homework8

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SECTION: 113523595
CS 5970: Machine Learning Practices

1 Homework 8: Support Vector Machines

1.1 Assignment Overview

Follow the TODOs and read through and understand any provided code.
Post any questions regarding the assignment, to the Canvas discussion. For all plots, make sure all necessary axes and curves are clearly and accurately labeled. Include figure/plot titles appropriately as well.

1.1.1 Task

For this assignment you will be exploring support vector machines (SVMs) using GridsearchCV and working with highly unbalanced datasets.

1.1.2 Data set

European Cardholder Credit Card Transactions, September 2013
This dataset presents transactions that occurred over two days. There were 492 incidents of frauds out of 284,807 transactions. The dataset is highly unbalanced, the positive class (frauds) accounts for 0.197% of all transactions.

Features
* V1, V2, … V28: are principal components obtained with PCA
* Time: the seconds elapsed between each transaction and the first transaction
* Amount: is the transaction Amount
* Class: the predicted variable; 1 in case of fraud and 0 otherwise.

Given the class imbalance ratio, it is recommended to use precision, recall and the Area Under the Precision-Recall Curve (AUPRC) to evaluate skill. Traditional accuracy and AUC are not meaningful for highly unbalanced classification. These scores are misleading due to the high impact of the large number of negative cases that can easily be identified.

Examining precision and recall is more informative as these disregard the number of correctly identified negative cases (i.e. TN) and focus on the number of correctly identified positive cases (TP) and mis-identified negative cases (FP). Another useful metric is the F1 score which is the harmonic mean of the precision and recall; 1 is the best F1 score.

Confusion Matrix
[TN FP]
[FN TP]

Accuracy = $\frac{TN+TP}{TN+TP+FN+FP}$
TPR = $\frac{TP}{TP+FN}$
FPR = $\frac{FP}{FP+TN}$

Recall = TPR = $\frac{TP}{TP+FN}$
Precision = $\frac{TP}{TP+FP}$
F1 Score = 2 * $\frac{precision*recall}{precision+recall}$

See the references below for more details on precision, recall, and the F1 score.

The dataset was collected and analysed during a research collaboration of Worldline and the Machine Learning Group (http://mlg.ulb.ac.be) of ULB (Université Libre de Bruxelles) on big data mining and fraud detection [1]

[1] Andrea Dal Pozzolo, Olivier Caelen, Reid A. Johnson and Gianluca Bontempi. Calibrating Probability with Undersampling for Unbalanced Classification. In Symposium on Computational Intelligence and Data Mining (CIDM), IEEE, 2015. http://mlg.ulb.ac.be/BruFence . http://mlg.ulb.ac.be/ARTML

1.1.3 Objectives

- Understanding Support Vector Machines
- GridSearch with Classification
- Creating Scoring functions
- Stratification

1.1.4 Notes

- Do not save work within the ml_practices folder

1.1.5 General References

- Guide to Jupyter
- Python Built-in Functions
- Python Data Structures
- Numpy Reference
- Numpy Cheat Sheet
- Summary of matplotlib
- DataCamp: Matplotlib

- Pandas DataFrames
- Sci-kit Learn Linear Models
- Sci-kit Learn Ensemble Models
- Sci-kit Learn Metrics
- Sci-kit Learn Model Selection
- Scoring Parameter
- Scoring
- Plot ROC
- Precision, Recall, F1 Score
- Precision-Recall Curve
- Probability Plot

[99]:
```
# THESE FIRST 3 IMPORTS ARE CUSTOM .py FILES AND CAN BE FOUND ON THE SERVER
# AND GIT
import visualize
import metrics_plots
from pipeline_components import DataSampleDropper, DataFrameSelector

import pandas as pd
import numpy as np
import scipy.stats as stats
import os, re, fnmatch
import pathlib, itertools
import time as timelib
import matplotlib.pyplot as plt

from math import floor, ceil
from matplotlib import cm
from mpl_toolkits.mplot3d import Axes3D
from sklearn.pipeline import Pipeline
from sklearn.base import BaseEstimator, TransformerMixin
from sklearn.impute import SimpleImputer
from sklearn.preprocessing import RobustScaler, StandardScaler
from sklearn.model_selection import cross_val_score, cross_val_predict
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.model_selection import learning_curve, StratifiedKFold
from sklearn.metrics import make_scorer, precision_recall_curve
from sklearn.metrics import confusion_matrix, precision_score
from sklearn.metrics import roc_curve, auc, f1_score, recall_score
from sklearn.svm import SVC
from sklearn.externals import joblib

HOME_DIR = pathlib.Path.home()
CW_DIR = pathlib.Path.cwd()

FIGW = 12
FIGH = 5
```

```
FONTSIZE = 8

plt.rcParams['figure.figsize'] = (FIGW, FIGH)
plt.rcParams['font.size'] = FONTSIZE

plt.rcParams['xtick.labelsize'] = FONTSIZE
plt.rcParams['ytick.labelsize'] = FONTSIZE

%matplotlib inline
```

2 LOAD DATA

[100]:
```
# 284806 rows, 'None' to read whole file
nRowsRead = None

# TODO: set appropriately
filename = 'creditcard.csv'

crime_stats_full = pd.read_csv(filename, delimiter=',', nrows=nRowsRead)
crime_stats_full.dataframeName = 'creditcard.csv'
nRows, nCols = crime_stats_full.shape
print(f'There are {nRows} rows and {nCols} columns')
```

```
There are 284806 rows and 31 columns
```

[101]:
```
""" PROVIDED
good (negative case = 0)
fraud (positive case = 1)
"""
targetnames = ['good', 'fraud']

pos_full = crime_stats_full.loc[crime_stats_full['Class'] == 1]
neg_full = crime_stats_full.loc[crime_stats_full['Class'] == 0]

pos_full.shape, neg_full.shape
```

[101]:
```
((492, 31), (284314, 31))
```

[102]:
```
""" PROVIDED
Compute the postive fraction
"""
pos_fraction = pos_full.shape[0] / nRows
neg_fraction = 1 - pos_fraction

pos_fraction, neg_fraction
```

[102]: (0.001727491696101908, 0.9982725083038981)

[103]:
```
""" PROVIDED
Select Random Subset of data
"""
np.random.seed(42)
subset_size = 20000
selected_indices = np.random.choice(range(nRows), size=subset_size,␣
 ↪replace=False)
selected_indices
```

[103]: array([43428, 49906, 29474, …, 192406, 124100, 12947])

[104]:
```
""" PROVIDED
List the features and shape of the data
"""
crime_stats = crime_stats_full.loc[selected_indices, :]
crime_stats.columns, crime_stats.shape
```

[104]:
```
(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'), (20000, 31))
```

[105]:
```
""" PROVIDED
Display whether there are any NaNs
"""
crime_stats.isna().any()
```

[105]:
```
Time      False
V1        False
V2        False
V3        False
V4        False
V5        False
V6        False
V7        False
V8        False
V9        False
V10       False
V11       False
V12       False
V13       False
V14       False
V15       False
V16       False
```

```
V17       False
V18       False
V19       False
V20       False
V21       False
V22       False
V23       False
V24       False
V25       False
V26       False
V27       False
V28       False
Amount    False
Class     False
dtype: bool
```

[106]:

```python
""" TODO
Display summary statistics for each feature of the dataframe
"""
crime_stats.describe()
```

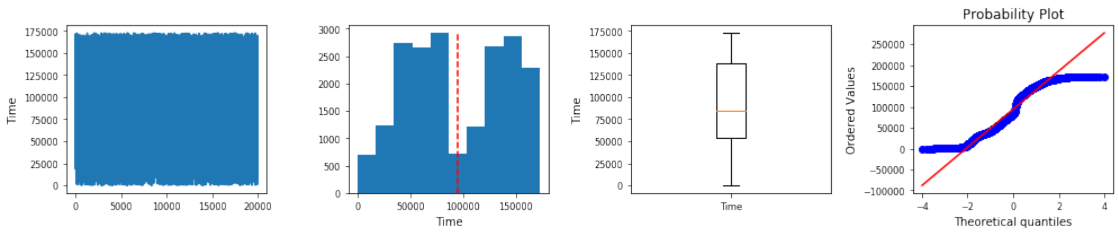
[106]:

```
                Time            V1            V2            V3            V4  \
count   20000.000000  20000.000000  20000.000000  20000.000000  20000.000000
mean    94490.802400      0.002913     -0.029847     -0.001526      0.018716
std     47313.538305      2.011012      1.721684      1.545744      1.414560
min         0.000000    -40.042538    -48.060856    -30.177317     -5.266509
25%     54111.000000     -0.916870     -0.607590     -0.904430     -0.840008
50%     84335.500000      0.041402      0.053039      0.186126      0.003204
75%    139023.250000      1.329557      0.780855      1.047085      0.758450
max    172782.000000      2.451888     16.497472      9.382558     12.699542

                 V5            V6            V7            V8            V9  \
count  20000.000000  20000.000000  20000.000000  20000.000000  20000.000000
mean      -0.009522     -0.002003     -0.008675      0.004225     -0.000767
std        1.390694      1.325199      1.223386      1.172031      1.105181
min      -23.611865    -20.869626    -31.197329    -37.353443     -9.462573
25%       -0.713130     -0.761379     -0.564197     -0.206495     -0.644663
50%       -0.066121     -0.270283      0.025205      0.021737     -0.048547
75%        0.593397      0.393435      0.562905      0.325365      0.597407
max       26.647697     16.493227     21.437514     17.052566     15.594995

       …           V21           V22           V23           V24  \
count  …  20000.000000  20000.000000  20000.000000  20000.000000
mean   …     -0.002876      0.000937      0.002760      0.000499
std    …      0.714353      0.719430      0.616109      0.603601
min    …    -13.963731     -8.887017    -22.575000     -2.824849
25%    …     -0.228380     -0.543027     -0.161554     -0.352267
```

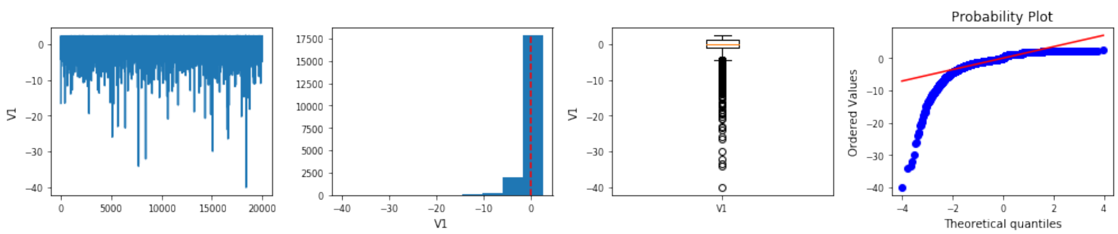
```
50%    ...   -0.030045   0.007540   -0.011669   0.044262
75%    ...    0.181191   0.526424    0.147149   0.441184
max    ...   27.202839   4.080214   19.002942   3.546031

                V25           V26           V27           V28        Amount  \
count  20000.000000  20000.000000  20000.000000  20000.000000  20000.000000
mean       0.004572     -0.003928     -0.000498     -0.001587     89.525975
std        0.517540      0.478031      0.437142      0.349640    247.838774
min       -4.196468     -2.068561    -22.565679    -11.710896      0.000000
25%       -0.311738     -0.325381     -0.070359     -0.052049      5.760000
50%        0.027412     -0.055531      0.001234      0.010908     22.035000
75%        0.351777      0.231973      0.088768      0.078558     77.720000
max        4.513681      2.952093      9.200883     16.129609   8787.000000

             Class
count  20000.00000
mean       0.00155
std        0.03934
min        0.00000
25%        0.00000
50%        0.00000
75%        0.00000
max        1.00000

[8 rows x 31 columns]
```

3 VISUALIZE DATA

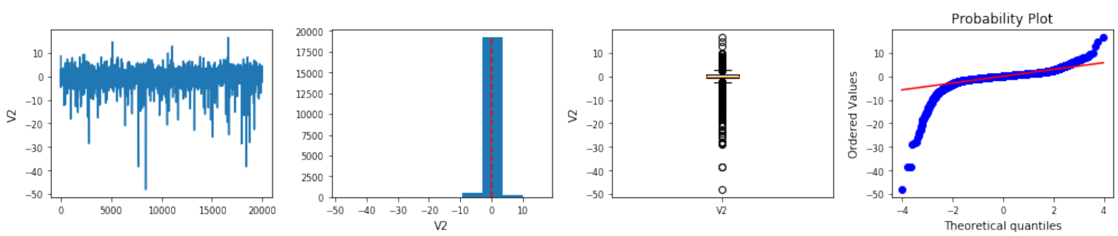
[107]:
```python
""" TODO
Display the distributions of the data
use visualize.featureplots(crime_stats_dropna.values, crime_stats.columns)
to generate trace plots, histograms, boxplots, and probability plots for
each feature.

A probability plot is utilized to evaulate the normality of a distribution.
The data are plot against a theoritical distribution, such that if the data
are normal, they'll follow the diagonal line. See the reference above for
more information.
"""
crime_stats_dropna = crime_stats.dropna()
# TODO: visualize the features
visualize.featureplots(crime_stats_dropna.values, crime_stats.columns)

# Right click to enable scrolling
```



