Predictive Analytics HW2

Import libararies

```
%matplotlib inline
from sklearn.utils.validation import column_or_1d
from sklearn import tree
from sklearn.linear_model import LogisticRegression
from sklearn import neighbors
from sklearn import svm,datasets
from sklearn.svm import SVC
from sklearn.model_selection import cross_val_score, train_test_split,
StratifiedKFold
from sklearn import neighbors, linear_model, metrics
from sklearn.metrics import classification_report
from sklearn.metrics import cohen_kappa_score
from sklearn.metrics import matthews_corrcoef
from sklearn.metrics import roc_auc_score
from sklearn.metrics import roc_curve,auc
from sklearn.multiclass import OneVsRestClassifier
from scipy.stats import scoreatpercentile
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sns
from sklearn.preprocessing import label_binarize
import scikitplot as skplt

#plt.style.use('ggplot')
```

Data importing and processing

```
wdbc = pd.read_csv("wdbc.data", header = None, names = ['id', 'diagnosis',

 'radius_mean','texture_mean','perimeter_mean','area_mean','smoothness_mean','com
pactness_mean','concavity_mean','concave_points_mean','symmetry_mean','fractal_di
mension_mean',

 'radius_se','texture_se','perimeter_se','area_se','smoothness_se','compactness_s
e','concavity_se','concave_points_se','symmetry_se','fractal_dimension_se',

 'radius_worst','texture_worst','perimeter_worst','area_worst','smoothness_worst'
,'compactness_worst','concavity_worst','concave_points_worst','symmetry_worst','f
ractal_dimension_worst'])
wdbc = wdbc.replace({'M': 0, 'B': 1})
```

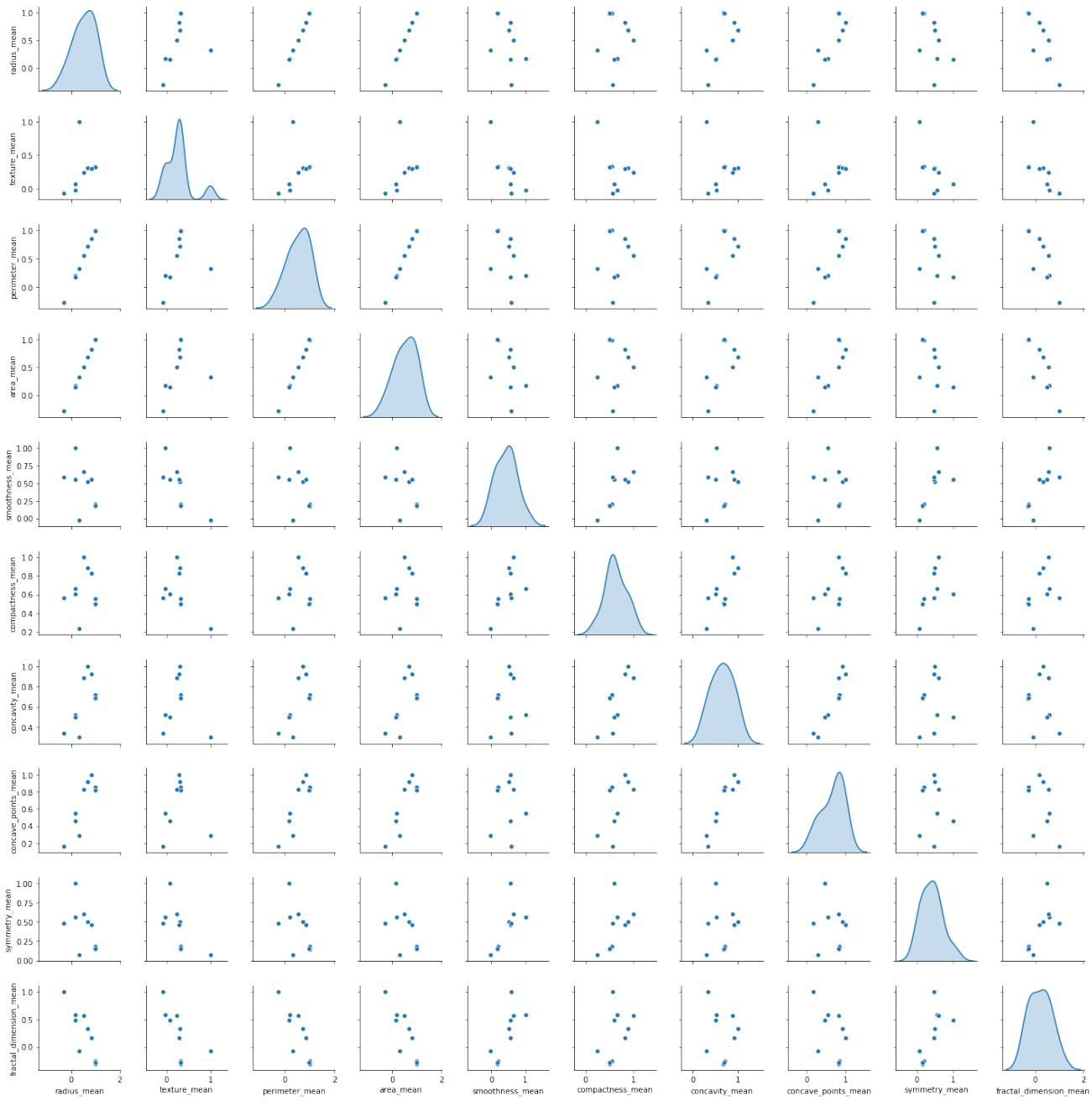
Explore the dataset

```
n_samples, n_features = wdbc.shape
print ('The dimensions of the data set are', n_samples, 'by', (n_features-2))
```

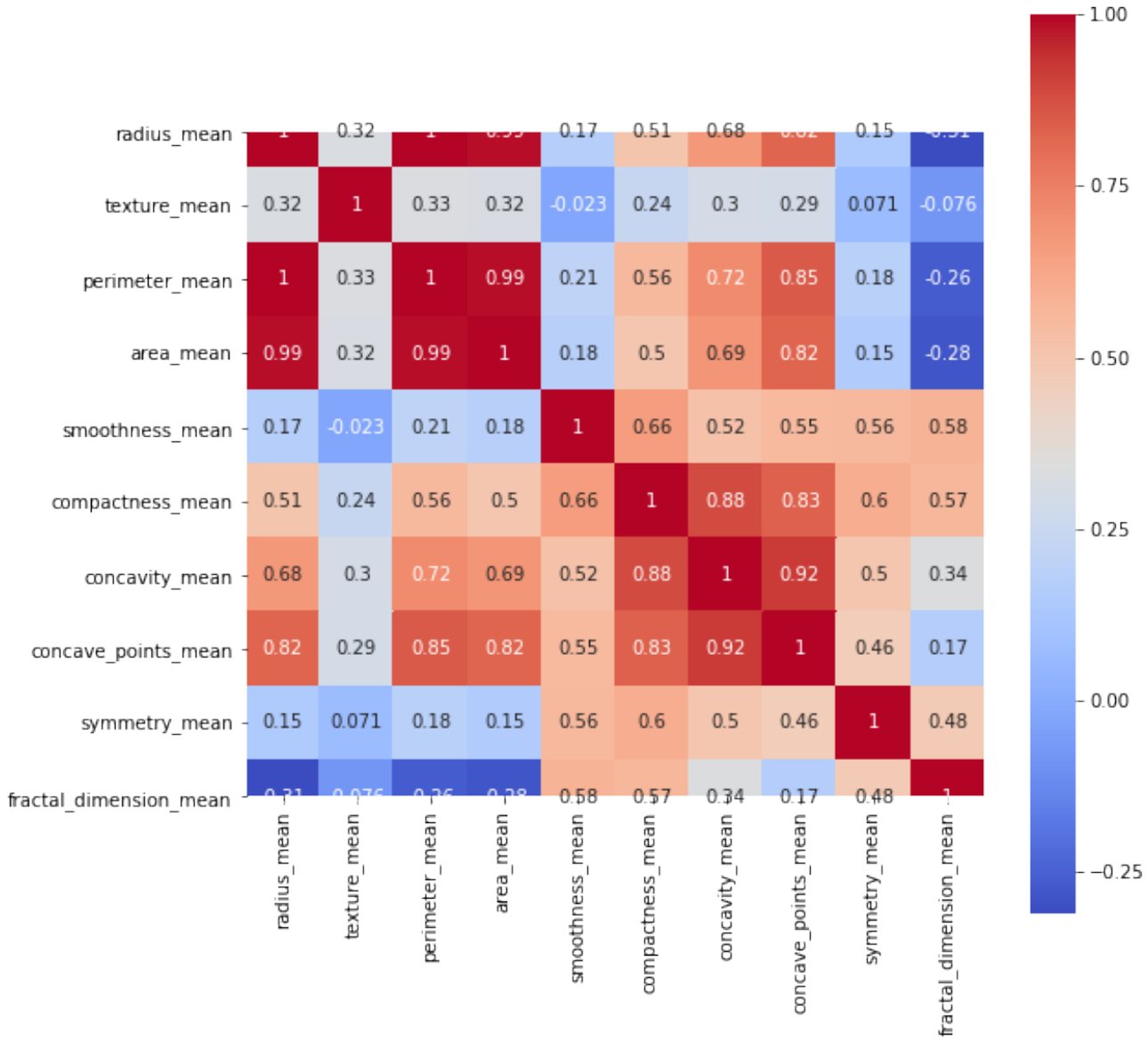
```
The dimensions of the data set are 569 by 30
```

