  0.0009144685956787081
CV Log Loss:  0.0026294304116278163
[0]     train-logloss:0.437896+2.21323e-05      test-
logloss:0.438055+9.10573e-05
[50]    train-logloss:0.000125+8.6487e-06       test-
logloss:0.0028162+0.000828017
[100]   train-logloss:5.36e-05+2.24499e-06      test-
logloss:0.0030314+0.000934211
[150]   train-logloss:4.02e-05+7.48331e-07      test-
logloss:0.0031026+0.000949287
[200]   train-logloss:3.42e-05+7.48331e-07      test-logloss:0.00315+0.000982203
Training Log Loss:  0.0005772056222738951
CV Log Loss:  0.0036862243093052187
XGBoost Gradient Boosting Log Loss:  0.0028265483151084
```

[93]:
```
preds = pd.concat([y_train, predictionsBasedOnKFolds.loc[:]], axis=1)
preds.columns = ["trueLabel", 'prediction']
predictionsBasedOnKFoldsXGB = preds.copy()
prCurve(preds)
rocCurve(preds)
```





2.4 LightGBM

[94]:
```
params_lightGB = {
'task': 'train',
'application':'binary',
'num_class':1,
'boosting': 'gbdt',
'objective': 'binary',
'metric': 'binary_logloss',
'metric_freq':50,
'is_training_metric':False,
'max_depth':4,
'num_leaves': 31,
'learning_rate': 0.01,
'feature_fraction': 1.0,
'bagging_fraction': 1.0,
'bagging_freq': 0,
'bagging_seed': 2018,
'verbose': 0,
'num_threads':16
}
```

[95]:
```
trainingScores = []
cvScores = []
predictionsBasedOnKFolds = pd.DataFrame(data=[], index=y_train.
 ↪index,columns=['prediction'])
for train_index, cv_index in k_fold.split(np.zeros(len(X_train)),
  y_train.ravel()):
  X_train_fold, X_cv_fold = X_train.iloc[train_index,:], X_train.iloc[cv_index,:
 ↪]
  y_train_fold, y_cv_fold = y_train.iloc[train_index],y_train.iloc[cv_index]
  lgb_train = lgb.Dataset(X_train_fold, y_train_fold)
  lgb_eval = lgb.Dataset(X_cv_fold, y_cv_fold, reference=lgb_train)
  gbm = lgb.train(params_lightGB, lgb_train, num_boost_round=2000,
                  valid_sets=lgb_eval, early_stopping_rounds=200)
  loglossTraining = log_loss(y_train_fold, gbm.predict(X_train_fold,␣
 ↪num_iteration=gbm.best_iteration))
  trainingScores.append(loglossTraining)
  predictionsBasedOnKFolds.loc[X_cv_fold.index,'prediction'] =   gbm.
 ↪predict(X_cv_fold, num_iteration=gbm.best_iteration)
  loglossCV = log_loss(y_cv_fold, \
  predictionsBasedOnKFolds.loc[X_cv_fold.index,'prediction'])
  cvScores.append(loglossCV)
  print('Training Log Loss: ', loglossTraining)
  print('CV Log Loss: ', loglossCV)
loglossLightGBMGradientBoosting = log_loss(y_train, predictionsBasedOnKFolds.
 ↪loc[:,'prediction'])
print('LightGBM gradient boosting Log Loss: ', loglossLightGBMGradientBoosting)
```

```
[1]     valid_0's binary_logloss: 0.00634115
Training until validation scores don't improve for 200 rounds.
[2]     valid_0's binary_logloss: 0.00627492
[3]     valid_0's binary_logloss: 0.00620527
[4]     valid_0's binary_logloss: 0.00616014
[5]     valid_0's binary_logloss: 0.00609608
[6]     valid_0's binary_logloss: 0.0060474
[7]     valid_0's binary_logloss: 0.0059922
[8]     valid_0's binary_logloss: 0.00593688
[9]     valid_0's binary_logloss: 0.00588275
[10]    valid_0's binary_logloss: 0.00582962
[11]    valid_0's binary_logloss: 0.00577838
[12]    valid_0's binary_logloss: 0.00573037
[13]    valid_0's binary_logloss: 0.00568343
[14]    valid_0's binary_logloss: 0.00563845
[15]    valid_0's binary_logloss: 0.00559177
[16]    valid_0's binary_logloss: 0.00554777
[17]    valid_0's binary_logloss: 0.00550471
[18]    valid_0's binary_logloss: 0.00546175
[19]    valid_0's binary_logloss: 0.00542175
```

```
[20]    valid_0's binary_logloss: 0.00538166
[21]    valid_0's binary_logloss: 0.00534326
[22]    valid_0's binary_logloss: 0.00530349
[23]    valid_0's binary_logloss: 0.00526531
[24]    valid_0's binary_logloss: 0.00522957
[25]    valid_0's binary_logloss: 0.00519479
[26]    valid_0's binary_logloss: 0.00516029
[27]    valid_0's binary_logloss: 0.00512786
[28]    valid_0's binary_logloss: 0.00509245
[29]    valid_0's binary_logloss: 0.00505942
[30]    valid_0's binary_logloss: 0.00502791
[31]    valid_0's binary_logloss: 0.00499303
[32]    valid_0's binary_logloss: 0.00496258
[33]    valid_0's binary_logloss: 0.00492924
[34]    valid_0's binary_logloss: 0.00490074
[35]    valid_0's binary_logloss: 0.00487056
[36]    valid_0's binary_logloss: 0.00483707
[37]    valid_0's binary_logloss: 0.00480635
[38]    valid_0's binary_logloss: 0.00477569
[39]    valid_0's binary_logloss: 0.00474644
[40]    valid_0's binary_logloss: 0.00471898
[41]    valid_0's binary_logloss: 0.00469203
[42]    valid_0's binary_logloss: 0.0046661
[43]    valid_0's binary_logloss: 0.00463991
[44]    valid_0's binary_logloss: 0.00461271
[45]    valid_0's binary_logloss: 0.00458752
[46]    valid_0's binary_logloss: 0.00456368
[47]    valid_0's binary_logloss: 0.00454001
[48]    valid_0's binary_logloss: 0.00451538
[49]    valid_0's binary_logloss: 0.00449281
[50]    valid_0's binary_logloss: 0.00446857
[51]    valid_0's binary_logloss: 0.00444683
[52]    valid_0's binary_logloss: 0.00442501
[53]    valid_0's binary_logloss: 0.00440435
[54]    valid_0's binary_logloss: 0.00438177
[55]    valid_0's binary_logloss: 0.00436166
[56]    valid_0's binary_logloss: 0.00434056
[57]    valid_0's binary_logloss: 0.00431917
[58]    valid_0's binary_logloss: 0.00429833
[59]    valid_0's binary_logloss: 0.00427711
[60]    valid_0's binary_logloss: 0.0042565
[61]    valid_0's binary_logloss: 0.00423721
[62]    valid_0's binary_logloss: 0.00421795
[63]    valid_0's binary_logloss: 0.0041992
[64]    valid_0's binary_logloss: 0.00418027
[65]    valid_0's binary_logloss: 0.00416311
[66]    valid_0's binary_logloss: 0.00414386
[67]    valid_0's binary_logloss: 0.0041271
```