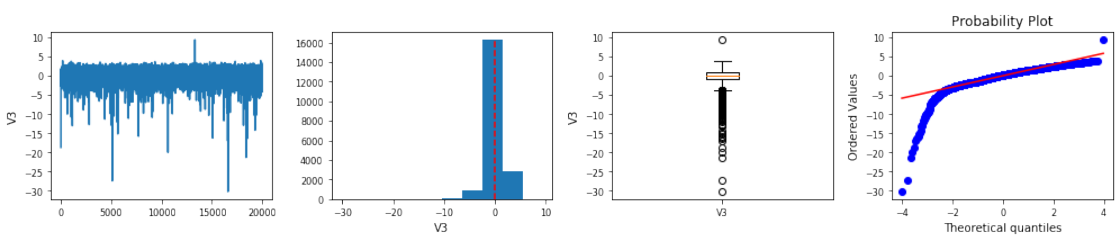
myplots Time



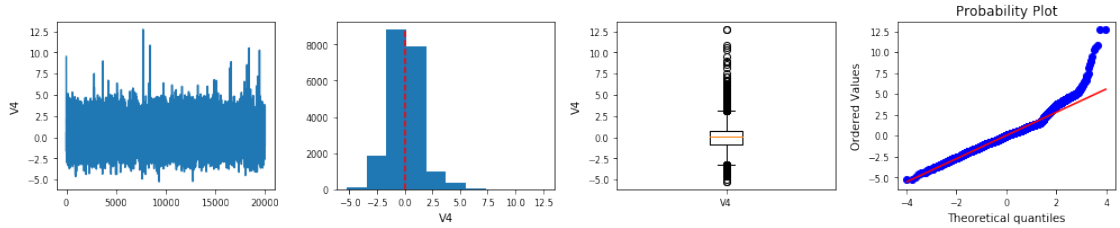
myplots V1



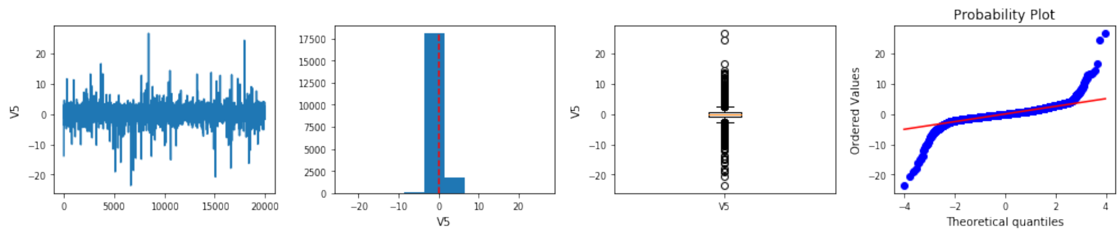
myplots V2



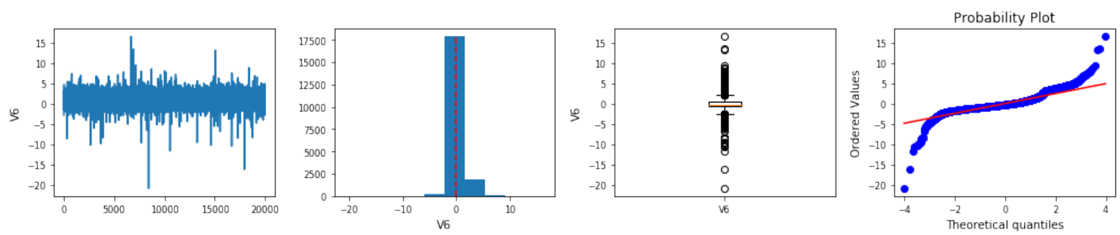
myplots V3



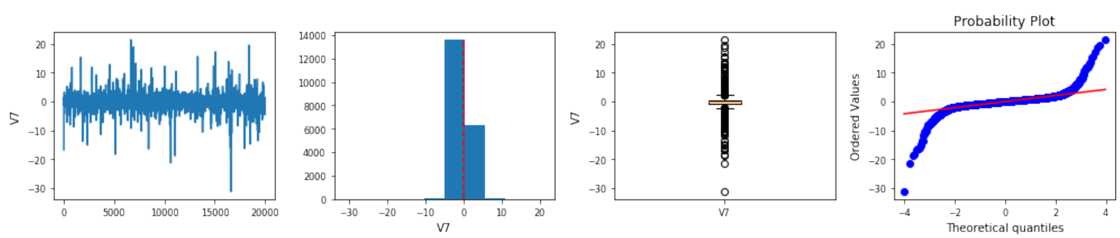
myplots V4



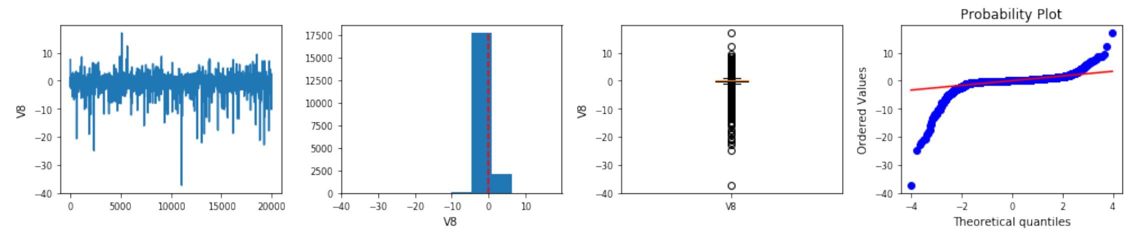
myplots V5



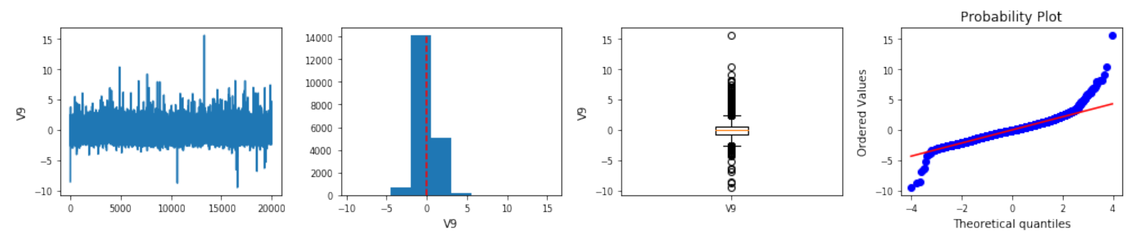
myplots V6



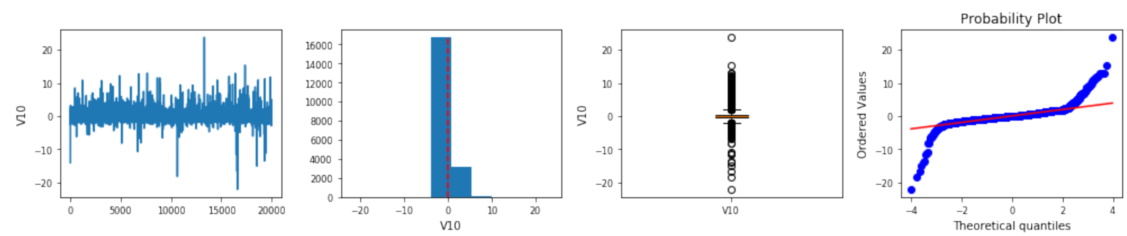
myplots V7



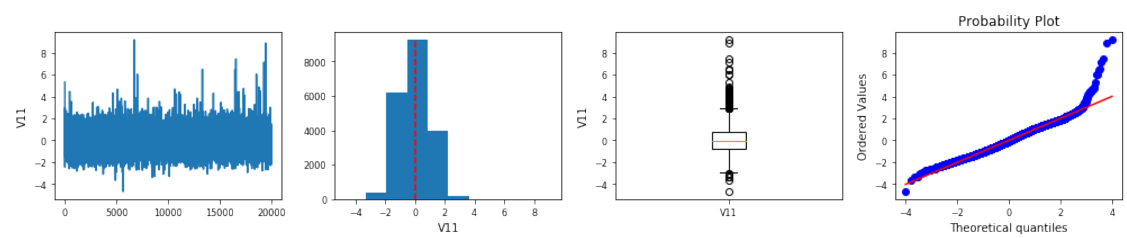
myplots V8



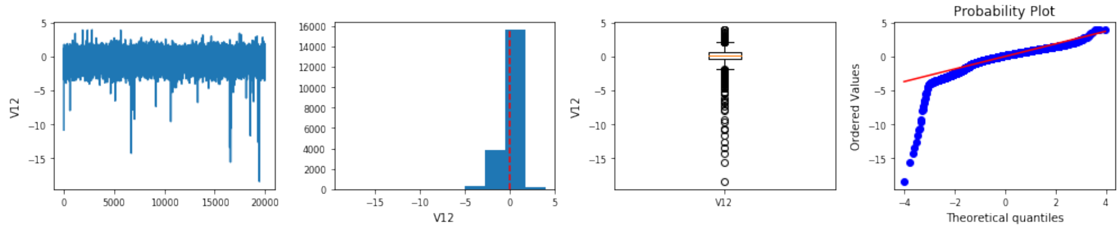
myplots V9



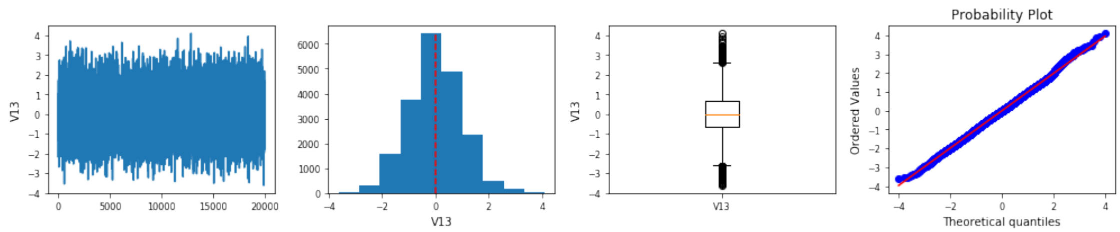
myplots V10



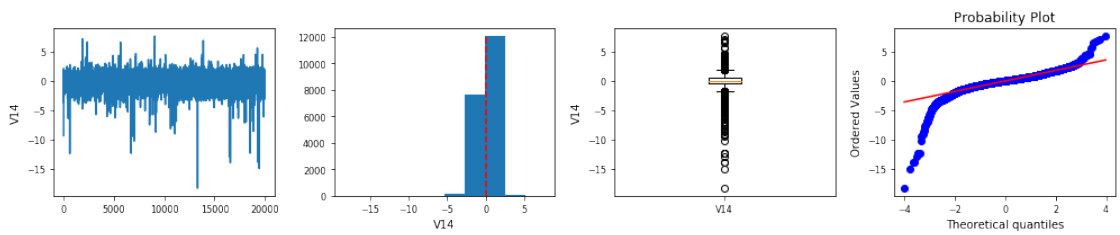
myplots V11



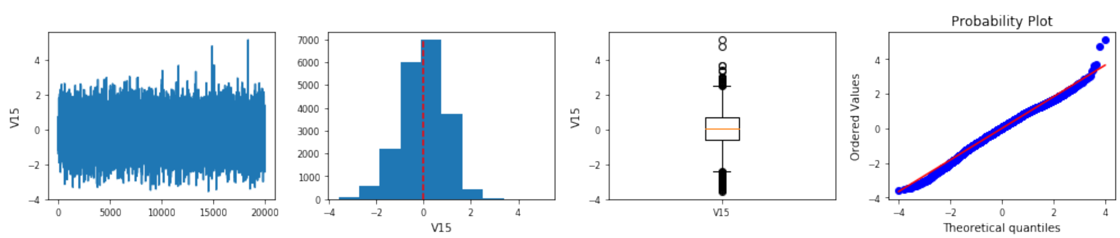
myplots V12



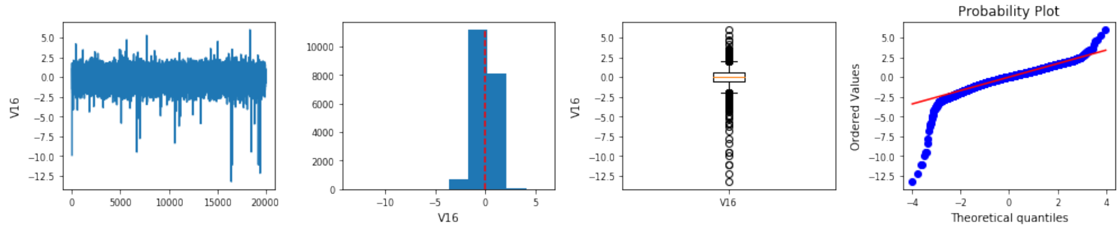
myplots V13



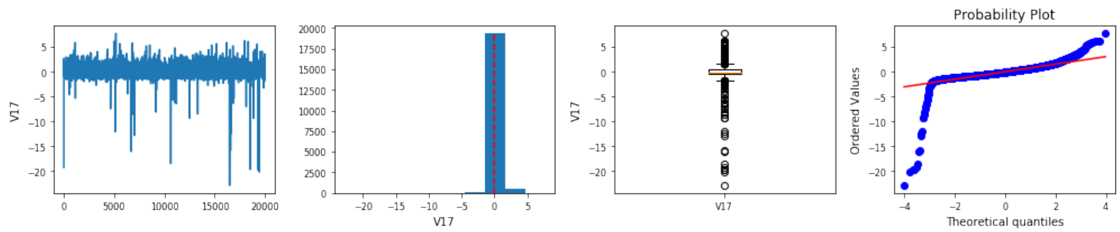
myplots V14



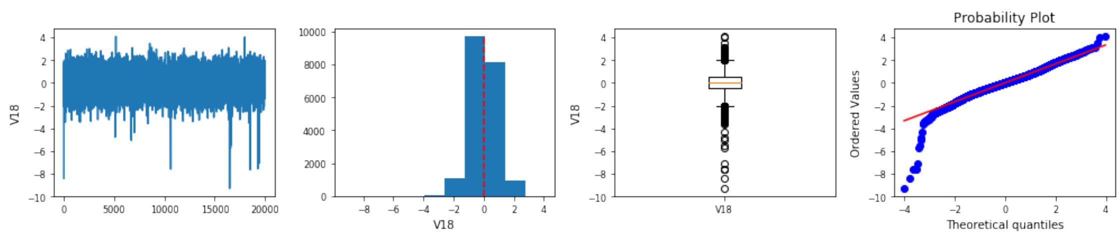
myplots V15



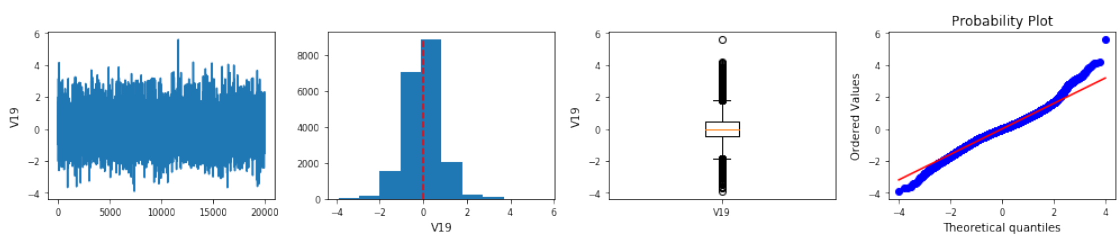
myplots V16



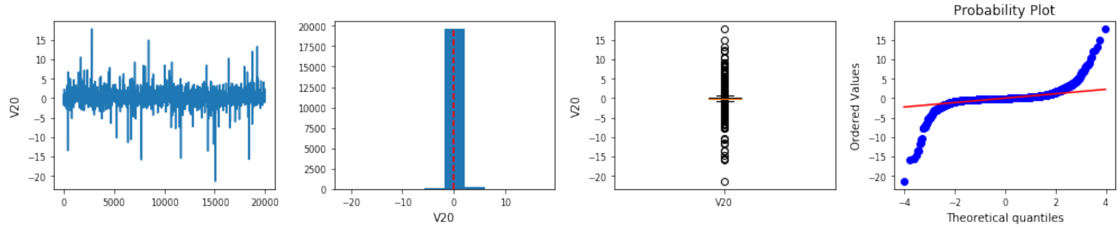