Observe the correlation matrix and create heat map

```
featureMeans = list(wdbc.columns[2:12])

correlationData = wdbc[featureMeans].corr()
sns.pairplot(wdbc[featureMeans].corr(), diag_kind='kde', height=2);
```




```
plt.figure(figsize=(9,9))
sns.heatmap(wdbc[featureMeans].corr(), annot=True, square=True, cmap='coolwarm')
plt.show()
```



Select features X and Y

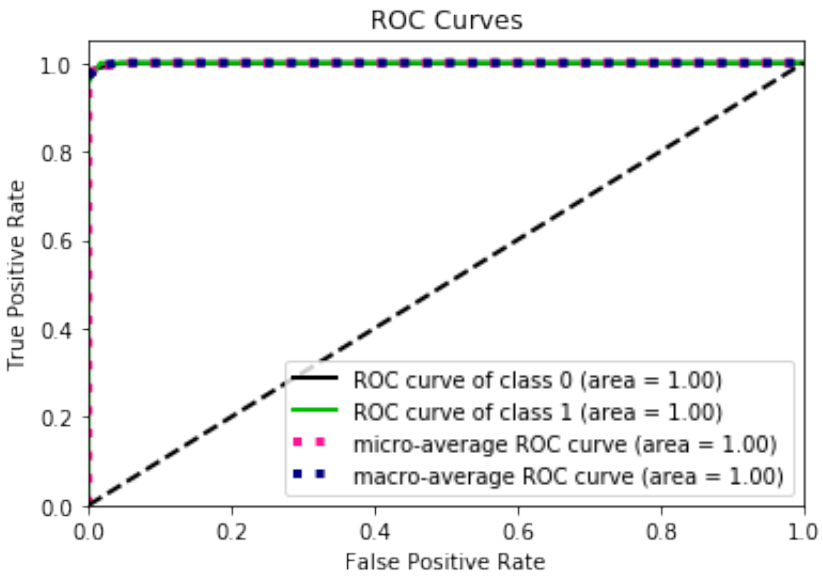
```
features = wdbc.columns[2:]
X = wdbc[features].values
y = wdbc['diagnosis'].values
```

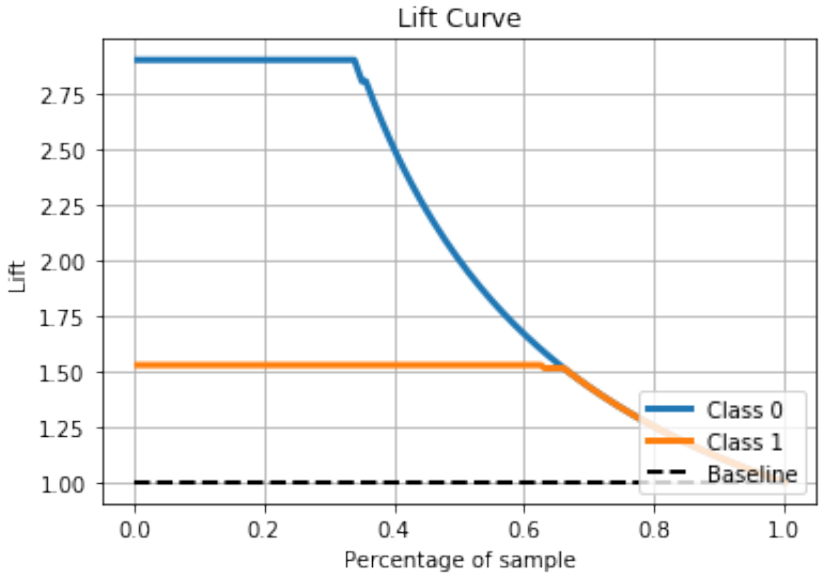
1. Decision Tree Model

```
for m in range(4,8):
    clf = tree.DecisionTreeClassifier(max_depth = m)
    clf = clf.fit(X, y)
    # cross validation
    scores = cross_val_score(clf, X, y, cv=10)
    #Splitting data into training set (70%) and testing set (30%)
```

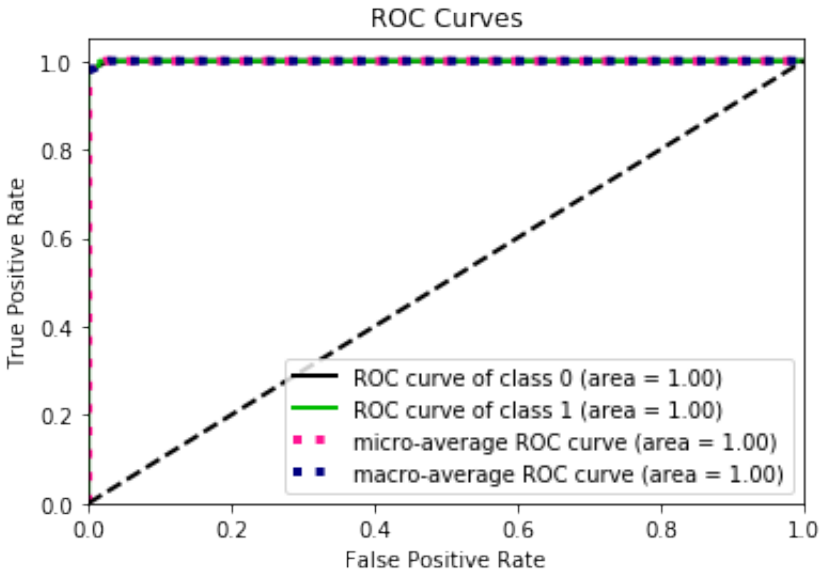
```
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
    y_true, y_pred = y_test, clf.predict(X_test)
    print("When max_depth =", m)
    print ('\t')
    print("The cross validation result: ", scores)
    print ('\t')
    print("Confusion matrix:\n%s" % metrics.confusion_matrix(y_test, y_pred))
    print ('\t')
    print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
    print ('\t')
    print("The kappa stats is: ", cohen_kappa_score(y_true, y_pred))
    print ('\t')
    print("The MCC stats is: ", matthews_corrcoef(y_true, y_pred))
    print ('\t')
    # auc value
    fpr, tpr, threshold = roc_curve(y_test, y_pred)
    auc = metrics.auc(fpr, tpr)
    print("The AUC stats is: ", auc)

    # Classification report
    print(classification_report(y_true, y_pred))
    print('\n')
    predicted_probas_clf = clf.predict_proba(X_test)
    # roc curve
    skplt.metrics.plot_roc(y_test, predicted_probas_clf)
    # lift curve
    skplt.metrics.plot_lift_curve(y_test, predicted_probas_clf)
    plt.show()


    #y_score = clf.fit(X_train, y_train).decision_function(X_test)
#     fpr, tpr, _ = roc_curve(y_test, y_pred)
#     roc_auc = auc(fpr, tpr)
#     plt.figure()
#     lw = 2
#     plt.plot(fpr, tpr, color='darkorange',
#              lw=lw, label='ROC curve (area = %0.2f)' % roc_auc)
#     plt.plot([0, 1], [0, 1], color='navy', lw=lw, 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 example')
#     plt.legend(loc="lower right")
#     plt.show()
```