```
[68]    valid_0's binary_logloss: 0.00411028
[69]    valid_0's binary_logloss: 0.00409324
[70]    valid_0's binary_logloss: 0.0040778
[71]    valid_0's binary_logloss: 0.00405932
[72]    valid_0's binary_logloss: 0.0040432
[73]    valid_0's binary_logloss: 0.00402664
[74]    valid_0's binary_logloss: 0.0040098
[75]    valid_0's binary_logloss: 0.00399677
[76]    valid_0's binary_logloss: 0.00398229
[77]    valid_0's binary_logloss: 0.00396538
[78]    valid_0's binary_logloss: 0.00395069
[79]    valid_0's binary_logloss: 0.00393679
[80]    valid_0's binary_logloss: 0.00392054
[81]    valid_0's binary_logloss: 0.00390906
[82]    valid_0's binary_logloss: 0.00389621
[83]    valid_0's binary_logloss: 0.00388076
[84]    valid_0's binary_logloss: 0.00386788
[85]    valid_0's binary_logloss: 0.00385374
[86]    valid_0's binary_logloss: 0.00383955
[87]    valid_0's binary_logloss: 0.00382839
[88]    valid_0's binary_logloss: 0.00381452
[89]    valid_0's binary_logloss: 0.00380258
[90]    valid_0's binary_logloss: 0.00379073
[91]    valid_0's binary_logloss: 0.00377709
[92]    valid_0's binary_logloss: 0.00376417
[93]    valid_0's binary_logloss: 0.00375197
[94]    valid_0's binary_logloss: 0.00374183
[95]    valid_0's binary_logloss: 0.00373005
[96]    valid_0's binary_logloss: 0.00371725
[97]    valid_0's binary_logloss: 0.00370687
[98]    valid_0's binary_logloss: 0.00369364
[99]    valid_0's binary_logloss: 0.00368175
[100]   valid_0's binary_logloss: 0.0036706
[101]   valid_0's binary_logloss: 0.00365895
[102]   valid_0's binary_logloss: 0.003648
[103]   valid_0's binary_logloss: 0.00363588
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[912]   valid_0's binary_logloss: 0.00261698
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[1214]  valid_0's binary_logloss: 0.00262258
[1215]  valid_0's binary_logloss: 0.00262245
[1216]  valid_0's binary_logloss: 0.00262353
Early stopping, best iteration is:
[1016]  valid_0's binary_logloss: 0.00260857
Training Log Loss:  0.0003371031599922104
```

```
CV Log Loss:  0.0026085672798391453
[1]     valid_0's binary_logloss: 0.00650326
Training until validation scores don't improve for 200 rounds.
[2]     valid_0's binary_logloss: 0.00640793
[3]     valid_0's binary_logloss: 0.00635164
[4]     valid_0's binary_logloss: 0.00628703
[5]     valid_0's binary_logloss: 0.00622074
[6]     valid_0's binary_logloss: 0.00617433
[7]     valid_0's binary_logloss: 0.00612783
[8]     valid_0's binary_logloss: 0.00607648
[9]     valid_0's binary_logloss: 0.00602712
[10]    valid_0's binary_logloss: 0.00598607
[11]    valid_0's binary_logloss: 0.00594311
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[14]    valid_0's binary_logloss: 0.00578116
[15]    valid_0's binary_logloss: 0.0057346
[16]    valid_0's binary_logloss: 0.00569229
[17]    valid_0's binary_logloss: 0.00564889
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[19]    valid_0's binary_logloss: 0.0055712
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[41]    valid_0's binary_logloss: 0.00481212
[42]    valid_0's binary_logloss: 0.00478318
[43]    valid_0's binary_logloss: 0.00475801
[44]    valid_0's binary_logloss: 0.00472987
[45]    valid_0's binary_logloss: 0.00470239
[46]    valid_0's binary_logloss: 0.00467869
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[47]    valid_0's binary_logloss: 0.0046528
[48]    valid_0's binary_logloss: 0.00462522
[49]    valid_0's binary_logloss: 0.00460046
[50]    valid_0's binary_logloss: 0.00457689
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[53]    valid_0's binary_logloss: 0.00450539
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[67]    valid_0's binary_logloss: 0.00424078
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[896]   valid_0's binary_logloss: 0.00293712
[897]   valid_0's binary_logloss: 0.00293725
[898]   valid_0's binary_logloss: 0.00293773
[899]   valid_0's binary_logloss: 0.00293803
[900]   valid_0's binary_logloss: 0.00293795
[901]   valid_0's binary_logloss: 0.00293794
[902]   valid_0's binary_logloss: 0.00293878
[903]   valid_0's binary_logloss: 0.00293891
[904]   valid_0's binary_logloss: 0.00293911
[905]   valid_0's binary_logloss: 0.00293987
[906]   valid_0's binary_logloss: 0.00293979
[907]   valid_0's binary_logloss: 0.00294011
[908]   valid_0's binary_logloss: 0.00294074
[909]   valid_0's binary_logloss: 0.0029403
[910]   valid_0's binary_logloss: 0.0029394
```

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[911]   valid_0's binary_logloss: 0.00294007
[912]   valid_0's binary_logloss: 0.00294059
[913]   valid_0's binary_logloss: 0.00294017
[914]   valid_0's binary_logloss: 0.00294018
[915]   valid_0's binary_logloss: 0.00294009
[916]   valid_0's binary_logloss: 0.00294022
[917]   valid_0's binary_logloss: 0.00293947
[918]   valid_0's binary_logloss: 0.00293907
[919]   valid_0's binary_logloss: 0.00293911
[920]   valid_0's binary_logloss: 0.0029394
[921]   valid_0's binary_logloss: 0.00293933
[922]   valid_0's binary_logloss: 0.00293996
[923]   valid_0's binary_logloss: 0.00293956
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[925]   valid_0's binary_logloss: 0.00293953
[926]   valid_0's binary_logloss: 0.00293971
[927]   valid_0's binary_logloss: 0.00293932
[928]   valid_0's binary_logloss: 0.00294018
[929]   valid_0's binary_logloss: 0.00293991
[930]   valid_0's binary_logloss: 0.0029407
[931]   valid_0's binary_logloss: 0.0029403
[932]   valid_0's binary_logloss: 0.00294024
[933]   valid_0's binary_logloss: 0.00293992
[934]   valid_0's binary_logloss: 0.00294071
[935]   valid_0's binary_logloss: 0.00294106
[936]   valid_0's binary_logloss: 0.00294107
[937]   valid_0's binary_logloss: 0.00294127
[938]   valid_0's binary_logloss: 0.00294086
[939]   valid_0's binary_logloss: 0.00294042
[940]   valid_0's binary_logloss: 0.00294034
[941]   valid_0's binary_logloss: 0.00294093
[942]   valid_0's binary_logloss: 0.0029409
[943]   valid_0's binary_logloss: 0.00294128
[944]   valid_0's binary_logloss: 0.00294202
[945]   valid_0's binary_logloss: 0.00294196
[946]   valid_0's binary_logloss: 0.0029423
[947]   valid_0's binary_logloss: 0.00294081
Early stopping, best iteration is:
[747]   valid_0's binary_logloss: 0.0029186
Training Log Loss:  0.00044251475230709897
CV Log Loss:  0.0029186030477989706
[1]     valid_0's binary_logloss: 0.00598384
Training until validation scores don't improve for 200 rounds.
[2]     valid_0's binary_logloss: 0.00591096
[3]     valid_0's binary_logloss: 0.00582392
[4]     valid_0's binary_logloss: 0.00574865
[5]     valid_0's binary_logloss: 0.00567836
[6]     valid_0's binary_logloss: 0.00559443
```