myplots V17



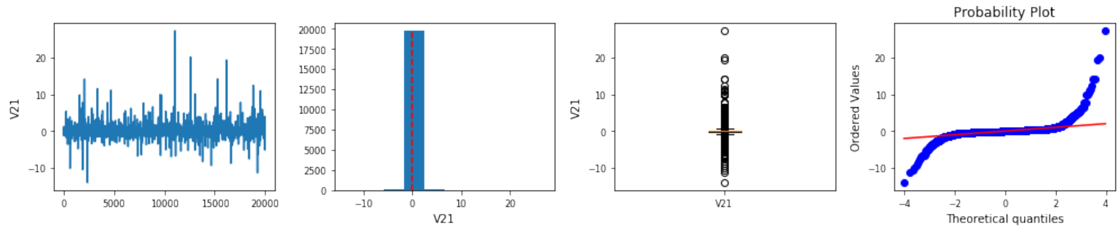
myplots V18



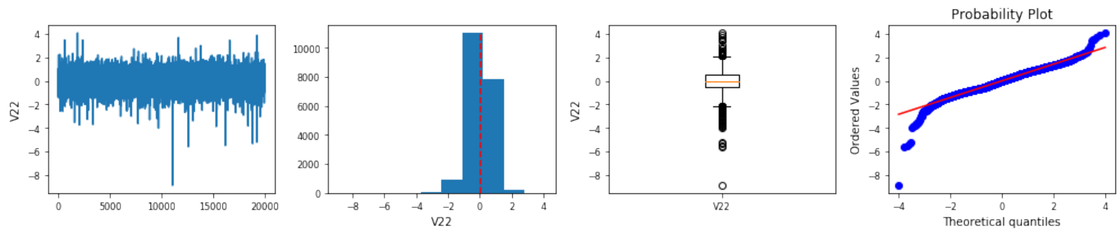
myplots V19



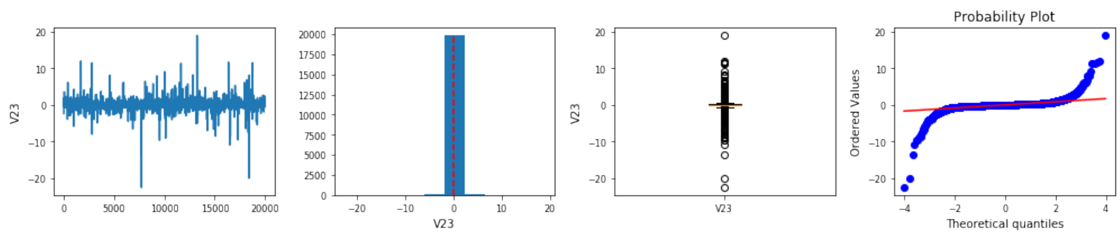
myplots V20



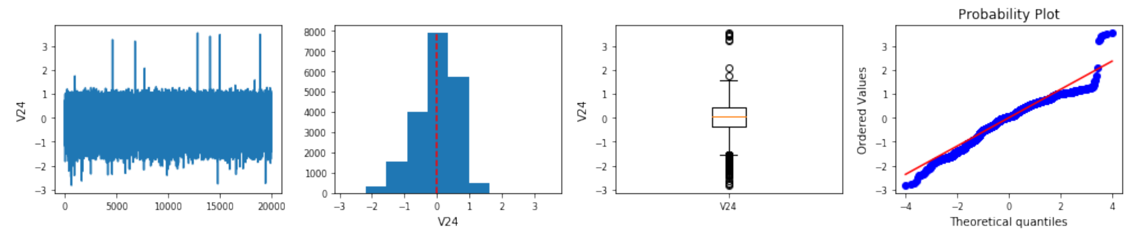
myplots V21



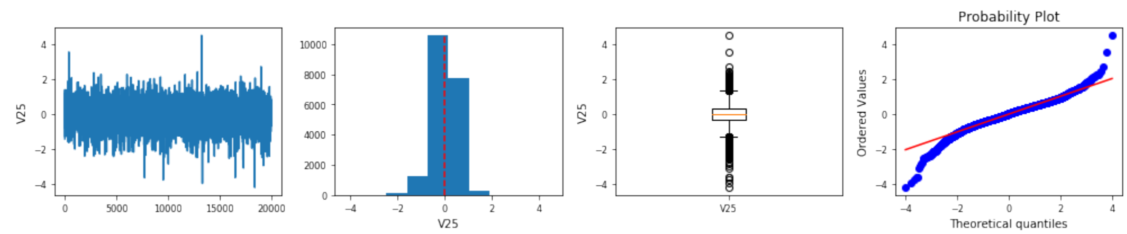
myplots V22



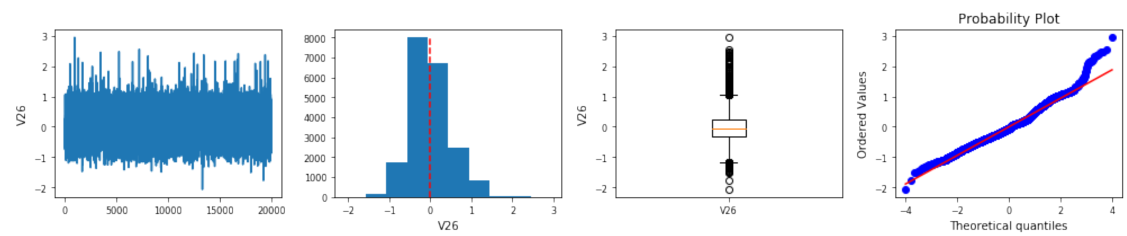
myplots V23



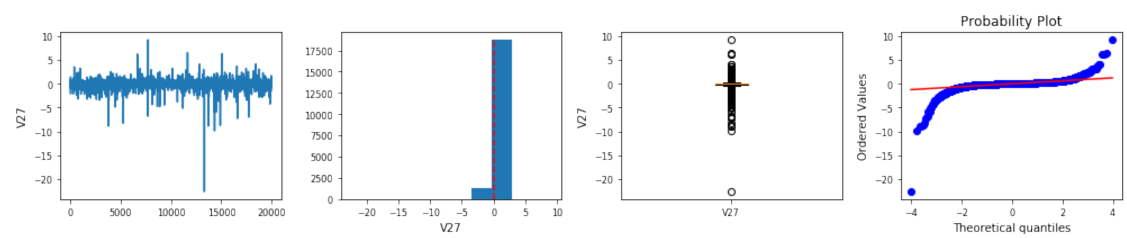
myplots V24



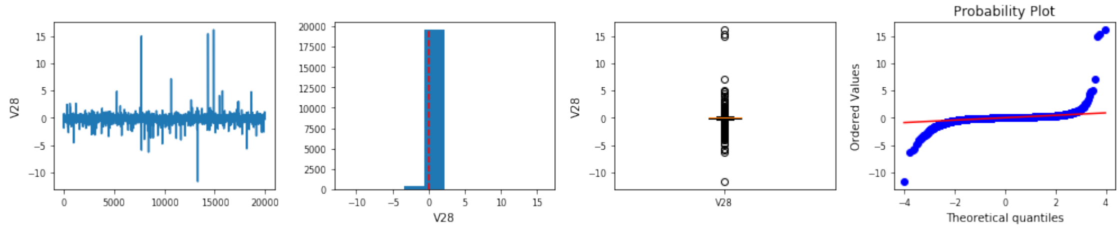
myplots V25



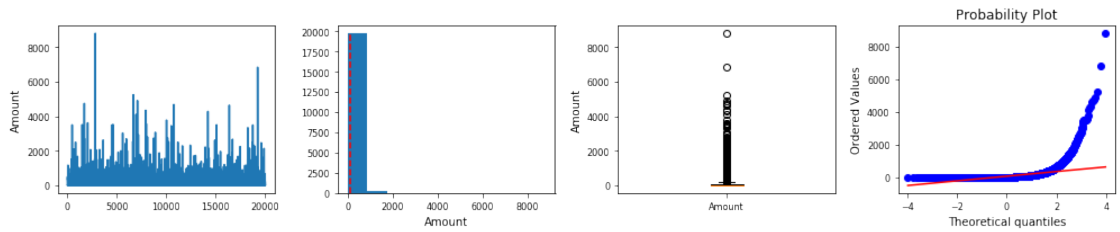
myplots V26



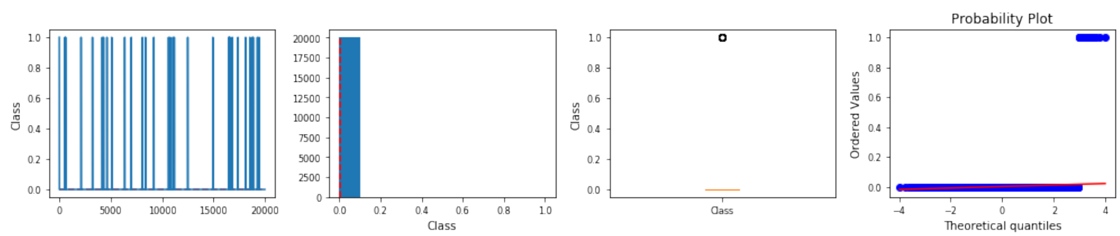
myplots V27



myplots V28

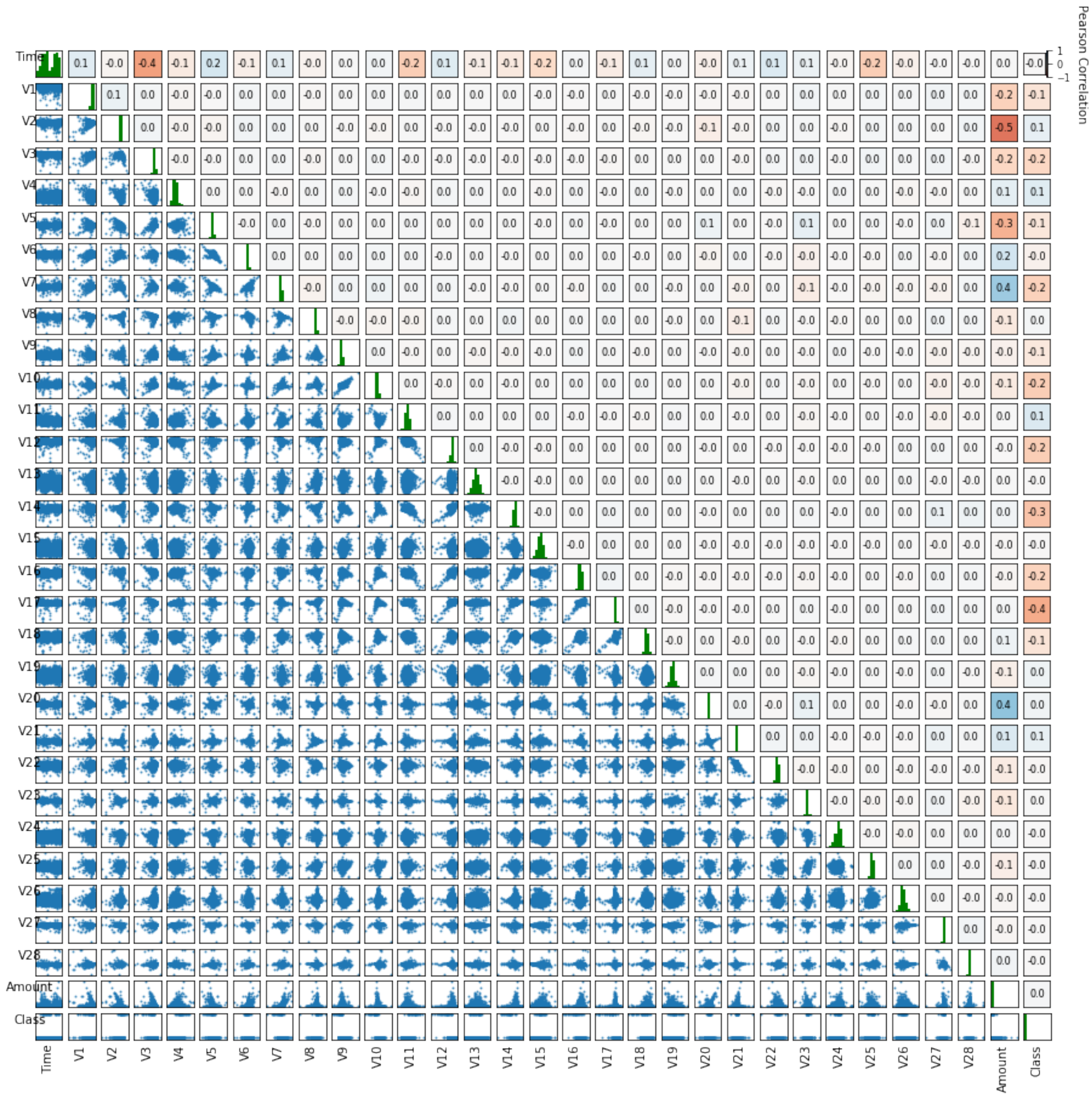


myplots Amount



myplots Class

[108]:
```
""" PROVIDED
Display the Pearson correlation between all pairs of the features
use visualize.scatter_corrplots(crime_stats_dropna.values, crime_stats.columns,␣
 ↪corrfmt="%.1f", FIGW=15)
"""
visualize.scatter_corrplots(crime_stats_dropna.values, crime_stats.columns,␣
 ↪corrfmt="%.1f", FIGW=15)
```