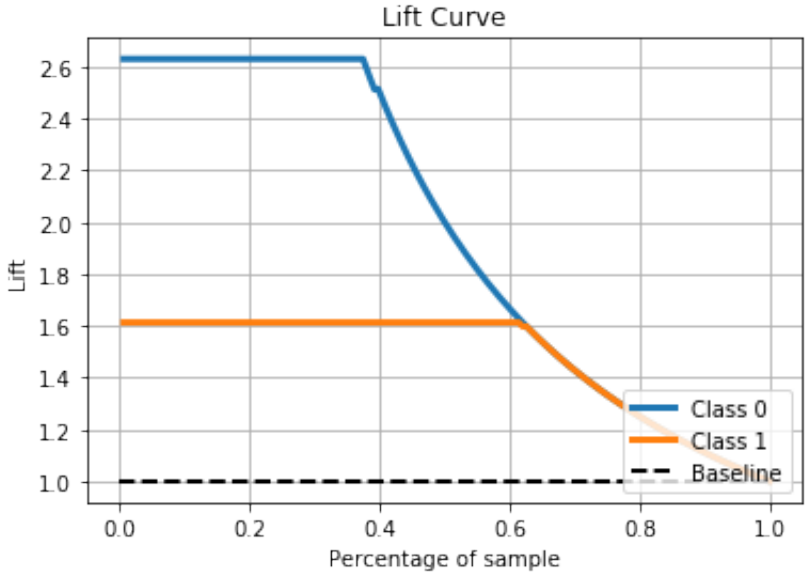
```
When max_depth = 4

The cross validation result:  [0.93103448 0.84482759 0.92982456 0.85964912
0.98245614 0.9122807
 0.89473684 0.92857143 0.91071429 1.        ]

Confusion matrix:
[[ 58   1]
 [  0 112]]

Accuracy: 0.92 (+/- 0.09)

The kappa stats is:  0.987009040492289

The MCC stats is:  0.9870923373402705

The AUC stats is:  0.9915254237288136
              precision    recall  f1-score   support

           0       1.00      0.98      0.99        59
           1       0.99      1.00      1.00       112

    accuracy                           0.99       171
   macro avg       1.00      0.99      0.99       171
weighted avg       0.99      0.99      0.99       171
```





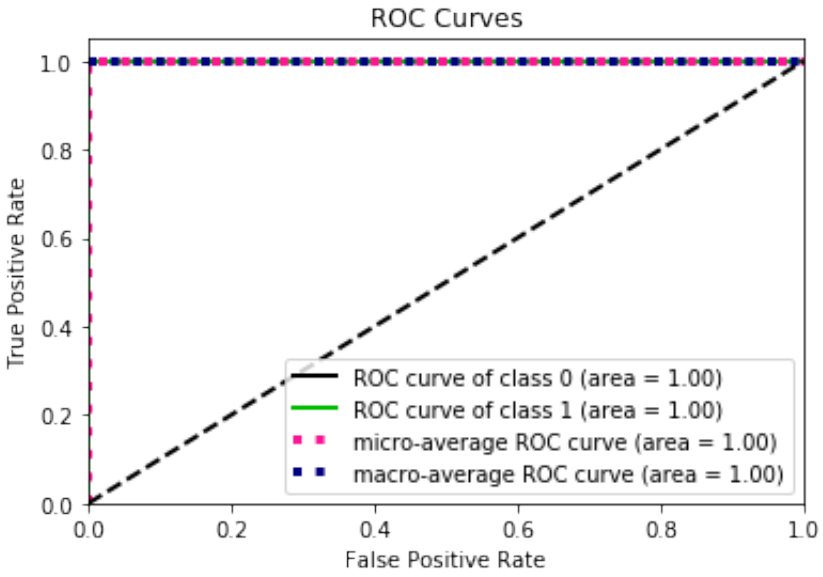

```
When max_depth = 5

The cross validation result:  [0.93103448 0.86206897 0.92982456 0.87719298
0.96491228 0.89473684
 0.85964912 0.94642857 0.92857143 0.98214286]

Confusion matrix:
[[ 64   1]
 [  0 106]]

Accuracy: 0.92 (+/- 0.08)

The kappa stats is:  0.987553679307082

The MCC stats is:  0.9876301796092776

The AUC stats is:  0.9923076923076923
              precision    recall  f1-score   support

           0       1.00      0.98      0.99        65
           1       0.99      1.00      1.00       106

    accuracy                           0.99       171
   macro avg       1.00      0.99      0.99       171
weighted avg       0.99      0.99      0.99       171
```