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[7]     valid_0's binary_logloss: 0.00550457
[8]     valid_0's binary_logloss: 0.00544018
[9]     valid_0's binary_logloss: 0.00536756
[10]    valid_0's binary_logloss: 0.0053157
[11]    valid_0's binary_logloss: 0.00526181
[12]    valid_0's binary_logloss: 0.00520665
[13]    valid_0's binary_logloss: 0.00515495
[14]    valid_0's binary_logloss: 0.00511009
[15]    valid_0's binary_logloss: 0.00506738
[16]    valid_0's binary_logloss: 0.00502552
[17]    valid_0's binary_logloss: 0.00497765
[18]    valid_0's binary_logloss: 0.00493184
[19]    valid_0's binary_logloss: 0.00488708
[20]    valid_0's binary_logloss: 0.00484414
[21]    valid_0's binary_logloss: 0.00480165
[22]    valid_0's binary_logloss: 0.00475938
[23]    valid_0's binary_logloss: 0.00472141
[24]    valid_0's binary_logloss: 0.00468493
[25]    valid_0's binary_logloss: 0.00464901
[26]    valid_0's binary_logloss: 0.004614
[27]    valid_0's binary_logloss: 0.00457978
[28]    valid_0's binary_logloss: 0.0045442
[29]    valid_0's binary_logloss: 0.00451255
[30]    valid_0's binary_logloss: 0.00448338
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[34]    valid_0's binary_logloss: 0.00436108
[35]    valid_0's binary_logloss: 0.00432986
[36]    valid_0's binary_logloss: 0.00430181
[37]    valid_0's binary_logloss: 0.004275
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[39]    valid_0's binary_logloss: 0.00422341
[40]    valid_0's binary_logloss: 0.00419919
[41]    valid_0's binary_logloss: 0.00416906
[42]    valid_0's binary_logloss: 0.00414561
[43]    valid_0's binary_logloss: 0.00411781
[44]    valid_0's binary_logloss: 0.00409342
[45]    valid_0's binary_logloss: 0.00407262
[46]    valid_0's binary_logloss: 0.00404416
[47]    valid_0's binary_logloss: 0.00402313
[48]    valid_0's binary_logloss: 0.00400268
[49]    valid_0's binary_logloss: 0.0039817
[50]    valid_0's binary_logloss: 0.00396142
[51]    valid_0's binary_logloss: 0.00394201
[52]    valid_0's binary_logloss: 0.00392287
[53]    valid_0's binary_logloss: 0.00390234
[54]    valid_0's binary_logloss: 0.00388319
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[56]    valid_0's binary_logloss: 0.00384343
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[60]    valid_0's binary_logloss: 0.00376937
[61]    valid_0's binary_logloss: 0.00375285
[62]    valid_0's binary_logloss: 0.00373564
[63]    valid_0's binary_logloss: 0.00371919
[64]    valid_0's binary_logloss: 0.00370004
[65]    valid_0's binary_logloss: 0.00368305
[66]    valid_0's binary_logloss: 0.00366655
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[71]    valid_0's binary_logloss: 0.00358698
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[79]    valid_0's binary_logloss: 0.00347359
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[84]    valid_0's binary_logloss: 0.00341204
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[86]    valid_0's binary_logloss: 0.00338694
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[96]    valid_0's binary_logloss: 0.00327872
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[101]   valid_0's binary_logloss: 0.00322771
[102]   valid_0's binary_logloss: 0.00321871
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[999]   valid_0's binary_logloss: 0.00231799
[1000]  valid_0's binary_logloss: 0.00231773
[1001]  valid_0's binary_logloss: 0.00231853
Early stopping, best iteration is:
[801]   valid_0's binary_logloss: 0.00230284
Training Log Loss:  0.0005303100840936764
CV Log Loss:  0.0023028376768372432
[1]     valid_0's binary_logloss: 0.00626824
Training until validation scores don't improve for 200 rounds.
[2]     valid_0's binary_logloss: 0.0061933
[3]     valid_0's binary_logloss: 0.00612433
[4]     valid_0's binary_logloss: 0.00604336
[5]     valid_0's binary_logloss: 0.00598282
[6]     valid_0's binary_logloss: 0.00593137
[7]     valid_0's binary_logloss: 0.00587492
[8]     valid_0's binary_logloss: 0.00580743
```

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[9]     valid_0's binary_logloss: 0.00575981
[10]    valid_0's binary_logloss: 0.0057057