[109]:
```python
""" PROVIDED
Separate the postive and negative examples
"""
pos = crime_stats.loc[crime_stats['Class'] == 1]
neg = crime_stats.loc[crime_stats['Class'] == 0]

pos.shape, neg.shape
```

[109]: ((31, 31), (19969, 31))

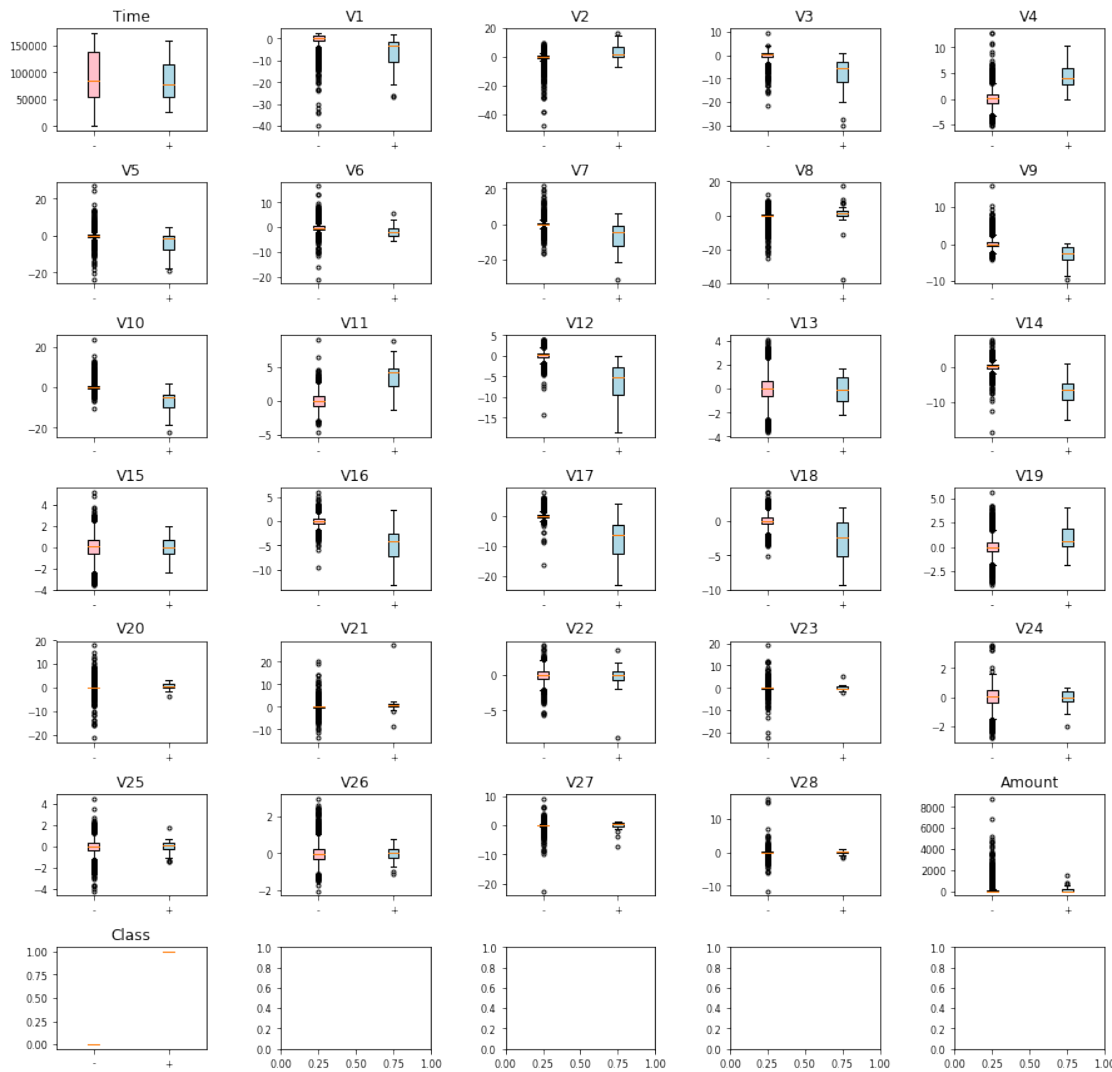
[110]:
```python
""" PROVIDED
Compute the postive fraction
"""
```

```
pos_fraction = pos.shape[0] / nRows
neg_fraction = 1 - pos_fraction

pos_fraction, neg_fraction
```

[110]: (0.00010884602150235599, 0.9998911539784976)

[111]:
```
""" PROVIDED
Compare the features for the positive and negative examples
"""
features_displayed = pos.columns
ndisplayed = len(features_displayed)
ncols = 5
nrows = ceil(ndisplayed / ncols)

fig, axs = plt.subplots(nrows, ncols, figsize=(15, 15))
fig.subplots_adjust(wspace=.5, hspace=.5)
axs = axs.ravel()
for ax, feat_name in zip(axs, features_displayed):
    boxplot = ax.boxplot([neg[feat_name], pos[feat_name]], patch_artist=True,␣
↪sym='.')
    boxplot['boxes'][0].set_facecolor('pink')
    boxplot['boxes'][1].set_facecolor('lightblue')
    ax.set_xticklabels(['-', '+'])
    ax.set(title=feat_name)
""""""
```

[111]: ''



4 PRE-PROCESS DATA

4.1 Data Clean Up and Feature Selection

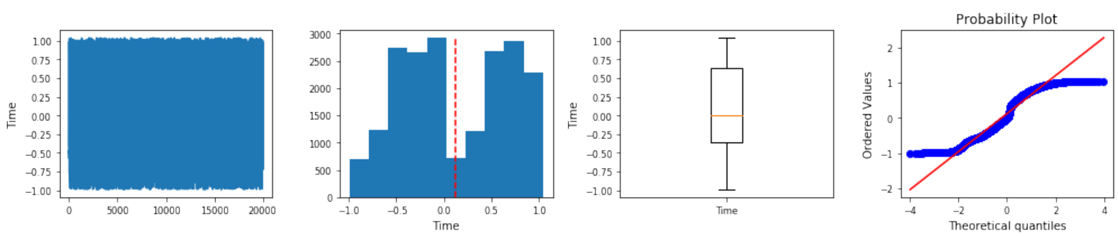
[112]:
```
""" PROVIDED
Construct Pipeline to pre-process data
"""
feature_names = crime_stats.columns.drop(['Class'])
pipe_X = Pipeline([
    ("NaNrowDropper", DataSampleDropper()),
    ("selectAttribs", DataFrameSelector(feature_names)),
    ("scaler", RobustScaler())
```

```
])

pipe_y = Pipeline([
    ("NaNrowDropper", DataSampleDropper()),
    ("selectAttribs", DataFrameSelector(['Class']))
])
```

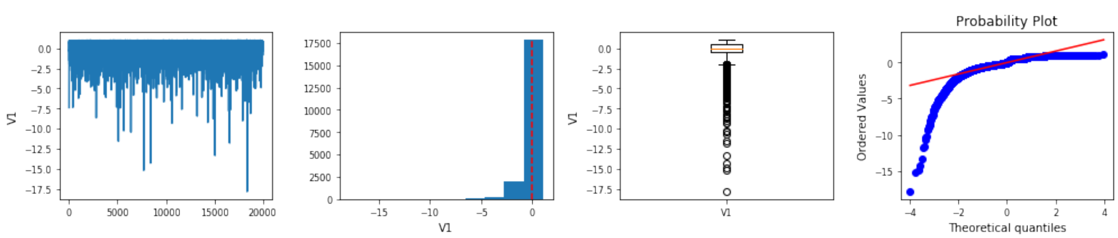
[113]:
```
""" TODO
Pre-process the data using the pipeliine
"""

X= pipe_X.fit_transform(crime_stats)
y= pipe_y.fit_transform(crime_stats)

np.any(np.isnan(X))
```

[113]: False

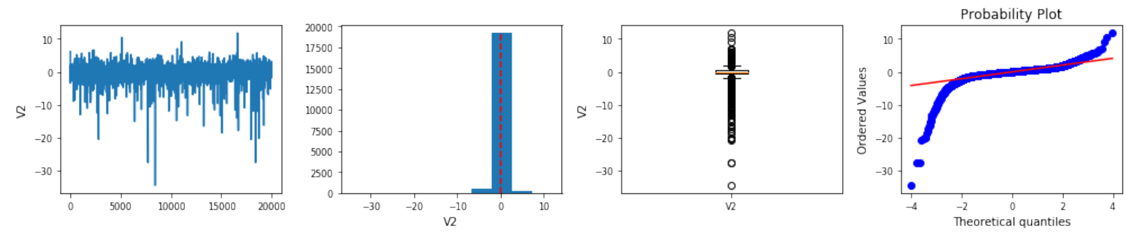
[114]:
```
""" TODO
Re-visualize the pre-processed data
use visualize.featureplots()
"""

visualize.featureplots(X, feature_names)
```