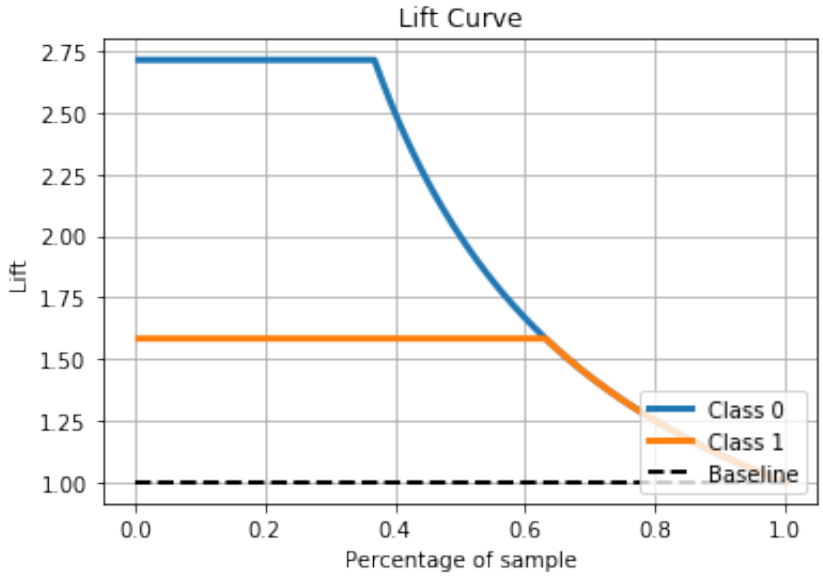




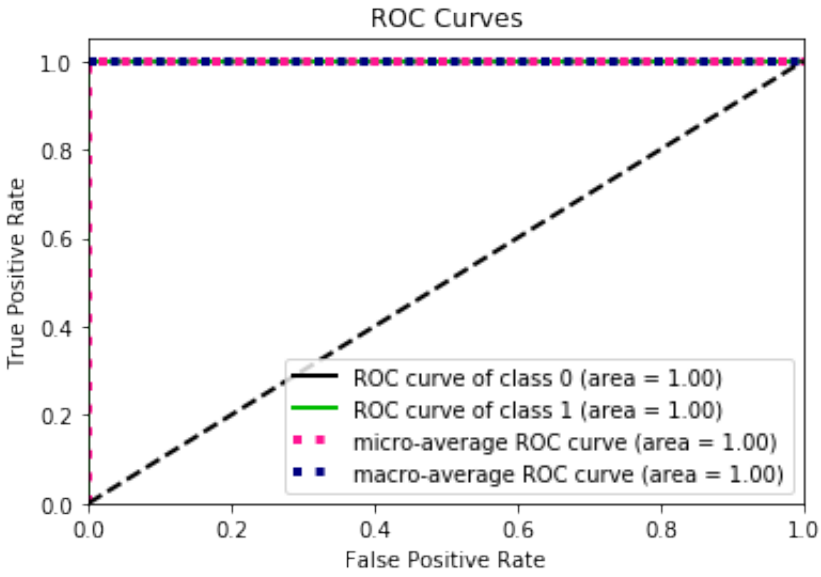

```
When max_depth = 6

The cross validation result:  [0.9137931  0.87931034 0.92982456 0.89473684
0.9122807  0.89473684
 0.9122807  0.94642857 0.91071429 1.        ]

Confusion matrix:
[[ 63   0]
 [  0 108]]

Accuracy: 0.92 (+/- 0.06)

The kappa stats is:  1.0
```

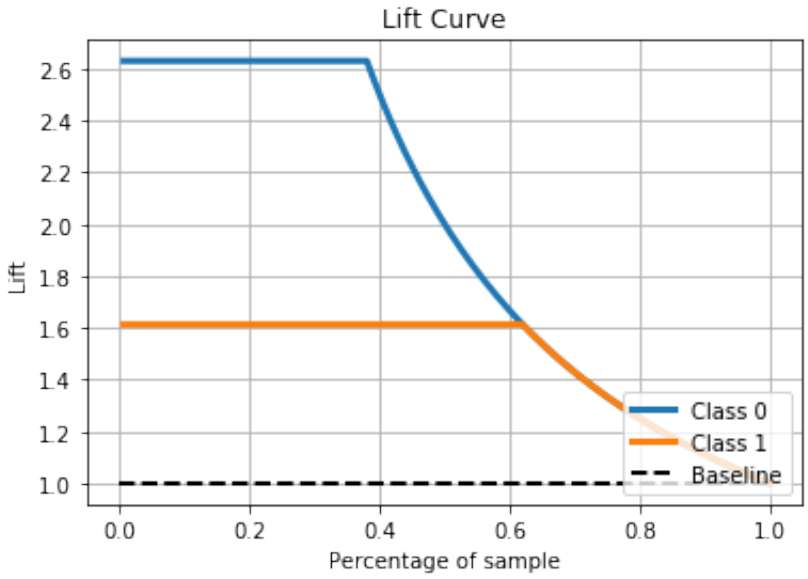
```
The MCC stats is:  1.0

The AUC stats is:  1.0
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        63
           1       1.00      1.00      1.00       108

    accuracy                           1.00       171
   macro avg       1.00      1.00      1.00       171
weighted avg       1.00      1.00      1.00       171
```






```
When max_depth = 7

The cross validation result:  [0.87931034 0.89655172 0.9122807  0.9122807
0.96491228 0.9122807
 0.85964912 0.94642857 0.92857143 1.        ]

Confusion matrix:
[[ 65   0]
 [  0 106]]

Accuracy: 0.92 (+/- 0.08)

The kappa stats is:  1.0

The MCC stats is:  1.0

The AUC stats is:  1.0
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        65
           1       1.00      1.00      1.00       106

    accuracy                           1.00       171
   macro avg       1.00      1.00      1.00       171
weighted avg       1.00      1.00      1.00       171
```





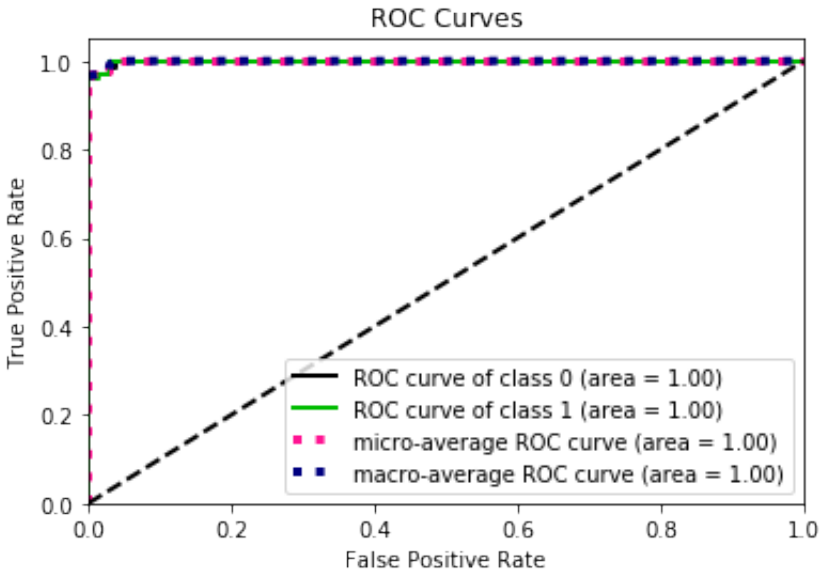
2. Logistic Regression Model

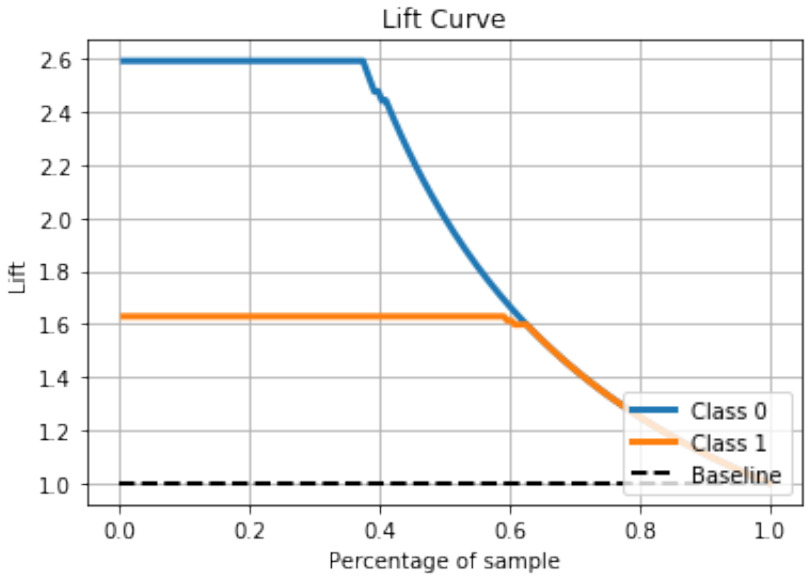
```
lr = LogisticRegression(C=1e5,multi_class='multinomial',solver ='newton-cg')
lr = lr.fit(X, y)

# cross validation
scores = cross_val_score(lr, X, y, cv=10)
print("The cross validation result: ", scores)
print("Confusion matrix:\n%s" % metrics.confusion_matrix(y_test, y_pred))
print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
print("The kappa stats is: ", cohen_kappa_score(y_true, y_pred))
print("The MCC stats is: ", matthews_corrcoef(y_true, y_pred))
#Splitting data into training set (70%) and testing set (30%)
```