[11]    valid_0's binary_logloss: 0.00565854
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[13]    valid_0's binary_logloss: 0.00556022
[14]    valid_0's binary_logloss: 0.00550985
[15]    valid_0's binary_logloss: 0.00547174
[16]    valid_0's binary_logloss: 0.00543205
[17]    valid_0's binary_logloss: 0.00539231
[18]    valid_0's binary_logloss: 0.00535171
[19]    valid_0's binary_logloss: 0.00531302
[20]    valid_0's binary_logloss: 0.00527614
[21]    valid_0's binary_logloss: 0.00524087
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[37]    valid_0's binary_logloss: 0.00471004
[38]    valid_0's binary_logloss: 0.0046848
[39]    valid_0's binary_logloss: 0.00465802
[40]    valid_0's binary_logloss: 0.00462986
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[45]    valid_0's binary_logloss: 0.00450722
[46]    valid_0's binary_logloss: 0.00448547
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[710]   valid_0's binary_logloss: 0.00274049
[711]   valid_0's binary_logloss: 0.00274112
[712]   valid_0's binary_logloss: 0.00274132
Early stopping, best iteration is:
[512]   valid_0's binary_logloss: 0.0027041
Training Log Loss:  0.0007956221997565104
CV Log Loss:  0.002704102673854306
[1]     valid_0's binary_logloss: 0.00657581
Training until validation scores don't improve for 200 rounds.
[2]     valid_0's binary_logloss: 0.00650072
[3]     valid_0's binary_logloss: 0.00645264
[4]     valid_0's binary_logloss: 0.00639842
[5]     valid_0's binary_logloss: 0.00634603
[6]     valid_0's binary_logloss: 0.00630228
[7]     valid_0's binary_logloss: 0.00626173
[8]     valid_0's binary_logloss: 0.00621253
[9]     valid_0's binary_logloss: 0.00616988
[10]    valid_0's binary_logloss: 0.00613037
[11]    valid_0's binary_logloss: 0.00608624
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[13]    valid_0's binary_logloss: 0.00600964
[14]    valid_0's binary_logloss: 0.00596746
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[18]    valid_0's binary_logloss: 0.00581339
[19]    valid_0's binary_logloss: 0.00578167
[20]    valid_0's binary_logloss: 0.00574519
[21]    valid_0's binary_logloss: 0.00571282
[22]    valid_0's binary_logloss: 0.00568294
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[27]    valid_0's binary_logloss: 0.00553142
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[29]    valid_0's binary_logloss: 0.00547782
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[39]    valid_0's binary_logloss: 0.00522439
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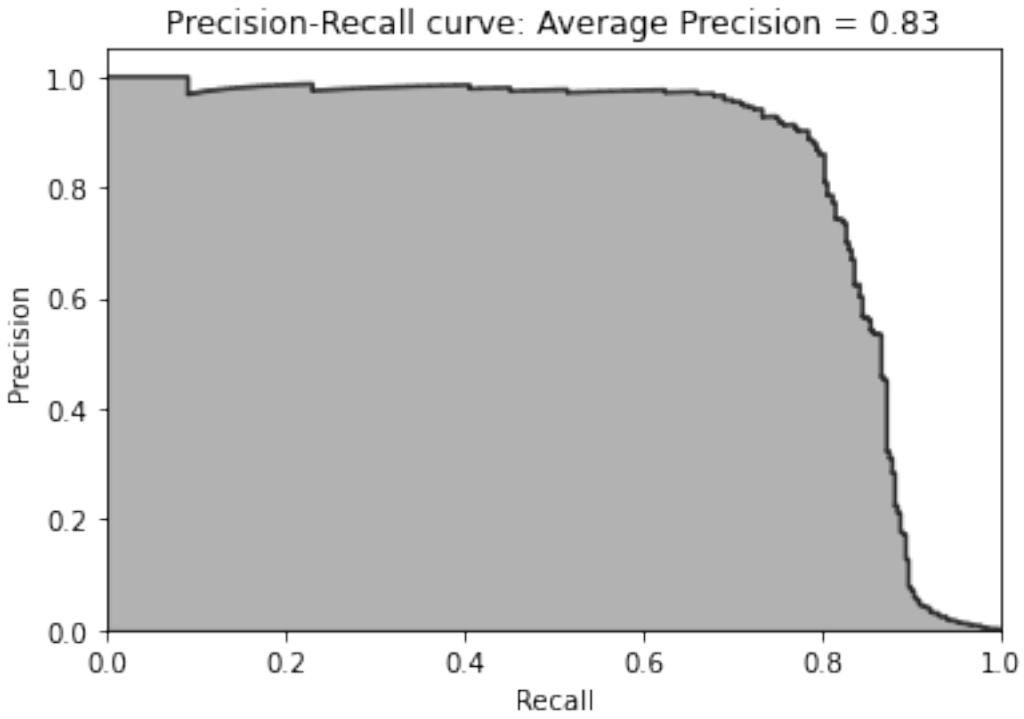
[649]   valid_0's binary_logloss: 0.00358626
[650]   valid_0's binary_logloss: 0.00358691
[651]   valid_0's binary_logloss: 0.00358554
[652]   valid_0's binary_logloss: 0.00358495
[653]   valid_0's binary_logloss: 0.00358627
[654]   valid_0's binary_logloss: 0.00358673
[655]   valid_0's binary_logloss: 0.00358614
[656]   valid_0's binary_logloss: 0.00358614
[657]   valid_0's binary_logloss: 0.00358511
[658]   valid_0's binary_logloss: 0.00358468
[659]   valid_0's binary_logloss: 0.00358472
[660]   valid_0's binary_logloss: 0.00358606
[661]   valid_0's binary_logloss: 0.00358595
[662]   valid_0's binary_logloss: 0.00358538
[663]   valid_0's binary_logloss: 0.00358618
[664]   valid_0's binary_logloss: 0.00358545
[665]   valid_0's binary_logloss: 0.00358524
[666]   valid_0's binary_logloss: 0.00358564
[667]   valid_0's binary_logloss: 0.00358508
[668]   valid_0's binary_logloss: 0.00358524
[669]   valid_0's binary_logloss: 0.00358525
[670]   valid_0's binary_logloss: 0.00358457
[671]   valid_0's binary_logloss: 0.00358385
[672]   valid_0's binary_logloss: 0.00358343
[673]   valid_0's binary_logloss: 0.00358394
[674]   valid_0's binary_logloss: 0.00358478
[675]   valid_0's binary_logloss: 0.00358423
[676]   valid_0's binary_logloss: 0.00358352
[677]   valid_0's binary_logloss: 0.00358403
[678]   valid_0's binary_logloss: 0.00358348
[679]   valid_0's binary_logloss: 0.00358485
[680]   valid_0's binary_logloss: 0.00358479
[681]   valid_0's binary_logloss: 0.00358579
[682]   valid_0's binary_logloss: 0.0035851
[683]   valid_0's binary_logloss: 0.00358457
```