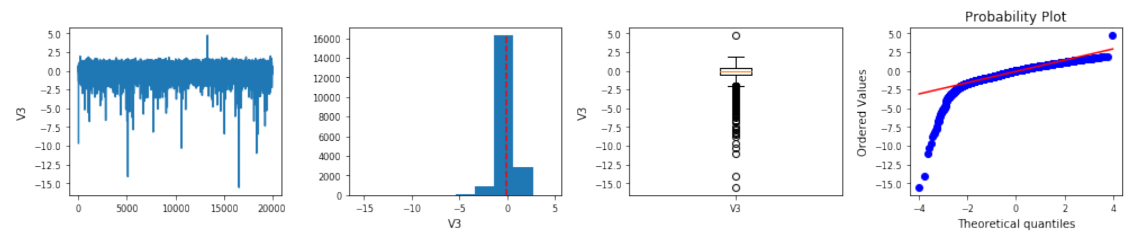
myplots Time



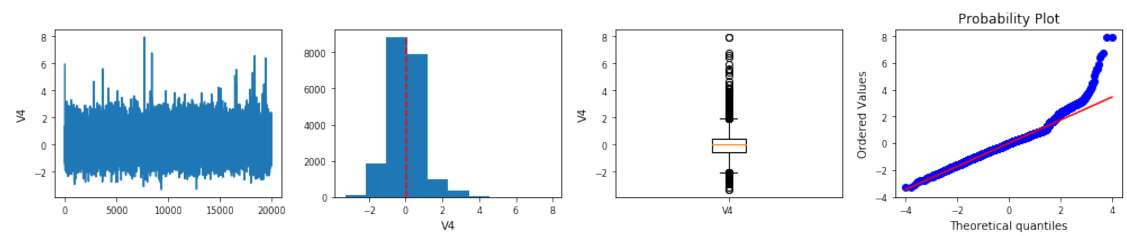
myplots V1



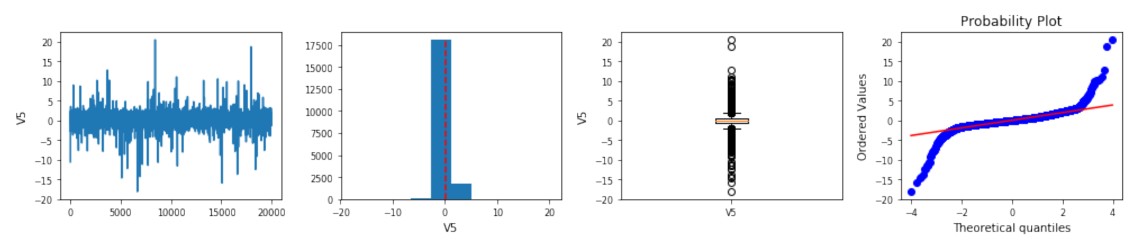
myplots V2



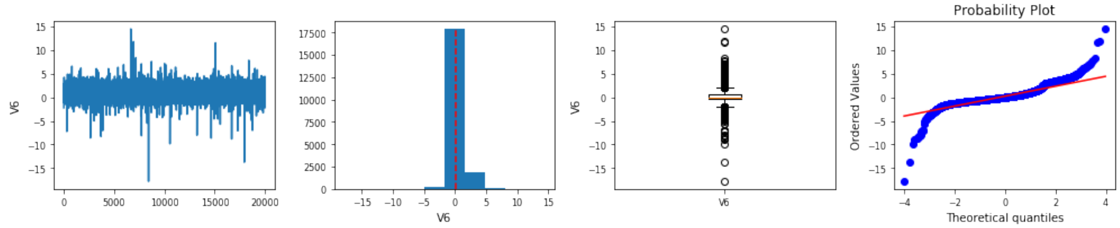
myplots V3



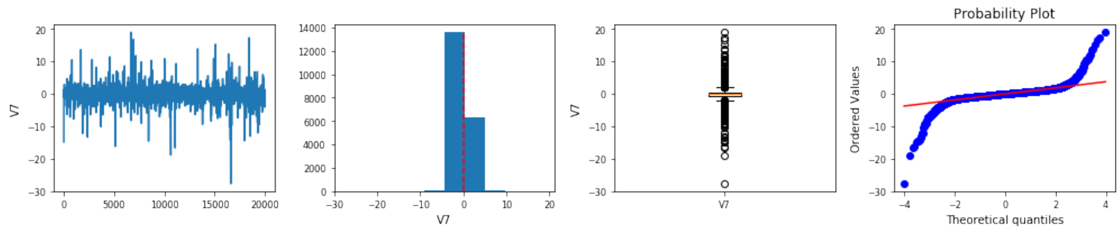
myplots V4



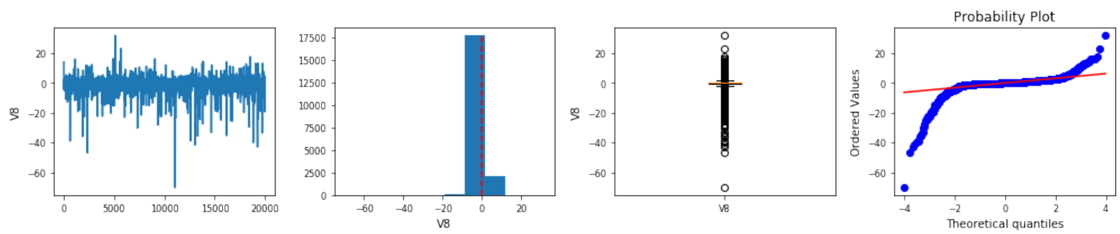
myplots V5



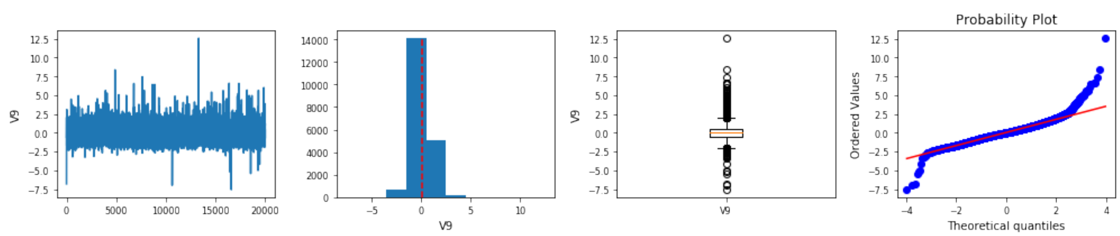
myplots V6



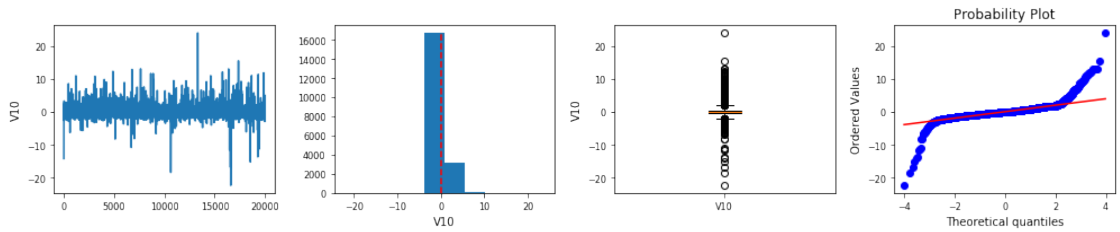
myplots V7



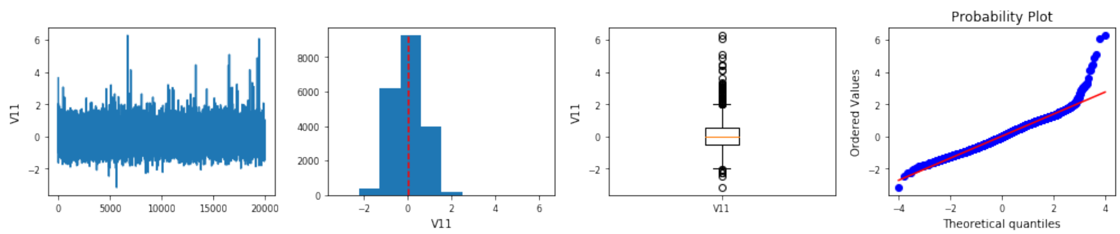
myplots V8



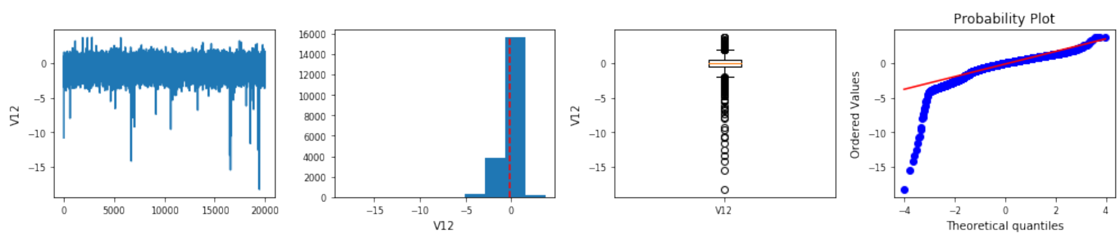
myplots V9



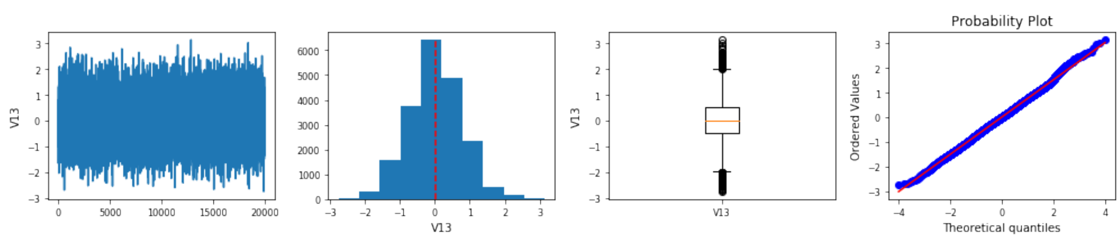
myplots V10



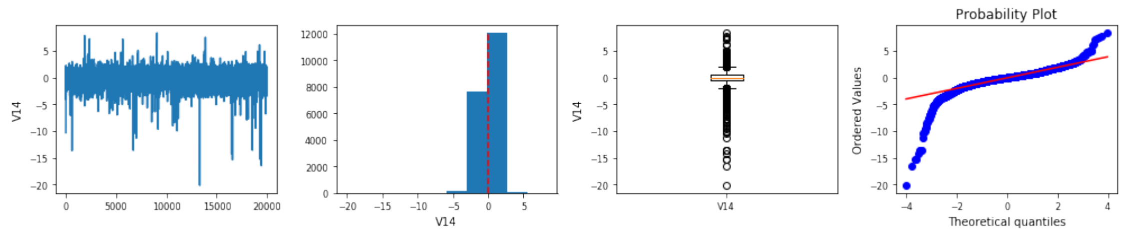
myplots V11



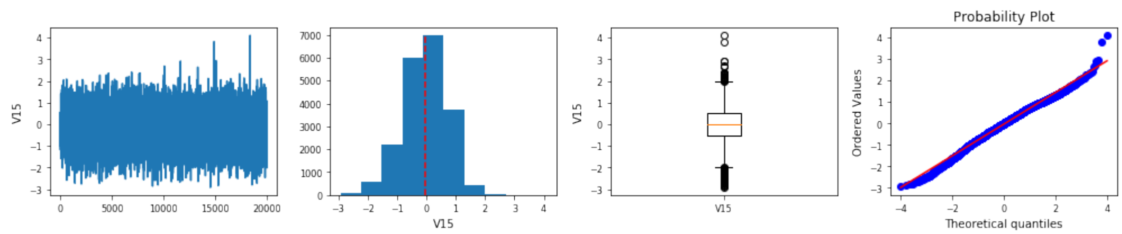
myplots V12



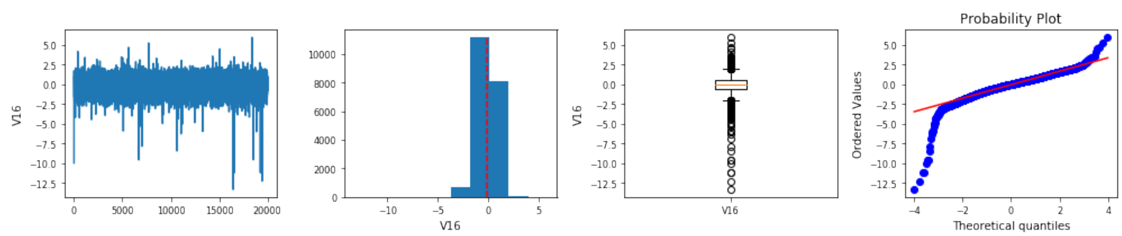
myplots V13



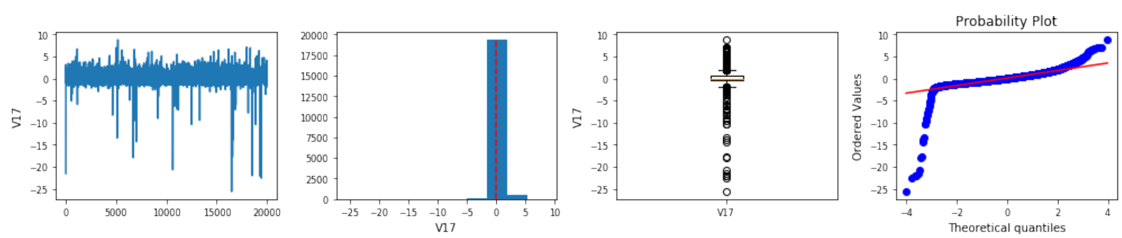
myplots V14



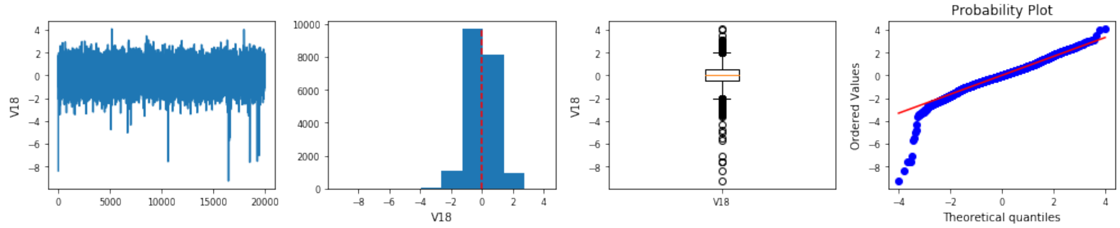
myplots V15



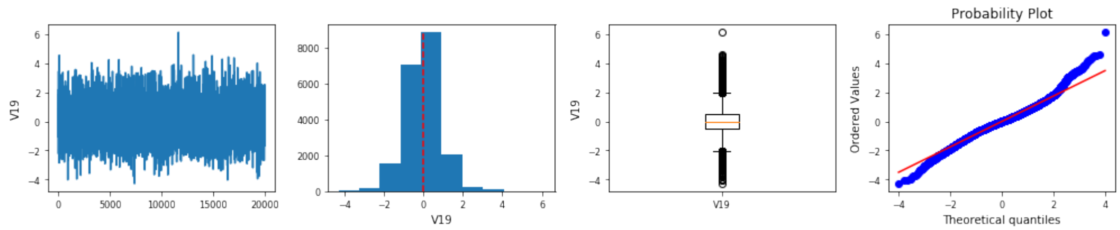
myplots V16



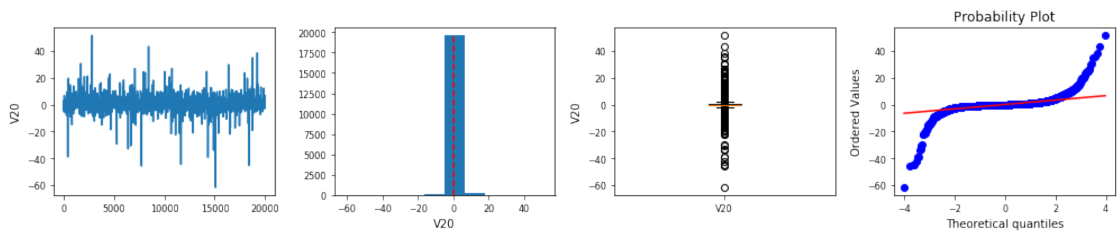
myplots V17



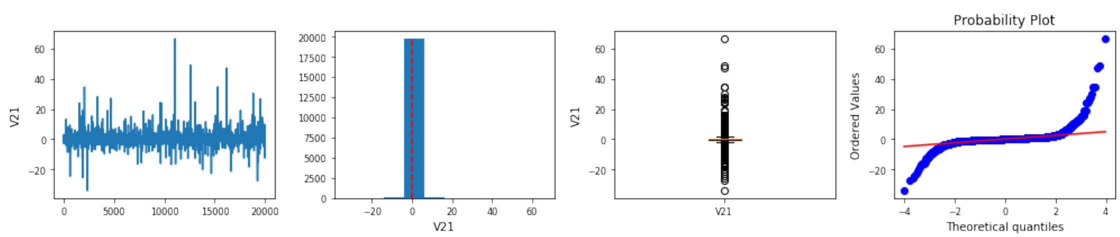

```
myplots V18
```



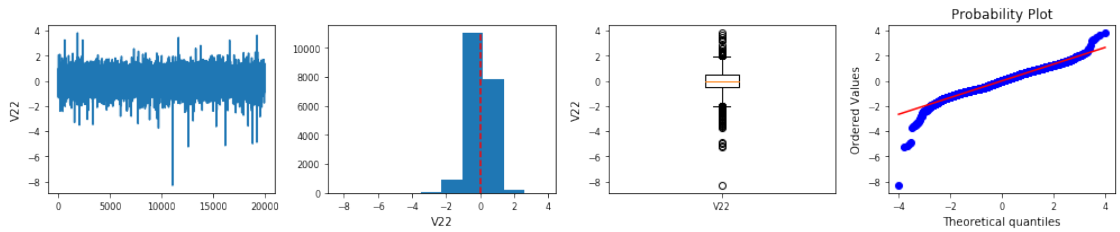

```
myplots V19
```



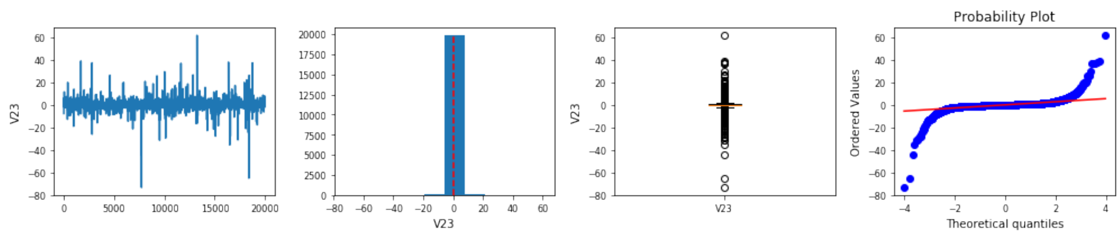

```
myplots V20
```



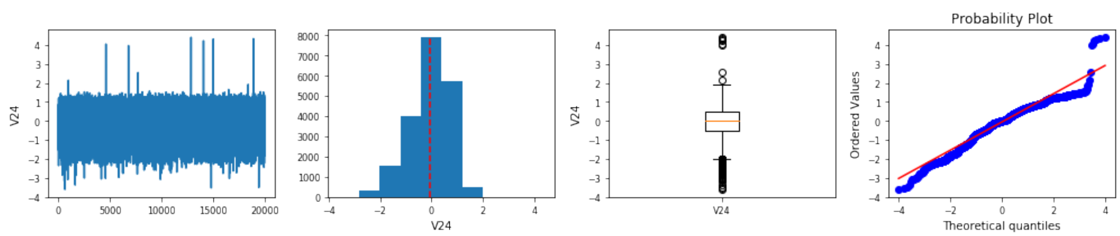

```
myplots V21
```



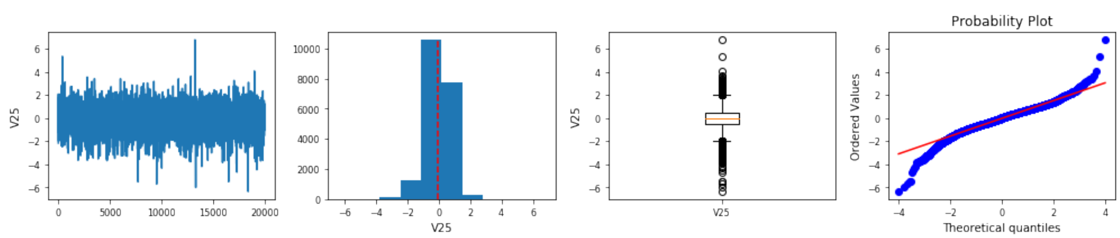
myplots V22



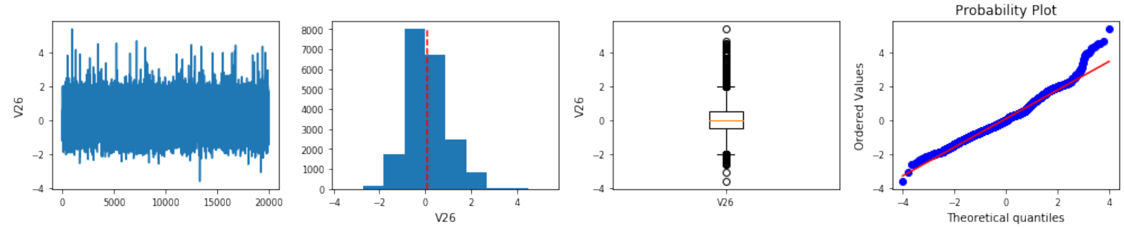
myplots V23



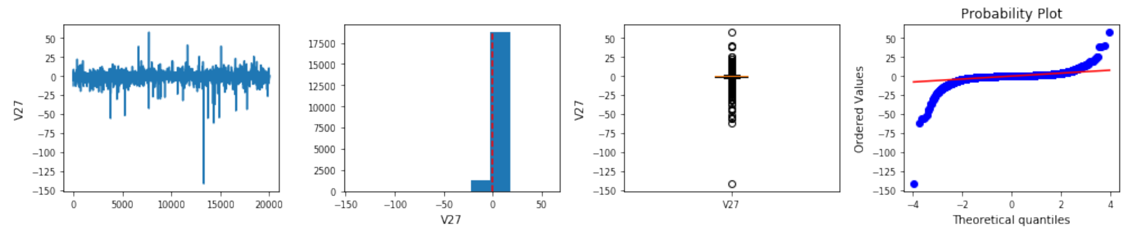
myplots V24



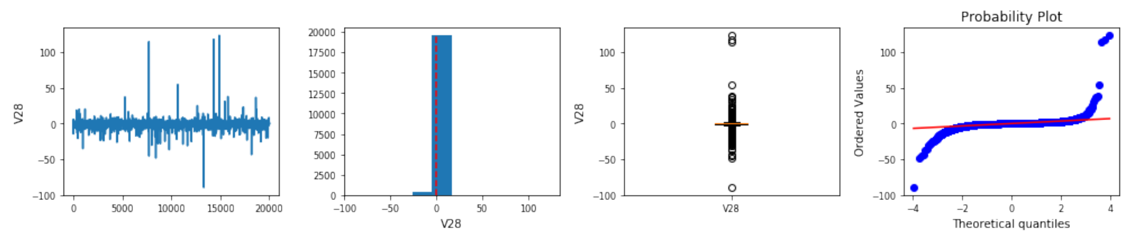
myplots V25



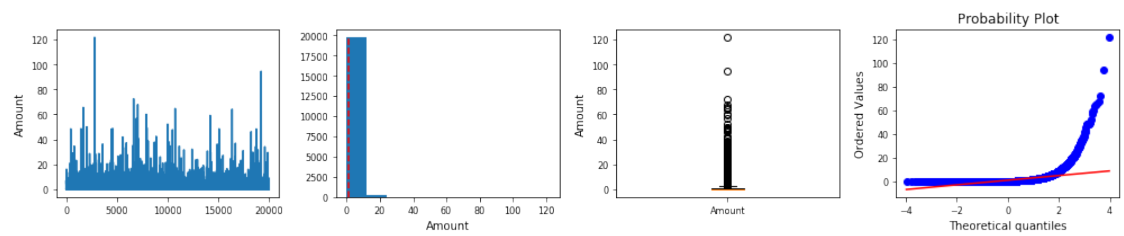
myplots V26



myplots V27



myplots V28



myplots Amount

5 SVMs: EXPLORATION

[127]:
```
""" TODO
Hold out a subset of the data, before training and cross validation
using train_test_split, with stratify NOT equal to None, and a test_size
fraction of .2.

For this exploratory section, the held out set of data is a validation set.
For the GridSearch section, the held out set of data is a test set.
"""

Xtrain, Xtest, ytrain, ytest= train_test_split(X, y, test_size= .2, stratify=y)
```

[128]:
```
""" TODO
Create and train SVC models.
Explore various configurations of the hyper-parameters.
Train the models on the training set and evaluate them for the training and
validation sets.

Play around with C, gamma, and class_weight. Feel free to play with other hyper-
parameters as well. See the API for more details.