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
Y_true, y_pred = y_test, lr.predict(X_test)
# auc value
fpr, tpr, threshold = roc_curve(y_test, y_pred)
auc = metrics.auc(fpr, tpr)
print("The AUC stats is: ", auc)
# Classification report
print(classification_report(y_true, y_pred))
# knn
predicted_probas_lr = lr.predict_proba(X_test)
# roc curve
skplt.metrics.plot_roc(y_test, predicted_probas_lr)

# lift curve
skplt.metrics.plot_lift_curve(y_test, predicted_probas_lr)
plt.show()




# y_score = lr.fit(X_train, y_train).decision_function(X_test)
# fpr, tpr, _ = roc_curve(y_test, y_score)
# roc_auc = auc(fpr, tpr)
# plt.figure()
# lw = 2
# plt.plot(fpr, tpr, color='darkorange',
#          lw=lw, label='ROC curve (area = %0.2f)' % roc_auc)
# plt.plot([0, 1], [0, 1], color='navy', lw=lw, 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 example')
# plt.legend(loc="lower right")
# plt.show()
```

```
The cross validation result:  [0.94827586 0.94827586 0.98245614 0.94736842
0.92982456 0.98245614
 0.96491228 0.98214286 0.98214286 0.98214286]
Confusion matrix:
[[ 62   2]
 [  0 107]]
Accuracy: 0.96 (+/- 0.04)
The kappa stats is:  -0.11334714412548097
The MCC stats is:  -0.11334714412548091
```

```
The AUC stats is:  0.9753246753246755
              precision    recall  f1-score   support

           0       0.35      0.37      0.36        62
           1       0.63      0.61      0.62       109

    accuracy                           0.52       171
   macro avg       0.49      0.49      0.49       171
weighted avg       0.53      0.52      0.52       171
```



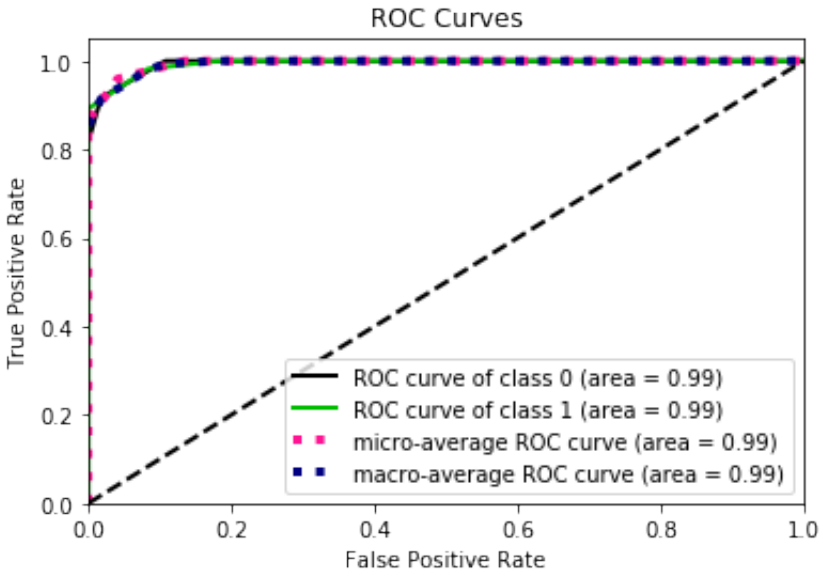


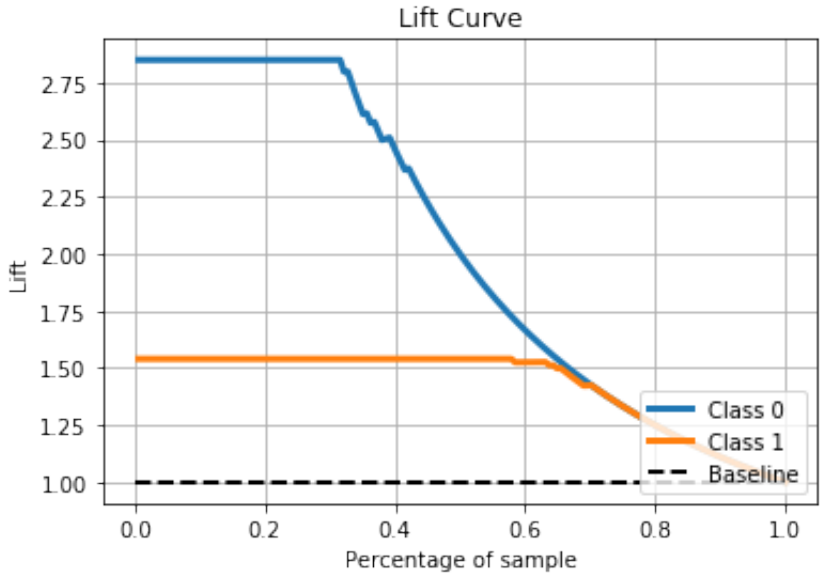
3. KNN Model

```
 for n_neighbors in range(3,7):
    knn = neighbors.KNeighborsClassifier(n_neighbors)
    knn = knn.fit(X, y)
    #Splitting data into training set (70%) and testing set (30%)
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3)
    y_true, y_pred = y_test, knn.predict(X_test)
    # cross validation
    scores = cross_val_score(knn, X, y, cv=10)
    print("When neighbors =", n_neighbors)
    print("The cross validation result: ", scores)
    print("Confusion matrix:\n%s" % metrics.confusion_matrix(y_test, y_pred))
    print("Accuracy: %0.2f (+/- %0.2f)" % (scores.mean(), scores.std() * 2))
    print("The kappa stats is: ", cohen_kappa_score(y_true, y_pred))
    print("The MCC stats is: ", matthews_corrcoef(y_true, y_pred))
    # auc value
    fpr, tpr, threshold = roc_curve(y_test, y_pred)
    auc = metrics.auc(fpr, tpr)
    print("The AUC stats is: ", auc)

    # Classification report
    print(classification_report(y_true, y_pred))
    print('\n')
    # knn
    predicted_probas_knn = knn.predict_proba(X_test)
    # roc curve
    skplt.metrics.plot_roc(y_test, predicted_probas_knn)

    # lift curve
    skplt.metrics.plot_lift_curve(y_test, predicted_probas_knn)
    plt.show()

#     #y_score = knn.fit(X_train, y_train).decision_function(X_test)
#     fpr, tpr, _ = roc_curve(y_test, y_pred)
#     roc_auc = auc(fpr, tpr)