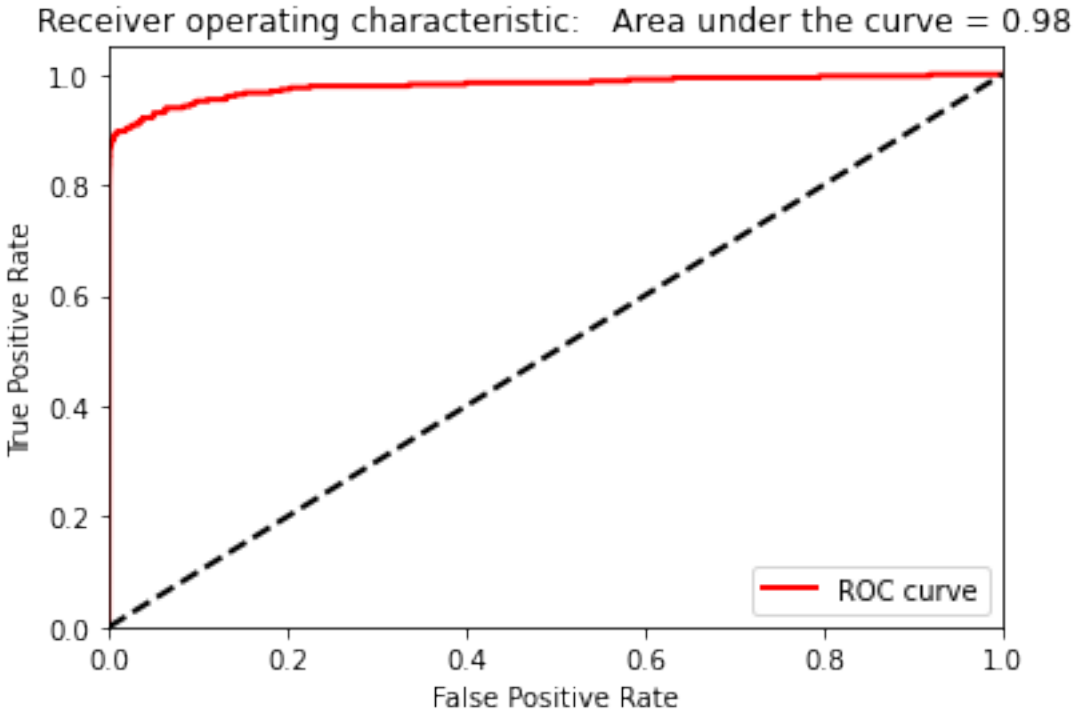
```
[684]   valid_0's binary_logloss: 0.00358477
[685]   valid_0's binary_logloss: 0.00358534
[686]   valid_0's binary_logloss: 0.00358539
[687]   valid_0's binary_logloss: 0.00358574
[688]   valid_0's binary_logloss: 0.00358734
[689]   valid_0's binary_logloss: 0.00358784
[690]   valid_0's binary_logloss: 0.00358836
[691]   valid_0's binary_logloss: 0.00358784
[692]   valid_0's binary_logloss: 0.00358744
[693]   valid_0's binary_logloss: 0.00358692
[694]   valid_0's binary_logloss: 0.00358724
[695]   valid_0's binary_logloss: 0.00358814
[696]   valid_0's binary_logloss: 0.00358857
[697]   valid_0's binary_logloss: 0.00358865
[698]   valid_0's binary_logloss: 0.00358897
[699]   valid_0's binary_logloss: 0.00358846
[700]   valid_0's binary_logloss: 0.00358917
[701]   valid_0's binary_logloss: 0.0035895
[702]   valid_0's binary_logloss: 0.00359041
[703]   valid_0's binary_logloss: 0.00359063
[704]   valid_0's binary_logloss: 0.00359097
[705]   valid_0's binary_logloss: 0.0035912
[706]   valid_0's binary_logloss: 0.00359163
[707]   valid_0's binary_logloss: 0.0035908
[708]   valid_0's binary_logloss: 0.00359174
[709]   valid_0's binary_logloss: 0.00359314
[710]   valid_0's binary_logloss: 0.00359309
[711]   valid_0's binary_logloss: 0.00359255
[712]   valid_0's binary_logloss: 0.00359206
[713]   valid_0's binary_logloss: 0.0035924
[714]   valid_0's binary_logloss: 0.00359265
[715]   valid_0's binary_logloss: 0.00359291
[716]   valid_0's binary_logloss: 0.00359252
[717]   valid_0's binary_logloss: 0.00359296
[718]   valid_0's binary_logloss: 0.003594
[719]   valid_0's binary_logloss: 0.00359478
[720]   valid_0's binary_logloss: 0.00359513
[721]   valid_0's binary_logloss: 0.00359542
[722]   valid_0's binary_logloss: 0.00359649
[723]   valid_0's binary_logloss: 0.00359673
[724]   valid_0's binary_logloss: 0.00359623
[725]   valid_0's binary_logloss: 0.00359652
[726]   valid_0's binary_logloss: 0.00359734
[727]   valid_0's binary_logloss: 0.00359695
[728]   valid_0's binary_logloss: 0.0035967
[729]   valid_0's binary_logloss: 0.00359623
[730]   valid_0's binary_logloss: 0.00359584
[731]   valid_0's binary_logloss: 0.00359629
```

```
[732]   valid_0's binary_logloss: 0.00359641
[733]   valid_0's binary_logloss: 0.00359625
[734]   valid_0's binary_logloss: 0.00359684
[735]   valid_0's binary_logloss: 0.00359709
[736]   valid_0's binary_logloss: 0.00359765
[737]   valid_0's binary_logloss: 0.00359795
[738]   valid_0's binary_logloss: 0.00359757
[739]   valid_0's binary_logloss: 0.00359839
[740]   valid_0's binary_logloss: 0.00359852
[741]   valid_0's binary_logloss: 0.00359878
[742]   valid_0's binary_logloss: 0.00359915
[743]   valid_0's binary_logloss: 0.00360066
[744]   valid_0's binary_logloss: 0.00360117
[745]   valid_0's binary_logloss: 0.00360174
[746]   valid_0's binary_logloss: 0.00360176
[747]   valid_0's binary_logloss: 0.00360134
[748]   valid_0's binary_logloss: 0.00360096
[749]   valid_0's binary_logloss: 0.00360123
[750]   valid_0's binary_logloss: 0.00360125
[751]   valid_0's binary_logloss: 0.00360136
[752]   valid_0's binary_logloss: 0.00360182
[753]   valid_0's binary_logloss: 0.00360145
[754]   valid_0's binary_logloss: 0.00360156
[755]   valid_0's binary_logloss: 0.00360242
[756]   valid_0's binary_logloss: 0.00360336
[757]   valid_0's binary_logloss: 0.00360349
[758]   valid_0's binary_logloss: 0.00360311
[759]   valid_0's binary_logloss: 0.00360344
[760]   valid_0's binary_logloss: 0.00360403
[761]   valid_0's binary_logloss: 0.00360486
[762]   valid_0's binary_logloss: 0.00360449
[763]   valid_0's binary_logloss: 0.00360502
[764]   valid_0's binary_logloss: 0.00360461
[765]   valid_0's binary_logloss: 0.003605
[766]   valid_0's binary_logloss: 0.00360664
[767]   valid_0's binary_logloss: 0.00360711
[768]   valid_0's binary_logloss: 0.00360798
[769]   valid_0's binary_logloss: 0.00360826
[770]   valid_0's binary_logloss: 0.00360926
[771]   valid_0's binary_logloss: 0.0036089
[772]   valid_0's binary_logloss: 0.00360822
[773]   valid_0's binary_logloss: 0.00360827
[774]   valid_0's binary_logloss: 0.00360995
[775]   valid_0's binary_logloss: 0.00361012
[776]   valid_0's binary_logloss: 0.00360977
[777]   valid_0's binary_logloss: 0.00360946
[778]   valid_0's binary_logloss: 0.00361035
[779]   valid_0's binary_logloss: 0.00361136
```

```
[780]   valid_0's binary_logloss: 0.00361164
[781]   valid_0's binary_logloss: 0.00361134
[782]   valid_0's binary_logloss: 0.00361218
[783]   valid_0's binary_logloss: 0.00361233
[784]   valid_0's binary_logloss: 0.00361371
[785]   valid_0's binary_logloss: 0.00361326
[786]   valid_0's binary_logloss: 0.00361413
[787]   valid_0's binary_logloss: 0.00361462
[788]   valid_0's binary_logloss: 0.00361521
[789]   valid_0's binary_logloss: 0.00361604
[790]   valid_0's binary_logloss: 0.00361761
[791]   valid_0's binary_logloss: 0.00361716
[792]   valid_0's binary_logloss: 0.00361853
[793]   valid_0's binary_logloss: 0.00361912
[794]   valid_0's binary_logloss: 0.0036188
[795]   valid_0's binary_logloss: 0.00361969
[796]   valid_0's binary_logloss: 0.00361939
[797]   valid_0's binary_logloss: 0.00361952
[798]   valid_0's binary_logloss: 0.00361989
[799]   valid_0's binary_logloss: 0.00362048
[800]   valid_0's binary_logloss: 0.00362017
[801]   valid_0's binary_logloss: 0.00362046
[802]   valid_0's binary_logloss: 0.00362054
[803]   valid_0's binary_logloss: 0.00362103
[804]   valid_0's binary_logloss: 0.00362184
[805]   valid_0's binary_logloss: 0.0036218
[806]   valid_0's binary_logloss: 0.00362235
[807]   valid_0's binary_logloss: 0.00362206
Early stopping, best iteration is:
[607]   valid_0's binary_logloss: 0.00357935
Training Log Loss:  0.0005965969618746658
CV Log Loss:  0.003579351379203011
LightGBM gradient boosting Log Loss:  0.0028226924115065354
```