C is a regularization parameter, gamma is the inverse of the radius of influence
of the support vectors (i.e. lower gamma means a higher radius of influence of␣
↪the
support vectors), and class weight determines whether to adjust the weights␣
↪inversely
to the class fractions.
"""

model= SVC(C= 0.1, gamma='auto', class_weight= 'balanced', random_state=42)
model.fit(Xtrain, ytrain)
```

```
/opt/conda/lib/python3.7/site-packages/sklearn/utils/validation.py:761:
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)
```

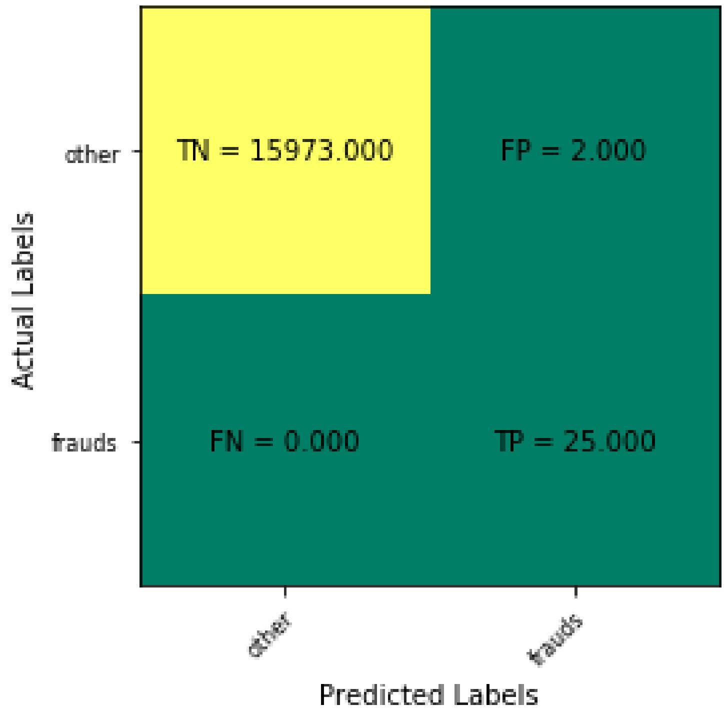
[128]:
```
SVC(C=0.1, cache_size=200, class_weight='balanced', coef0=0.0,
  decision_function_shape='ovr', degree=3, gamma='auto', kernel='rbf',
  max_iter=-1, probability=False, random_state=42, shrinking=True,
  tol=0.001, verbose=False)
```

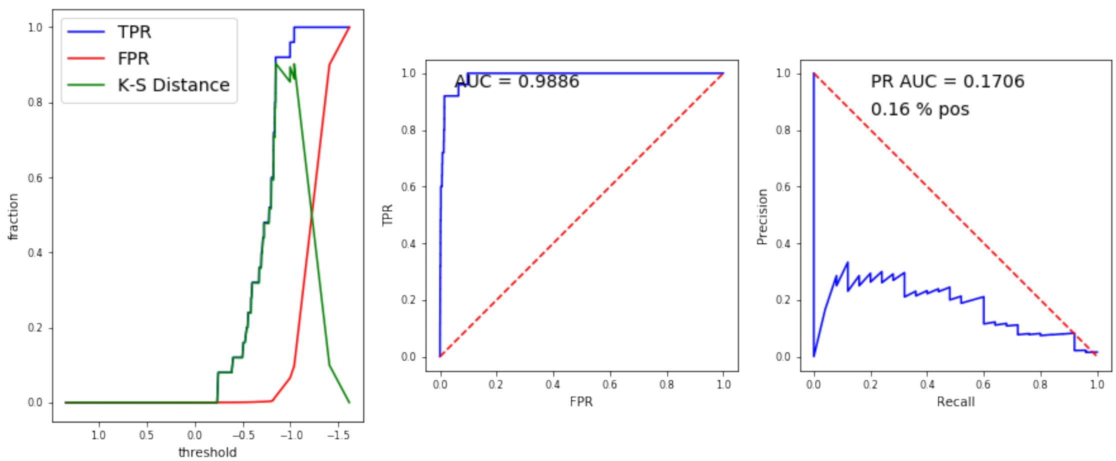
[129]:
```
""" TODO
Evaluate training set performance.
Display the confusion matrix, KS plot with
the cumulative distributions of the TPR and FPR, the ROC curve and the
```

```
precision-recall curve (PRC). use metrics_plots.ks_roc_prc_plot(ytrue, scores)

The PRC, unlike the AUC, does not consider the true negative (i.e. TN) counts,
making the PRC more robust to unbalanced datasets.
"""
# TODO: Confusion matrix
# First, compute the predictions for the training set
# Second, use confusion_matrix
# Third, use metrics_plots.confusion_mtx_colormap() to display the matrix
preds = model.predict(Xtrain)
confusionMat = confusion_matrix(ytrain, preds)
metrics_plots.confusion_mtx_colormap(confusionMat, ['other', 'frauds'],␣
 ↪['other', 'frauds'])



# TODO: Curves
# First, use the model's decision function to compute the scores
# Second, use metrics_plots.ks_roc_prc_plot() to display the KS plot, ROC, and␣
 ↪PRC
scores= cross_val_predict(model, Xtrain, ytrain, cv=20, method=␣
 ↪'decision_function')
metrics_plots.ks_roc_prc_plot(ytrain ,scores)


pss_train = metrics_plots.skillScore(ytrain.values, preds)
f1_train = f1_score(ytrain.values.ravel(), preds)
print("PSS: %.4f" % pss_train[0])
print("F1 Score %.4f" % f1_train)
```

```
/opt/conda/lib/python3.7/site-packages/sklearn/preprocessing/label.py:235:
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)
```

```
ROC AUC: 0.9885533646322379
PRC AUC: 0.17062531753598112
PSS: 0.9999
F1 Score 0.9615
```