#     plt.figure()
#     lw = 2
#     plt.plot(fpr, tpr, color='darkorange',
#              lw=lw, label='ROC curve (area = %0.2f)' % roc_auc)
#     plt.plot([0, 1], [0, 1], color='navy', lw=lw, 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 example')
#     plt.legend(loc="lower right")
```

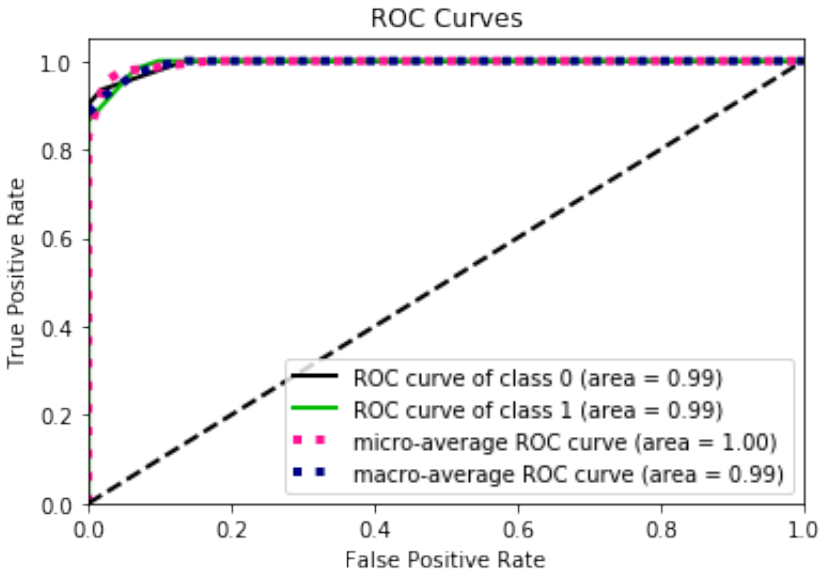
```
#     plt.show()
```

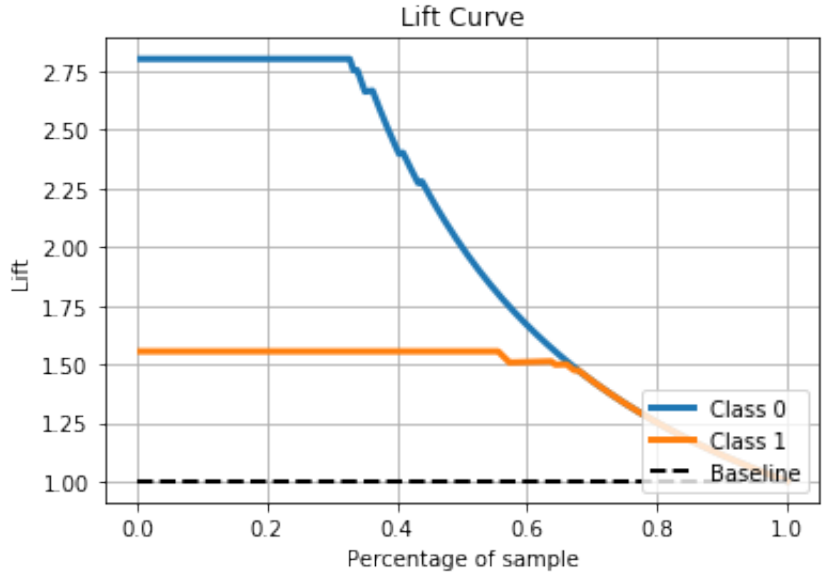
```
When neighbors = 3
The cross validation result:  [0.9137931  0.86206897 0.89473684 0.94736842
0.94736842 0.94736842
 0.96491228 0.94642857 0.91071429 0.92857143]
Confusion matrix:
[[ 55   5]
 [  2 109]]
Accuracy: 0.93 (+/- 0.06)
The kappa stats is:  0.9090909090909091
The MCC stats is:  0.9097816785925636
The AUC stats is:  0.9493243243243242
              precision    recall  f1-score   support

           0       0.96      0.92      0.94        60
           1       0.96      0.98      0.97       111

    accuracy                           0.96       171
   macro avg       0.96      0.95      0.95       171
weighted avg       0.96      0.96      0.96       171
```





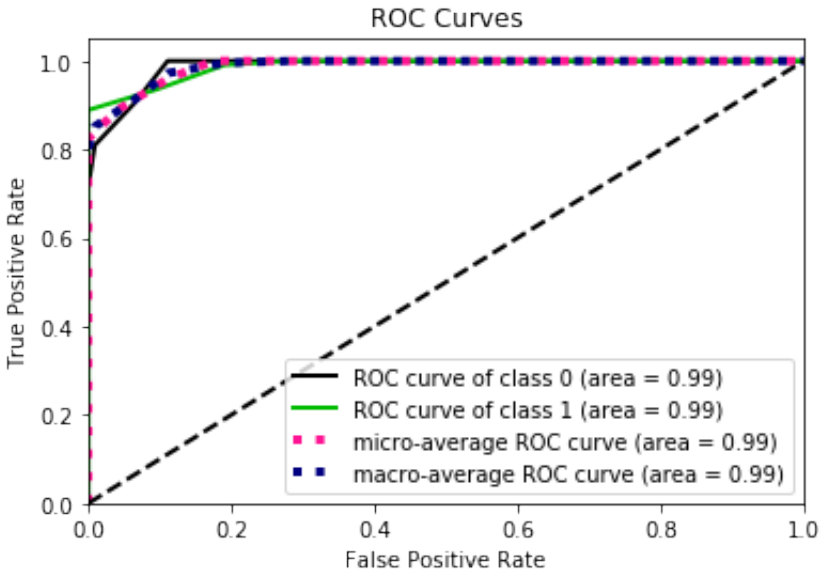

```
When neighbors = 4
The cross validation result:  [0.9137931  0.87931034 0.89473684 0.94736842
0.94736842 0.94736842
 0.96491228 0.91071429 0.875      0.92857143]
Confusion matrix:
[[ 57   4]
 [  2 108]]
Accuracy: 0.92 (+/- 0.06)
The kappa stats is:  0.9229845368563279
The MCC stats is:  0.9232888302415534
The AUC stats is:  0.9581222056631894
              precision    recall  f1-score   support

           0       0.97      0.93      0.95        61
           1       0.96      0.98      0.97       110

    accuracy                           0.96       171
   macro avg       0.97      0.96      0.96       171
weighted avg       0.96      0.96      0.96       171
```

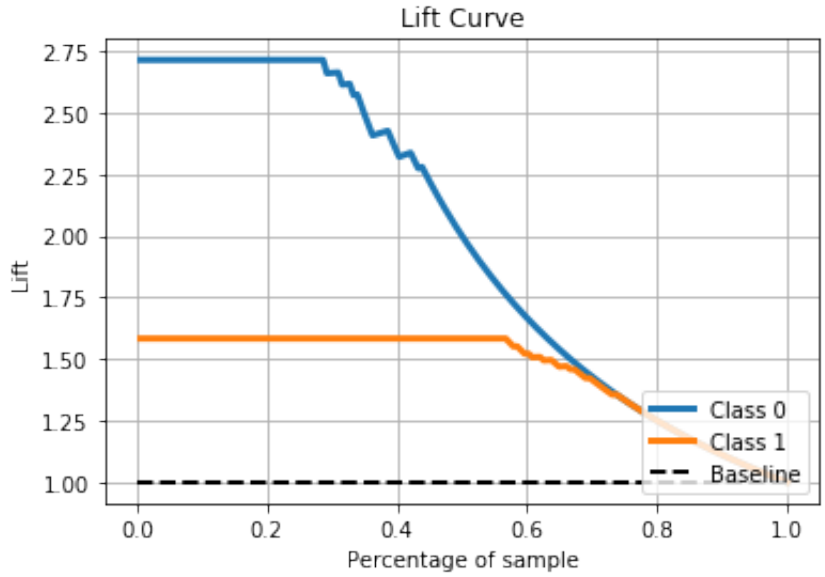