[96]:
```
preds = pd.concat([y_train, predictionsBasedOnKFolds.loc[:]], axis=1)
preds.columns = ["trueLabel", 'prediction']
predictionsBasedOnKFoldsLGB = preds.copy()
prCurve(preds)
rocCurve(preds)
```


Precision-Recall curve: Average Precision = 0.83
Precision
Recall
0.0
0.2
0.4
0.6
0.8
1.0


Receiver operating characteristic: Area under the curve = 0.98
True Positive Rate
False Positive Rate
ROC curve
0.0
0.2
0.4
0.6
0.8
1.0

2.5 Testing

[99]:
```
predictionsTestSetLogisticRegression = pd.DataFrame(data=[],index=y_test.
 ↪index,columns=['prediction','trueLabel'])
predictionsTestSetLogisticRegression.loc[:,'prediction'] = logReg.
 ↪predict_proba(X_test)[:,1]
predictionsTestSetLogisticRegression.loc[:,'trueLabel'] = y_test
logLossTestSetLogisticRegression = log_loss(y_test,␣
 ↪predictionsTestSetLogisticRegression['prediction'])
print("Log Loss of Logistic Regression:", logLossTestSetLogisticRegression)

predictionsTestSetRandomForests = pd.DataFrame(data=[],index=y_test.
 ↪index,columns=['prediction','trueLabel'])
predictionsTestSetRandomForests.loc[:,'prediction'] = RFC.
 ↪predict_proba(X_test)[:,1]
predictionsTestSetRandomForests.loc[:,'trueLabel'] = y_test
logLossTestSetRandomForests = log_loss(y_test,␣
 ↪predictionsTestSetRandomForests['prediction'])
print("Log Loss of Random Forest:", logLossTestSetRandomForests)

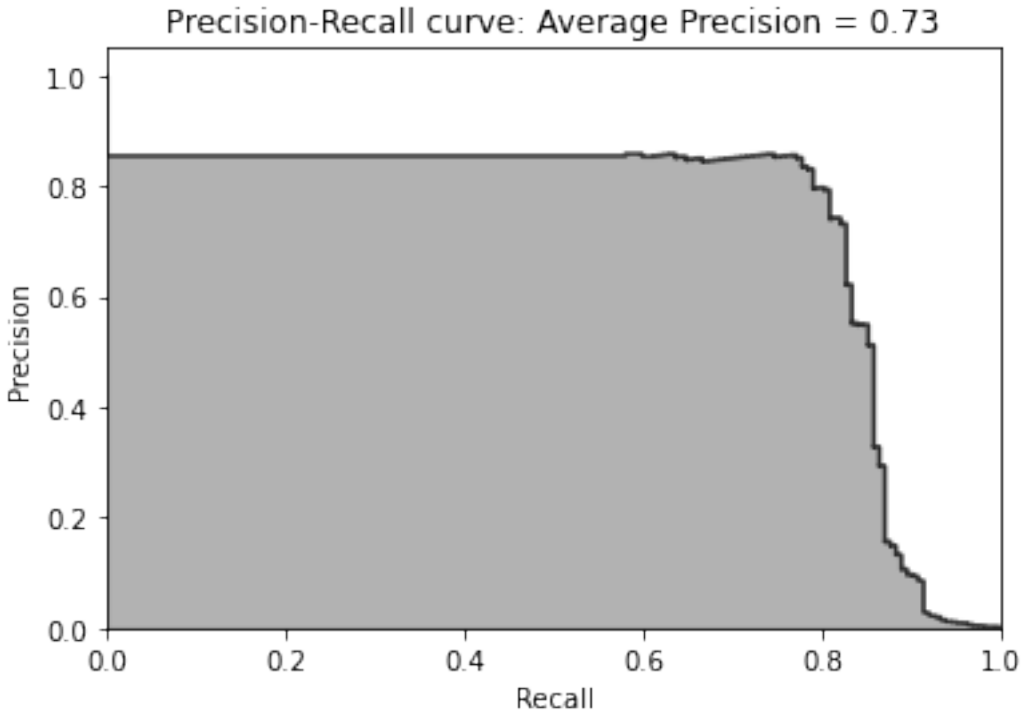
predictionsTestSetXGBoostGradientBoosting = pd.DataFrame(data=[],index=y_test.
 ↪index,columns=['prediction','trueLabel'])
dtest = xgb.DMatrix(data=X_test)
predictionsTestSetXGBoostGradientBoosting.loc[:,'prediction'] = bst.
 ↪predict(dtest)
predictionsTestSetXGBoostGradientBoosting.loc[:,'trueLabel'] = y_test
logLossTestSetXGBoostGradientBoosting = log_loss(y_test,␣
 ↪predictionsTestSetXGBoostGradientBoosting['prediction'])
print("Log Loss of XGBoost:", logLossTestSetXGBoostGradientBoosting)

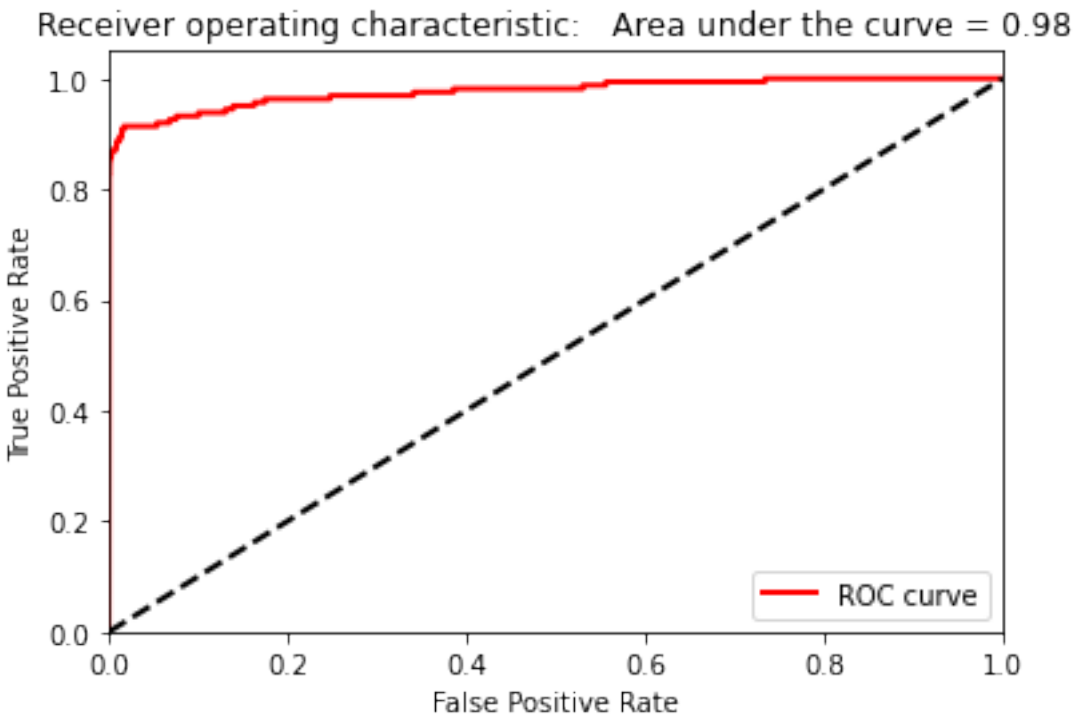
predictionsTestSetLightGBMGradientBoosting = pd.DataFrame(data=[],index=y_test.
 ↪index,columns=['prediction','trueLabel'])
predictionsTestSetLightGBMGradientBoosting.loc[:,'prediction'] = gbm.
 ↪predict(X_test, num_iteration=gbm.best_iteration)
predictionsTestSetLightGBMGradientBoosting.loc[:,'trueLabel'] = y_test
logLossTestSetLightGBMGradientBoosting = log_loss(y_test,␣
 ↪predictionsTestSetLightGBMGradientBoosting['prediction'])
print("Log Loss of LightGBoost:", logLossTestSetLightGBMGradientBoosting)
```

```
Log Loss of Logistic Regression: 0.09674819407933428
Log Loss of Random Forest: 0.009038985836715724
Log Loss of XGBoost: 0.002424374472450827
Log Loss of LightGBoost: 0.002516958317012632
```

2.5.1 Logistic Regression

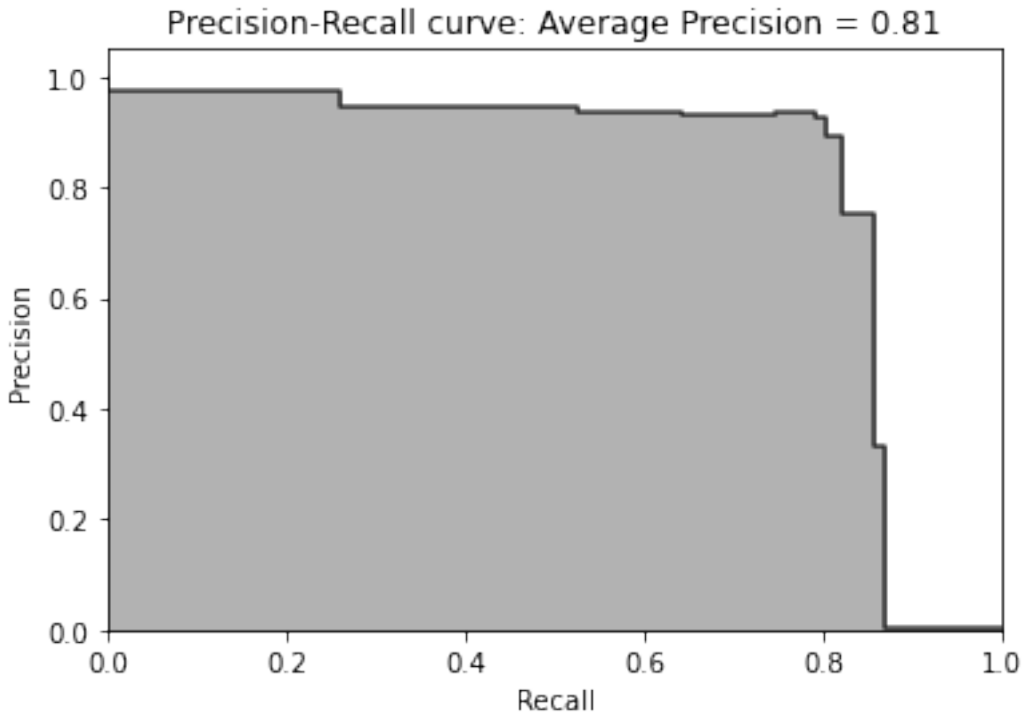
[100]:
```
prCurve(predictionsTestSetLogisticRegression)
rocCurve(predictionsTestSetLogisticRegression)
```