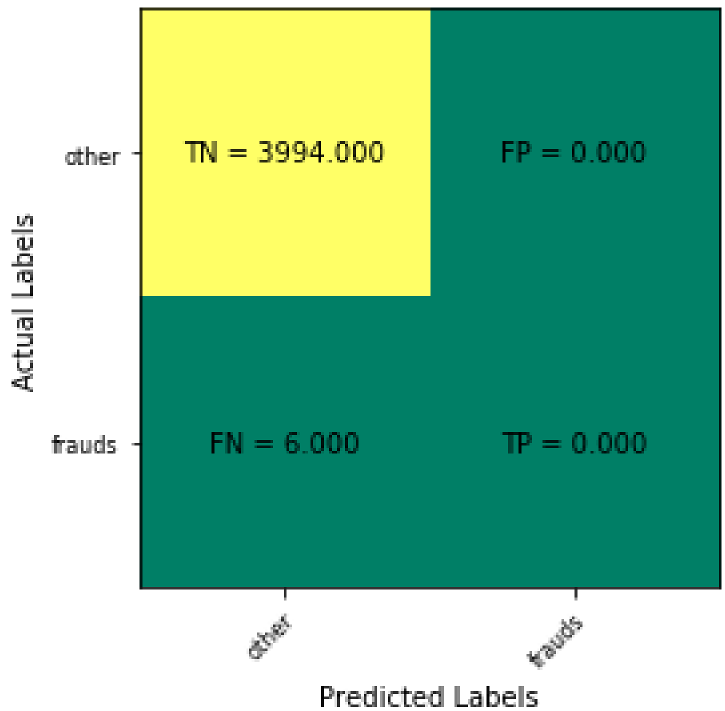
[130]:
```python
""" TODO
Evaluate validation performance.
Display the confusion matrix, KS plot with the cumulative distributions of the␣
↪TPR
and FPR, the ROC curve and the precision-recall curve (PRC).
"""
# TODO: Confusion matrix
```

```python
preds_test = model.predict(Xtest)
confusionMat = confusion_matrix(ytest, preds_test)
metrics_plots.confusion_mtx_colormap(confusionMat, ['other', 'frauds'],␣
↪['other', 'frauds'])


# TODO: Curves
scores= cross_val_predict(model, Xtest, ytest, cv=20, method=␣
↪'decision_function')
metrics_plots.ks_roc_prc_plot(ytest ,scores)



pss_test = metrics_plots.skillScore(ytest.values, preds_test)
f1_test = f1_score(ytest.values.ravel(), preds_test)
print("PSS: %.4f" % pss_test[0])
print("F1 Score %.4f" % f1_test)
```

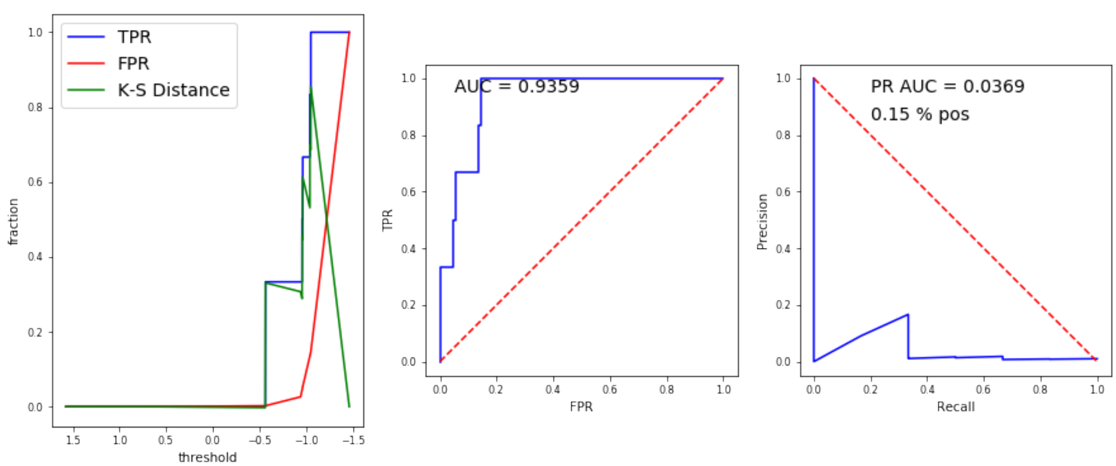
```
/opt/conda/lib/python3.7/site-packages/sklearn/preprocessing/label.py:235:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/opt/conda/lib/python3.7/site-packages/sklearn/model_selection/_split.py:652:
Warning: The least populated class in y has only 6 members, which is too few.
The minimum number of members in any class cannot be less than n_splits=20.
  % (min_groups, self.n_splits)), Warning)
```

```
ROC AUC: 0.9358621265231181
PRC AUC: 0.036948108862163195
PSS: 0.0000
F1 Score 0.0000
```

```
/opt/conda/lib/python3.7/site-packages/sklearn/metrics/classification.py:1143:
UndefinedMetricWarning: F-score is ill-defined and being set to 0.0 due to no
predicted samples.
  'precision', 'predicted', average, warn_for)
```



Actual Labels
other
frauds
TN = 3994.000
FP = 0.000
FN = 6.000
TP = 0.000
other
frauds
Predicted Labels



TPR
FPR
K-S Distance
fraction
threshold
AUC = 0.9359
TPR
FPR
PR AUC = 0.0369
0.15 % pos
Precision
Recall

6 SVMs: STRATIFIED GRID SEARCH

6.1 Scorers

[119]:
```
""" PROVIDED
List of available scoring functions from the sklearn module
"""
import sklearn
sorted(sklearn.metrics.SCORERS.keys())
```

[119]:
```
['accuracy',
 'adjusted_mutual_info_score',
 'adjusted_rand_score',
 'average_precision',
 'balanced_accuracy',
 'brier_score_loss',
 'completeness_score',
 'explained_variance',
 'f1',
 'f1_macro',
 'f1_micro',
 'f1_samples',
 'f1_weighted',
 'fowlkes_mallows_score',
 'homogeneity_score',
 'mutual_info_score',
 'neg_log_loss',
 'neg_mean_absolute_error',
 'neg_mean_squared_error',
 'neg_mean_squared_log_error',
 'neg_median_absolute_error',
 'normalized_mutual_info_score',
 'precision',
 'precision_macro',
 'precision_micro',
 'precision_samples',
 'precision_weighted',
 'r2',
 'recall',
 'recall_macro',
 'recall_micro',
 'recall_samples',
 'recall_weighted',
 'roc_auc',
 'v_measure_score']
```

6.2 Execute Grid Search

[131]:
```
""" TODO
Estimated time: ~30 min on mlserver
Set up and run the grid search using GridSearchCV and the following
settings:
* SVC for the model,
* The above scoring dictionary for scoring,
* refit set to 'f1' as the optimized metric
* Three for the number of cv folds,
* n_jobs=3,
* verbose=2,
* return_train_score=True
"""
# Optimized metric
opt_metric = 'f1'
scoring = {'f1':'f1'}

# Flag to re-load previous run
force = True
# File previous run is saved to
srchfname = "hw8_search_" + opt_metric + ".pkl"

# SETUP EXPERIMENT HYPERPARAMETERS
Cs = [.5, 1, 10, 100, 200]
gammas = np.logspace(-4, 0, num=5, endpoint=True, base=5)

nCs = len(Cs)
ngammas = len(gammas)

hyperparams = {'C':Cs, 'gamma':gammas, 'tol':[1e-4],
               'class_weight':[None, 'balanced']}

# RUN EXPERIMENT
time0 = timelib.time()
search = None
if force or (not os.path.exists(srchfname)):
    # TODO: Create the GridSearchCV object
    svc= SVC()
    search = GridSearchCV(svc, hyperparams, scoring=scoring,refit='f1', cv=3,␣
↪n_jobs=3, verbose=2, return_train_score=True)# TODO

    # TODO: Execute the grid search by calling fit using the training data
    search.fit(Xtrain, ytrain)

    # TODO: Save the grid search object
    joblib.dump(search, srchfname)
```

```
    print("Saved %s" % srchfname)
else:
    search = joblib.load(srchfname)
    print("Loaded %s" % srchfname)

time1 = timelib.time()
duration = time1 - time0
print("Elapsed Time: %.2f min" % (duration / 60))

search
```

```
Fitting 3 folds for each of 50 candidates, totalling 150 fits
```

```
[Parallel(n_jobs=3)]: Using backend LokyBackend with 3 concurrent workers.
/opt/conda/lib/python3.7/site-
packages/sklearn/externals/joblib/externals/loky/process_executor.py:706:
UserWarning: 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
[Parallel(n_jobs=3)]: Done  35 tasks      | elapsed:  2.4min
```

```
Saved hw8_search_f1.pkl
Elapsed Time: 13.34 min
```

```
[Parallel(n_jobs=3)]: Done 150 out of 150 | elapsed: 13.3min finished
/opt/conda/lib/python3.7/site-packages/sklearn/utils/validation.py:761:
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)
```

[131]:
```
GridSearchCV(cv=3, error_score='raise-deprecating',
       estimator=SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.0,
  decision_function_shape='ovr', degree=3, gamma='auto_deprecated',
  kernel='rbf', max_iter=-1, probability=False, random_state=None,
  shrinking=True, tol=0.001, verbose=False),
       fit_params=None, iid='warn', n_jobs=3,
       param_grid={'C': [0.5, 1, 10, 100, 200], 'gamma': array([0.0016, 0.008 ,
0.04  , 0.2   , 1.    ]), 'tol': [0.0001], 'class_weight': [None, 'balanced']},
       pre_dispatch='2*n_jobs', refit='f1', return_train_score=True,
       scoring={'f1': 'f1'}, verbose=2)
```

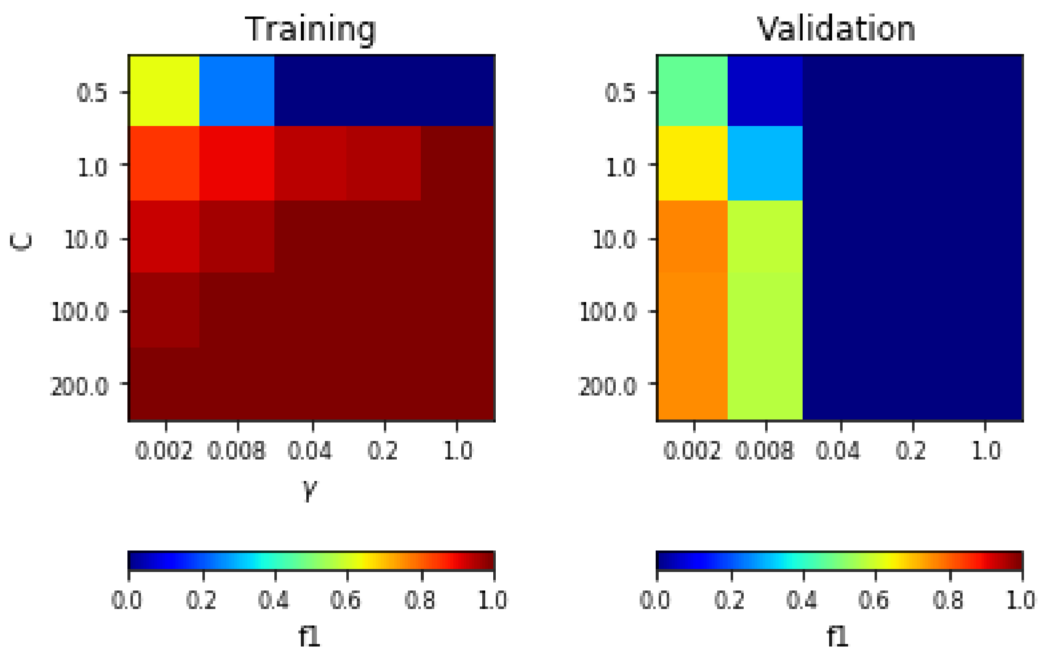
7 RESULTS

[132]:
```python
""" PROVIDED
Display the head of the results for the grid search
See the cv_results_ attribute
"""
all_results = search.cv_results_
df_res = pd.DataFrame(all_results)
df_res.head()
```

[132]:
```
   mean_fit_time  std_fit_time  mean_score_time  std_score_time param_C  \
0       0.229647      0.061313         0.093902        0.001744     0.5
1       0.397064      0.046760         0.140793        0.003350     0.5
2       1.299552      0.127318         0.489186        0.038924     0.5
3      12.348436      1.743320         2.744865        0.148128     0.5
4      25.194287      1.775394         6.590689        0.298260     0.5

  param_class_weight param_gamma param_tol  \
0               None      0.0016    0.0001
1               None       0.008    0.0001
2               None        0.04    0.0001
3               None         0.2    0.0001
4               None           1    0.0001

                                              params  split0_test_f1  \
0  {'C': 0.5, 'class_weight': None, 'gamma': 0.00…             0.2
1  {'C': 0.5, 'class_weight': None, 'gamma': 0.00…             0.0
2  {'C': 0.5, 'class_weight': None, 'gamma': 0.04…             0.0
3  {'C': 0.5, 'class_weight': None, 'gamma': 0.2,…             0.0
4  {'C': 0.5, 'class_weight': None, 'gamma': 1.0,…             0.0

   split1_test_f1  split2_test_f1  mean_test_f1  std_test_f1  rank_test_f1  \
0        0.666667        0.545455      0.470690     0.197717            18
1        0.181818        0.000000      0.060602     0.085709            20
2        0.000000        0.000000      0.000000     0.000000            21
3        0.000000        0.000000      0.000000     0.000000            21
4        0.000000        0.000000      0.000000     0.000000            21

   split0_train_f1  split1_train_f1  split2_train_f1  mean_train_f1  \
0             0.56         0.740741         0.592593       0.631111
1             0.00         0.521739         0.210526       0.244088
2             0.00         0.000000         0.000000       0.000000
3             0.00         0.000000         0.000000       0.000000
4             0.00         0.000000         0.000000       0.000000

   std_train_f1
0      0.078654
```

```
1      0.214317
2      0.000000
3      0.000000
4      0.000000
```

[133]:
```python
""" PROVIDED
Plot the mean training and validation results from the grid search as a
colormap, for C (y-axis) vs the gamma (x-axis), for class_weight=None
"""
results_grid_train = df_res['mean_train_'+opt_metric].values.reshape(nCs, 2,␣
↪ngammas)
results_grid_val = df_res['mean_test_'+opt_metric].values.reshape(nCs, 2,␣
↪ngammas)

fig, axs = plt.subplots(1, 2, figsize=(6,6))
fig.subplots_adjust(wspace=.45)
axs = axs.ravel()
means = [("Training", results_grid_train),
         ("Validation", results_grid_val)]
for i, (name, result) in enumerate(means):
    img = axs[i].imshow(result[:,0,:], cmap="jet", vmin=0, vmax=1)
    axs[i].set_title(name)
    axs[i].set_xticks(range(ngammas))
    axs[i].set_yticks(range(nCs))
    axs[i].set_xticklabels(np.around(gammas, 3))
    axs[i].set_yticklabels(np.around(Cs, 3))
    axs[i].figure.colorbar(img, ax=axs[i], label=opt_metric,
                           orientation='horizontal')
    if i == 0:
        axs[i].set_xlabel(r"$\gamma$")
        axs[i].set_ylabel("C")
#fig.suptitle('class_weight=None')
```