```
When neighbors = 5
The cross validation result:  [0.9137931  0.87931034 0.89473684 0.96491228
0.94736842 0.92982456
 0.96491228 0.92857143 0.91071429 0.96428571]
Confusion matrix:
[[ 55   8]
 [  5 103]]
Accuracy: 0.93 (+/- 0.06)
The kappa stats is:  0.8350033400133601
The MCC stats is:  0.8356092901248081
The AUC stats is:  0.9133597883597884
              precision    recall  f1-score   support
```

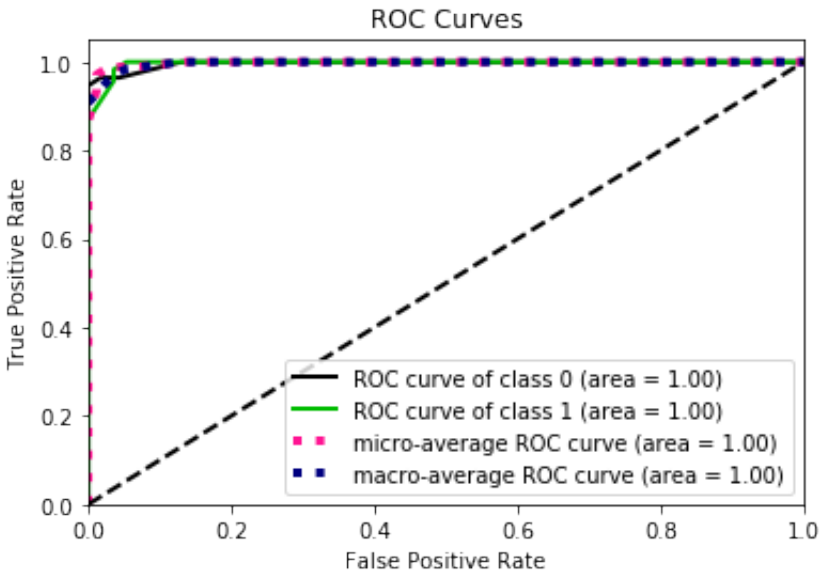
```
              0       0.92      0.87      0.89        63
              1       0.93      0.95      0.94       108

    accuracy                            0.92       171
   macro avg       0.92      0.91      0.92       171
weighted avg       0.92      0.92      0.92       171
```

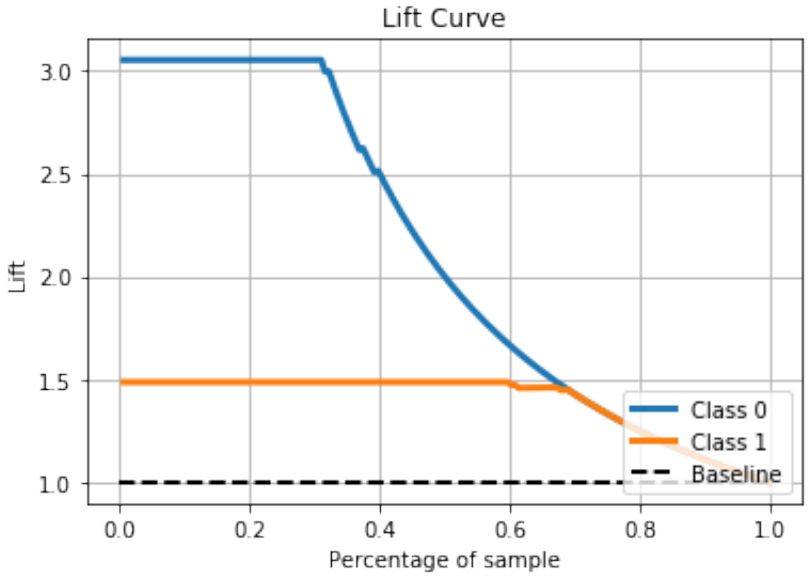





```
When neighbors = 6
The cross validation result:  [0.9137931  0.87931034 0.89473684 0.96491228
0.94736842 0.92982456
```

```
 0.96491228 0.92857143 0.89285714 0.94642857]
Confusion matrix:
[[ 54   2]
 [  2 113]]
Accuracy: 0.93 (+/- 0.06)
The kappa stats is:  0.9468944099378882
The MCC stats is:  0.9468944099378882
The AUC stats is:  0.9734472049689441
              precision    recall  f1-score   support

           0       0.96      0.96      0.96        56
           1       0.98      0.98      0.98       115

    accuracy                           0.98       171
   macro avg       0.97      0.97      0.97       171
weighted avg       0.98      0.98      0.98       171
```





4. SVM Model

```
C = 1.0 # SVM regularization parameter
svc = svm.SVC(kernel='linear', C=C, probability=True).fit(X, y)
rbf_svc = svm.SVC(kernel='rbf', gamma=0.7, C=C, probability=True).fit(X, y)
lin_svc = svm.LinearSVC(C=C).fit(X, y)
# cross validation
scores_1 = cross_val_score(svc, X, y, cv=20)
scores_2 = cross_val_score(rbf_svc, X, y, cv=20)
scores_3 = cross_val_score(lin_svc, X, y, cv=20)

# Classification report
# auc value
y_true_1, y_pred_1 = y_test, svc.predict(X_test)
fpr_1, tpr_1, threshold_1 = roc_curve(y_test, y_pred_1)
auc = metrics.auc(fpr_1, tpr_1)
print("The AUC stats is: ", auc)
print(scores_1,'\n')
print(classification_report(y_true_1, y_pred_1))
print('\n')

y_true_2, y_pred_2 = y_test, rbf_svc.predict(X_test)
fpr_2, tpr_2, threshold_2 = roc_curve(y_test, y_pred_2)
auc = metrics.auc(fpr_2, tpr_2)
print("The AUC stats is: ", auc)
print(scores_2,'\n')
print(classification_report(y_true_2, y_pred_2))
print('\n')

y_true_3, y_pred_3 = y_test, lin_svc.predict(X_test)
```

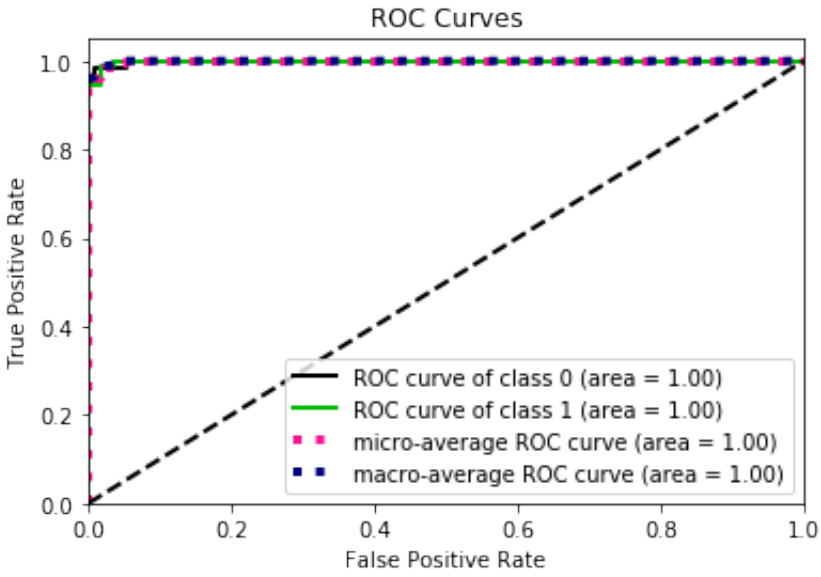
```
fpr_3, tpr_3, threshold_3 = roc_curve(y_test, y_pred_3)
auc = metrics.auc(fpr_3, tpr_3)
print("The AUC stats is: ", auc)
print(scores_3,'\n')
print(classification_report(y_true_3, y_pred_3))
print('\n')
```

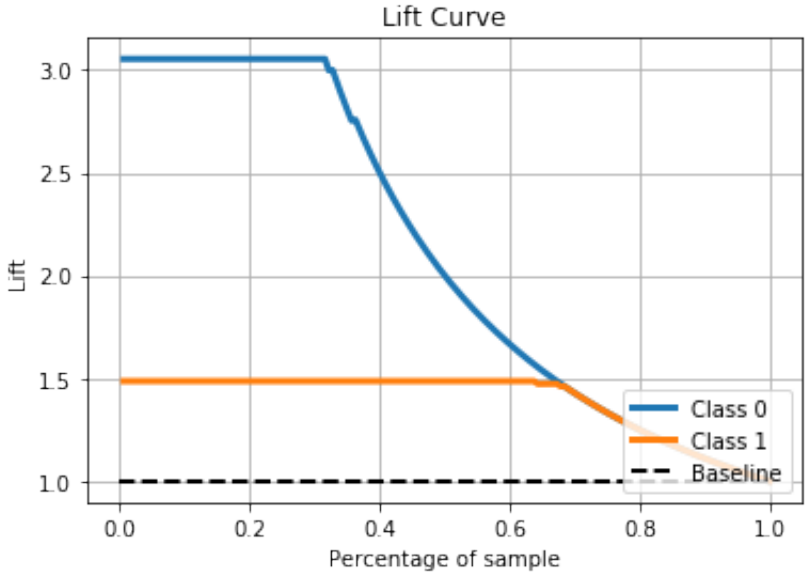
```
The AUC stats is:  0.991304347826087
[1.         0.96551724 1.         0.86206897 0.93103448 0.89655172
 0.96551724 0.93103448 0.96551724 0.93103448 0.96551724 1.
 0.96428571 0.89285714 0.96428571 0.89285714 0.96428571 1.
 0.96296296 0.96296296]

              precision    recall  f1-score   support

           0       0.97      1.00      0.98        56
           1       1.00      0.98      0.99       115

    accuracy                           0.99       171
   macro avg       0.98      0.99      0.99       171
weighted avg       0.99      0.99      0.99       171
```