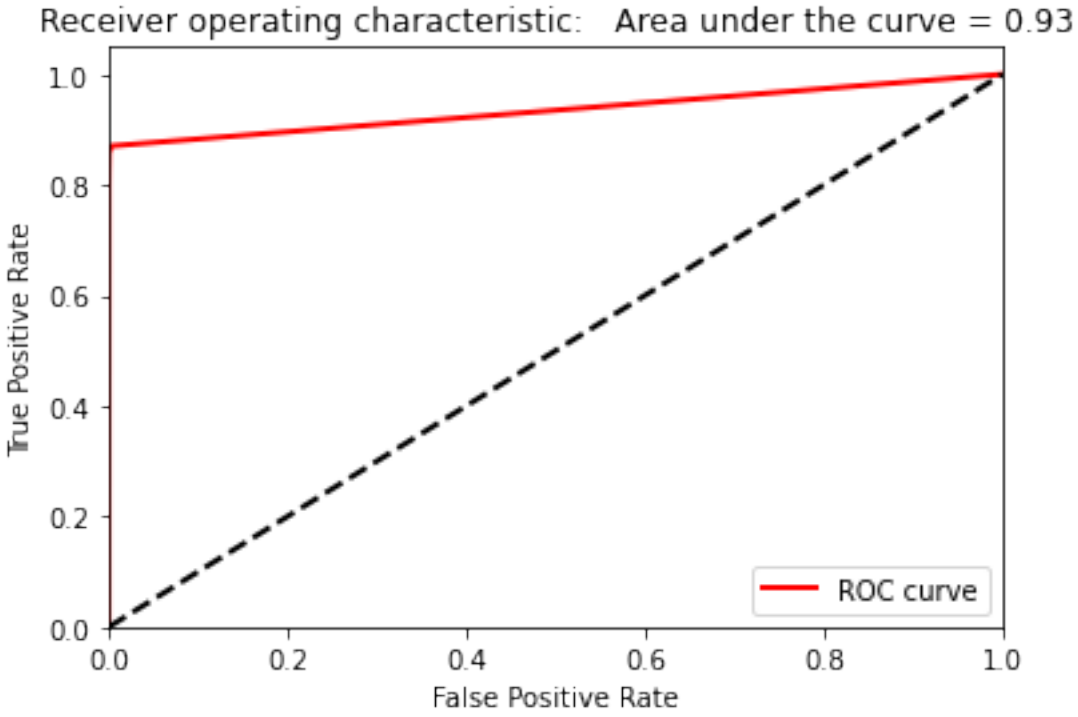




2.5.2 Random Forest

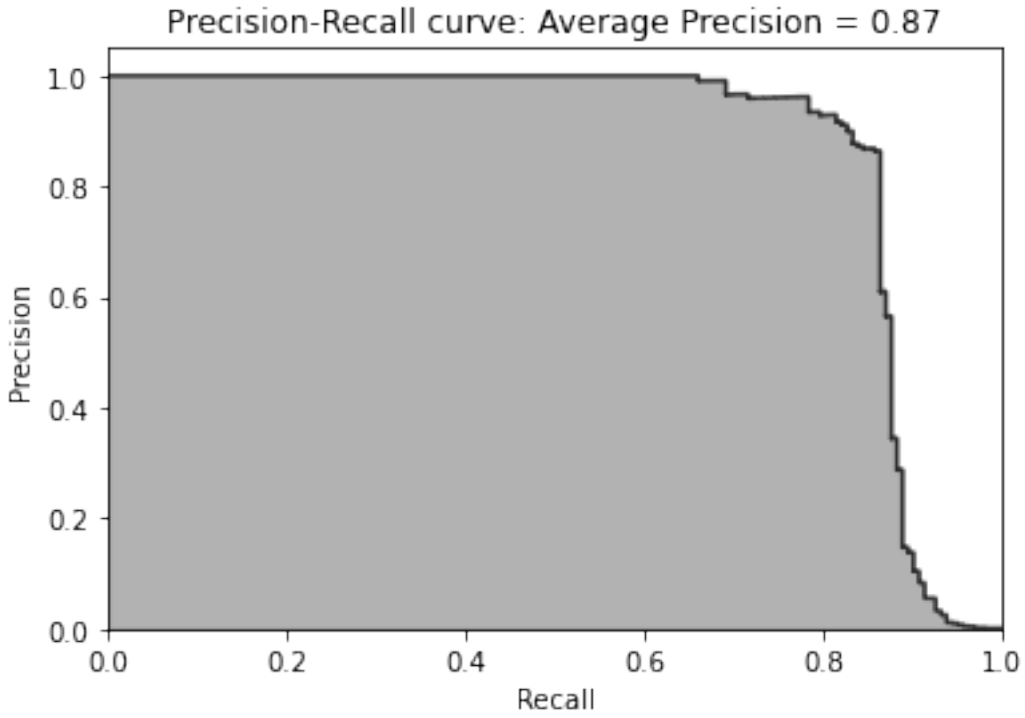
[101]:
```
prCurve(predictionsTestSetRandomForests)
rocCurve(predictionsTestSetRandomForests)
```

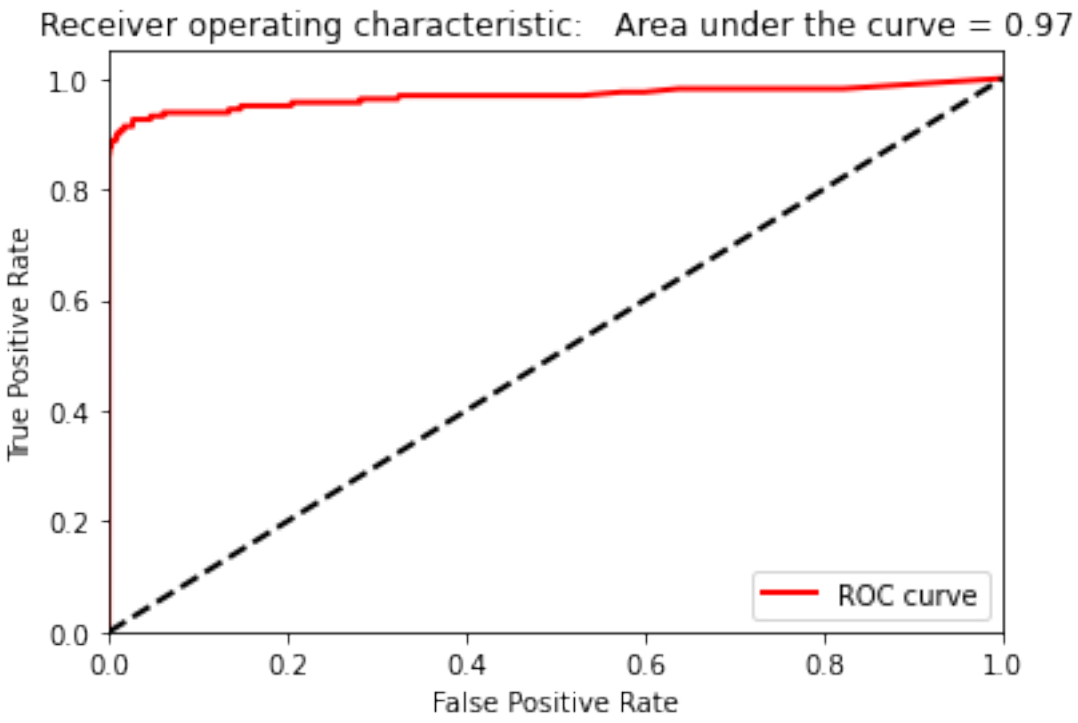

Precision-Recall curve: Average Precision = 0.81
Precision
Recall
0.0
0.2
0.4
0.6
0.8
1.0