[134]:
```
""" TODO
Obtain the best model from the grid search and
fit it to the full training data
"""
optModel= search.best_estimator_
optModel.fit(Xtrain, ytrain)
```

```
/opt/conda/lib/python3.7/site-packages/sklearn/utils/validation.py:761:
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)
```

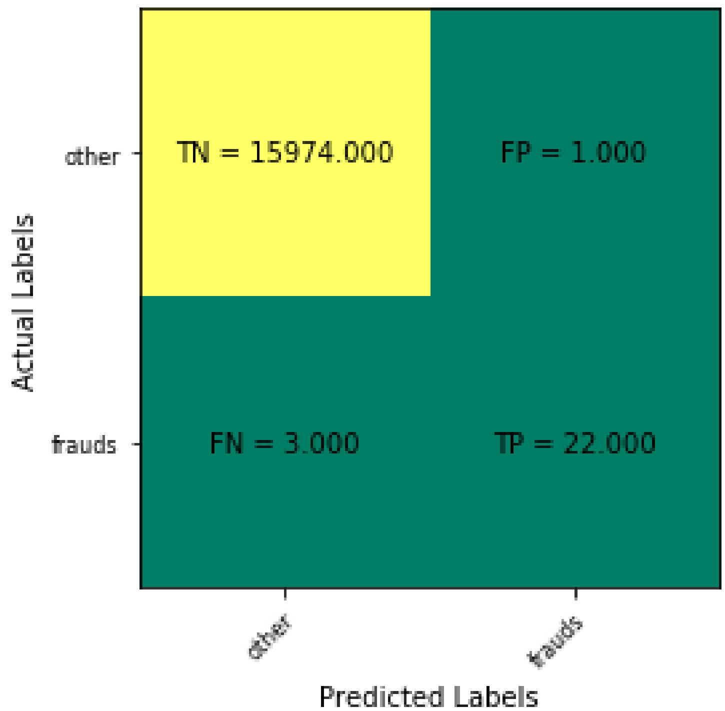
[134]:
```
SVC(C=10, cache_size=200, class_weight=None, coef0=0.0,
  decision_function_shape='ovr', degree=3, gamma=0.0016, kernel='rbf',
  max_iter=-1, probability=False, random_state=None, shrinking=True,
  tol=0.0001, verbose=False)
```

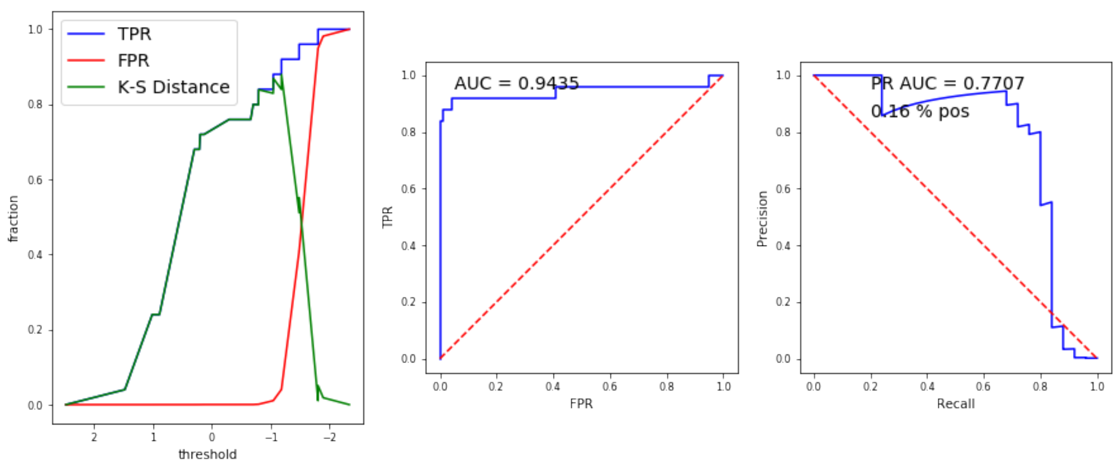
[135]:
```
""" TODO
For the best model, display the confusion matrix, KS plot, ROC curve,
and PR curve for the training set
"""
# TODO: Confusion Matrix
preds = optModel.predict(Xtrain)
confusionMat = confusion_matrix(ytrain, preds)
```

```
metrics_plots.confusion_mtx_colormap(confusionMat, ['other', 'frauds'],␣
 ↪['other', 'frauds'])



# TODO: Curves
scores= cross_val_predict(optModel, Xtrain, ytrain, cv=20, method=␣
 ↪'decision_function')
metrics_plots.ks_roc_prc_plot(ytrain ,scores)



pss_res = metrics_plots.skillScore(ytrain.values, preds)
f1_res = f1_score(ytrain.values.ravel(), preds)
print("PSS: %.4f" % pss_res[0])
print("F1 Score %.4f" % f1_res)
```

```
/opt/conda/lib/python3.7/site-packages/sklearn/preprocessing/label.py:235:
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)
```

```
ROC AUC: 0.9435392801251956
PRC AUC: 0.7706877017913669
PSS: 0.8799
F1 Score 0.9167
```



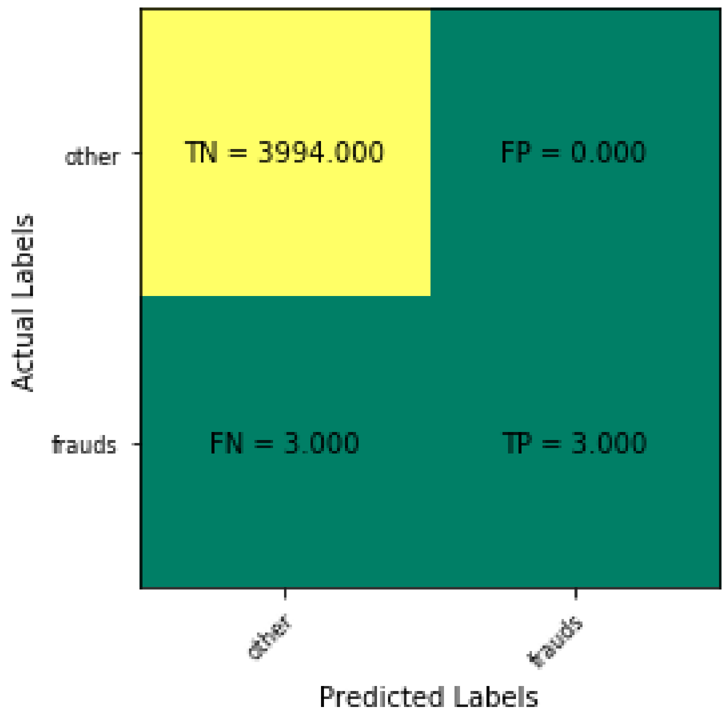


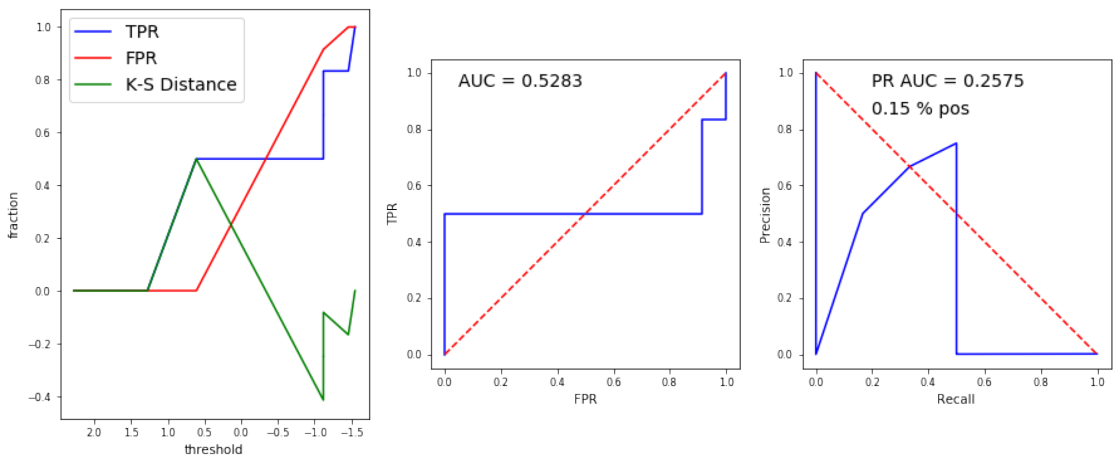
[136]:
```
""" TODO
For the best model, display the confusion matrix, KS plot, ROC curve,
and PR curve for the test set
"""
# TODO: Confusion matrix
preds_test = optModel.predict(Xtest)
confusionMat = confusion_matrix(ytest, preds_test)
```

```
metrics_plots.confusion_mtx_colormap(confusionMat, ['other', 'frauds'],␣
↪['other', 'frauds'])


# TODO: Curves
scores= cross_val_predict(optModel, Xtest, ytest, cv=20, method=␣
↪'decision_function')
metrics_plots.ks_roc_prc_plot(ytest ,scores)



pss_res_test = metrics_plots.skillScore(ytest.values, preds_test)
f1_res_test = f1_score(ytest.values.ravel(), preds_test)
print("PSS: %.4f" % pss_res_test[0])
print("F1 Score %.4f" % f1_res_test)
```

```
/opt/conda/lib/python3.7/site-packages/sklearn/preprocessing/label.py:235:
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)
/opt/conda/lib/python3.7/site-packages/sklearn/model_selection/_split.py:652:
Warning: The least populated class in y has only 6 members, which is too few.
The minimum number of members in any class cannot be less than n_splits=20.
  % (min_groups, self.n_splits)), Warning)
```

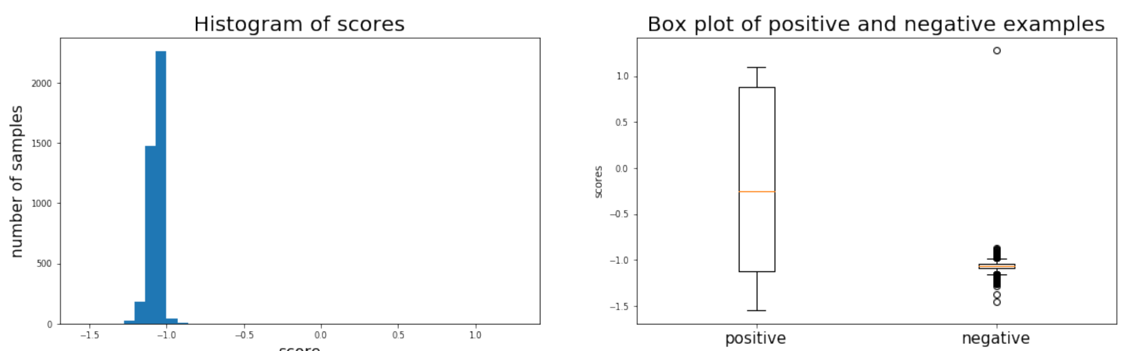
```
ROC AUC: 0.5282924386579869
PRC AUC: 0.25753815386078444
PSS: 0.5000
F1 Score 0.6667
```





[137]:
```
""" TODO
Plot a histogram of the test scores from the best model.
Compare the distribution of scores for positive and negative examples
using boxplots.

Create one subplot of the distribution of all the scores, with a histogram.
Create a second subplot comparing the distribution of the scores of the
```

```python
positive examples with the distribution of the negative examples, with boxplots.
"""
# TODO: Obtain the pos and neg indices
pos= [i for i in range(len(ytest)) if ytest.iloc[i,:].Class==1]
neg= [i for i in range(len(ytest)) if ytest.iloc[i,:].Class==0]


# TODO: Separate the scores for the pos and neg examples
pos_scores= scores[pos]
neg_scores= scores[neg]

# TODO: Plot the distribution of all scores
nbins = 41
fig= plt.figure(figsize= (1.5*FIGW, FIGH))
ax= fig.add_subplot(121)
ax.hist(scores, bins=nbins);
ax.set_title('Histogram of scores',fontsize= 20)
ax.set_xlabel('score',fontsize= 15)
ax.set_ylabel('number of samples',fontsize= 15)


# TODO: Plot the boxplots of the pos and neg examples
ax2= fig.add_subplot(122)
ax2.boxplot([pos_scores, neg_scores]);
ax2.set_title('Box plot of positive and negative examples', fontsize=20)
ax2.set_ylabel('scores')
ax2.set_xticks([1,2])
ax2.set_xticklabels(['positive', 'negative'], fontsize= 15);
```



8 Discussion

In 3 to 4 paragraphs, discuss and interpret the test results for the best model. Include a brief discussion of the difference in the meaning of the AUC for the ROC vs the AUC for the PRC. Also, discuss the histogram and boxplots of the scores.

Firstly, the relationship of AUC for ROC and PRC is that both metrics are derived from contigency table, with ROC accounting for TPR and FPR while PRC measuring Precision and Recall. Thus, becasue FPR's denominator has TN which is often biased by large samples of negative case, like non-fraud in our situation. That data biasness causes our AUC of ROC very high. On the other hand, AUC for PRC avoids this situation because it only accounts positive. From test samples, the optimized model could reach a very high value for AUC comparing to previous models.

The scores computed are accumulated in the range of (-1.5, -1.0) from the histogram because large samples of negative labels. And from the right pane boxplot, there is no clear boundary that can seperate negative samples and positive samples even though there is a good fit for training process (0.77 PR AUC)

This test model correctly predicted 3990 negative labels, and 9 positive samples. Only 1 positive case was wrongly classified and which is acceptable. From the K-S distance, we found when the score equals 0.6 around, it is able to seperate the two labels.