```
The AUC stats is:  1.0
[0.62068966 0.62068966 0.62068966 0.62068966 0.62068966 0.62068966
 0.62068966 0.62068966 0.62068966 0.62068966 0.62068966 0.62068966
 0.64285714 0.64285714 0.64285714 0.64285714 0.64285714 0.62962963
 0.62962963 0.62962963]

              precision    recall  f1-score   support

           0       1.00      1.00      1.00        56
           1       1.00      1.00      1.00       115

    accuracy                           1.00       171
   macro avg       1.00      1.00      1.00       171
weighted avg       1.00      1.00      1.00       171
```

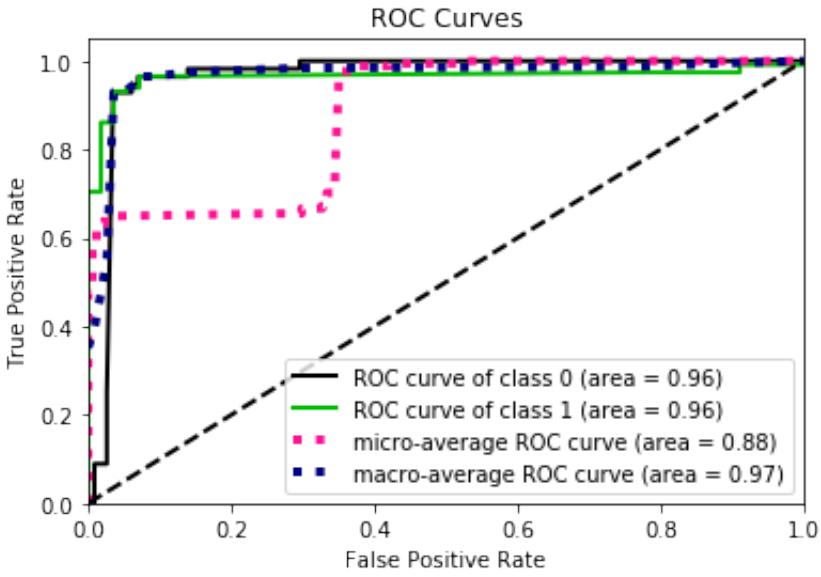
```
The AUC stats is:  0.9558229813664596
[0.86206897 0.82758621 1.         0.82758621 0.93103448 0.82758621
 0.44827586 0.93103448 0.93103448 0.96551724 0.89655172 0.96551724
 0.96428571 0.92857143 0.89285714 0.92857143 0.64285714 0.92592593
 0.92592593 0.92592593]

              precision    recall  f1-score   support

           0       0.93      0.95      0.94        56
           1       0.97      0.97      0.97       115

    accuracy                           0.96       171
   macro avg       0.95      0.96      0.95       171
weighted avg       0.96      0.96      0.96       171
```

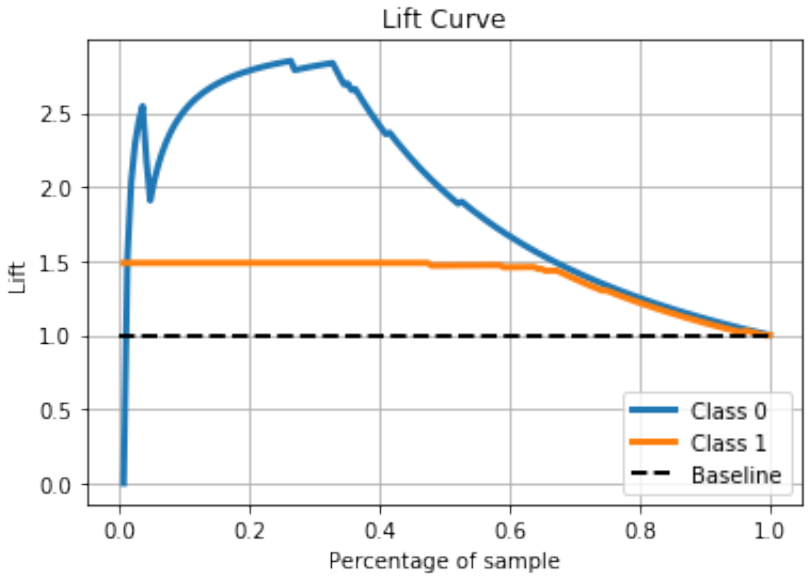
```
# Use lin_svc model
linear_svc = SVC(kernel='linear', gamma='scale', C=1.0,
probability=True).fit(X_train, y_train)
predicted_probas_linear_svc = linear_svc.predict_proba(X_test)


# roc curve
skplt.metrics.plot_roc(y_test, predicted_probas_linear_svc)

# lift curve
skplt.metrics.plot_lift_curve(y_test, predicted_probas_linear_svc)
plt.show()
```






```
# Use rbf_svc model
rbf_svc = SVC(kernel='rbf', gamma='auto', C = 1, probability=True).fit(X_train,
y_train)
predicted_probas_rbf_svc = rbf_svc.predict_proba(X_test)
# roc curve
skplt.metrics.plot_roc(y_test, predicted_probas_rbf_svc)

# lift curve
skplt.metrics.plot_lift_curve(y_test, predicted_probas_rbf_svc)
plt.show()
```





Combing models under different hyper parameters, I can conclude that:

The overall accuracy of Decision Tree is around 92%, the precision is 0.975, the recall is 0.975, the F1-measure is 0.975, the AUC is 0.99.

The overall accuracy of Logistic Regression is around 96%, the precision is 0.47, the recall is 0.50, the F1-measure is 0.50, the AUC is 0.975.

The overall accuracy of KNN is around 93%, the precision is 0.95, the recall is 0.94, the F1-measure is 0.95, the AUC is 0.948.

The overall accuracy of SVM Linear is around 94%, the precision is 0.94, the recall is 0.93, the F1-measure is 0.94, the AUC is 0.99.

The overall accuracy of SVM RBF is around 97%, the precision is 0.97, the recall is 0.97, the F1-measure is 0.97, the AUC is 0.95.

Basic concept of ROC & Lift curves:

ROC curve is a performance measurement for classification problem at various thresholds settings. ROC is a probability curve and AUC represents degree or measure of separability. It tells how much model is capable of distinguishing between classes. Higher the AUC, better the model is at predicting 0s as 0s and 1s as 1s. By analogy, Higher the AUC, better the model is at distinguishing between patients with disease and no disease. The ROC curve is plotted with TPR against the FPR where TPR is on y-axis and FPR is on the x-axis. Lift curve is a way of visualizing the performance of a classification model. A lift curve shows the ratio of a model to a random guess ('model cumulative sum' / 'random guess' from above).

According to the plots:

In terms of the ROC curve, the best model among these is the Logistic Regression. In terms of the Lift curve, the best model among these is the SVC.