Receiver operating characteristic: Area under the curve = 0.93
True Positive Rate
False Positive Rate
ROC curve
0.0
0.2
0.4
0.6
0.8
1.0

2.5.3 XGBoost

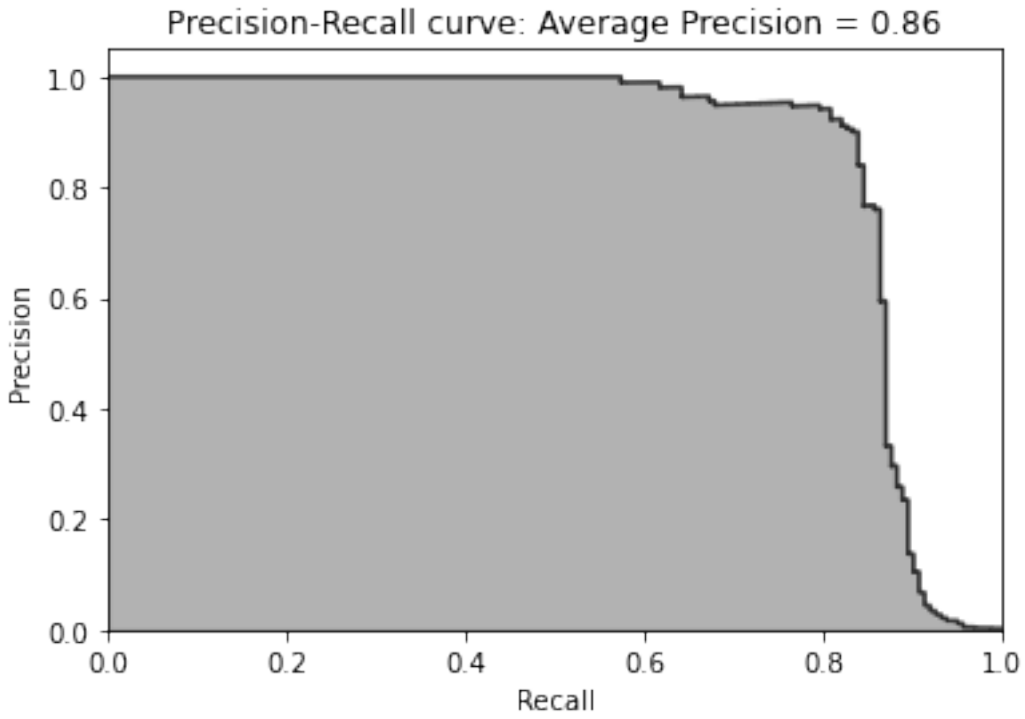
[102]:
```
prCurve(predictionsTestSetXGBoostGradientBoosting)
rocCurve(predictionsTestSetXGBoostGradientBoosting)
```

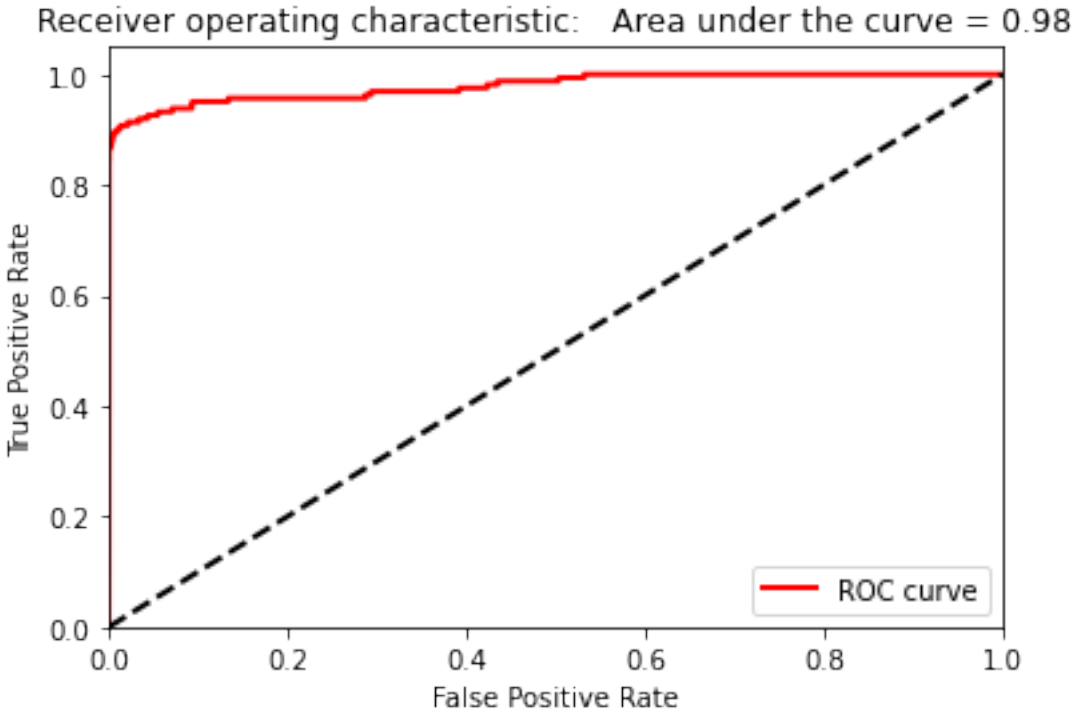




2.5.4 LightGBM

[103]:
```
prCurve(predictionsTestSetLightGBMGradientBoosting)
rocCurve(predictionsTestSetLightGBMGradientBoosting)
```


Precision-Recall curve: Average Precision = 0.86
Precision
Recall
0.0
0.2
0.4
0.6
0.8
1.0


Receiver operating characteristic: Area under the curve = 0.98
True Positive Rate
False Positive Rate
ROC curve
0.0
0.2
0.4
0.6
0.8
1.0

2.6 Conclusion

The results of LightGBM gradient boosting are impressive—we can catch over 80% of the fraudulent transactions with nearly 90% precision (in other words, in catching 80% of the total fraud the LightGBM model gets only 10% of the cases wrong).

[ ]:
```
!wget -nc https://raw.githubusercontent.com/brpy/colab-pdf/master/colab_pdf.py
from colab_pdf import colab_pdf
colab_pdf('Credit_Card.ipynb')
```

```
--2021-08-05 09:25:52--  https://raw.githubusercontent.com/brpy/colab-
pdf/master/colab_pdf.py
Resolving raw.githubusercontent.com (raw.githubusercontent.com)...
185.199.110.133, 185.199.111.133, 185.199.108.133, ...
Connecting to raw.githubusercontent.com
(raw.githubusercontent.com)|185.199.110.133|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1864 (1.8K) [text/plain]
Saving to: colab_pdf.py

colab_pdf.py        100%[===================>]   1.82K  --.-KB/s    in 0s

2021-08-05 09:25:52 (23.7 MB/s) - colab_pdf.py saved [1864/1864]

Mounted at /content/drive/

WARNING: apt does not have a stable CLI interface. Use with caution in scripts.


WARNING: apt does not have a stable CLI interface. Use with caution in scripts.

Extracting templates from packages: 100%
```

[ ]:
```

```