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Lab5. Diabetes Classification using Logistic Regression

Step1. [Understand Data]. Using Pandas, import “diabetes.csv” file and print properties such as head, shape, columns, dtype, info and value_counts

In [2]:
```
import pandas as pd
data = pd.read_csv('diabetes.csv')
data.head()
```

Out[2]:

	Pregnancies	Glucose	BloodPressure	SkinThickness	Insulin	BMI	DiabetesPedigreeFunction
0	6	148	72	35	0	33.6	0.627
1	1	85	66	29	0	26.6	0.351
2	8	183	64	0	0	23.3	0.672
3	1	89	66	23	94	28.1	0.167
4	0	137	40	35	168	43.1	2.288

In [3]:
```
data.shape
```

Out[3]:
```
(768, 9)
```

In [4]:
```
data.columns
```

Out[4]:
```
Index(['Pregnancies', 'Glucose', 'BloodPressure', 'SkinThickness', 'Insulin',
       'BMI', 'DiabetesPedigreeFunction', 'Age', 'Outcome'],
      dtype='object')
```

In [5]:
```
data.dtypes
```

Out[5]:
```
Pregnancies                   int64
Glucose                       int64
BloodPressure                 int64
SkinThickness                 int64
Insulin                       int64
BMI                         float64
DiabetesPedigreeFunction    float64
Age                           int64
Outcome                       int64
dtype: object
```

In [6]:
```
type(data)
```

Out[6]:
```
pandas.core.frame.DataFrame
```

In [7]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 768 entries, 0 to 767
Data columns (total 9 columns):
 #   Column                    Non-Null Count  Dtype  
---  ------                    --------------  -----  
 0   Pregnancies               768 non-null    int64  
 1   Glucose                   768 non-null    int64  
 2   BloodPressure             768 non-null    int64  
 3   SkinThickness             768 non-null    int64  
 4   Insulin                   768 non-null    int64  
 5   BMI                       768 non-null    float64
 6   DiabetesPedigreeFunction  768 non-null    float64
 7   Age                       768 non-null    int64  
 8   Outcome                   768 non-null    int64  
dtypes: float64(2), int64(7)
memory usage: 54.1 KB
```

In [8]:
```
data.value_counts()
```

Out[8]:
```
Pregnancies  Glucose  BloodPressure  SkinThickness  Insulin  BMI   DiabetesPedi
greeFunction  Age  Outcome
0            57       60             0              0        21.7  0.735
67   0          1
             67       76             0              0        45.3  0.194
46   0          1
5            103      108            37             0        39.2  0.305
65   0          1
             104      74             0              0        28.8  0.153
48   0          1
             105      72             29             325      36.9  0.159
28   0          1

..
2            84       50             23             76       30.4  0.968
21   0          1
             85       65             0              0        39.6  0.930
27   0          1
             87       0              23             0        28.9  0.773
25   0          1
                      58             16             52       32.7  0.166
25   0          1
17           163      72             41             114      40.9  0.817
47   1          1
Length: 768, dtype: int64
```

Step2. [Build Logistic Regression Model]

Prepare X matrix (8 feature columns) and y vector (ie., Outcome column)

In [9]:
```
X=data.drop("Outcome", axis=1)
y=data[["Outcome"]]
```

In [10]:
```
X
```

Out[10]:

	Pregnancies	Glucose	BloodPressure	SkinThickness	Insulin	BMI	DiabetesPedigreeFunction
0	6	148	72	35	0	33.6	0.627
1	1	85	66	29	0	26.6	0.351
2	8	183	64	0	0	23.3	0.672
3	1	89	66	23	94	28.1	0.167
4	0	137	40	35	168	43.1	2.288
...	...	...	...	...	...	...	...
763	10	101	76	48	180	32.9	0.171
764	2	122	70	27	0	36.8	0.340
765	5	121	72	23	112	26.2	0.245
766	1	126	60	0	0	30.1	0.349
767	1	93	70	31	0	30.4	0.315

768 rows × 8 columns

In [11]:
```
y
```

Out[11]:

	Outcome
0	1
1	0
2	1
3	0
4	1
...	...
763	0
764	0
765	0
766	1
767	0

768 rows × 1 columns

Split dataset with stratified shuffle split for training and testing as X_train, X_test, y_train, y_test (use 25% test size).

In [12]:
```
from sklearn.model_selection import StratifiedShuffleSplit
```

In [13]:
```
StratifiedShuffleSplit()
shuffle = StratifiedShuffleSplit(n_splits=4, test_size=0.25,random_state=0)
```

In [14]:
```
shuffle.get_n_splits(X,y)
```

Out[14]: 4

Create LogisticRegression model, fit on training set and predict on test set

In [15]:
```
import warnings
warnings.filterwarnings('ignore')
```

In [16]:
```
for train, test in shuffle.split(X, y):
    X_train, X_test = X.iloc[train], X.iloc[test]
    y_train, y_test = y.iloc[train], y.iloc[test]
```

In [17]:
```
from sklearn.linear_model import LogisticRegression
```

In [18]:
```
lmodel = LogisticRegression()
```

In [19]:
```
lmodel.fit(X_train,y_train)
```

Out[19]:
```
LogisticRegression()
```

In [20]:
```
y_predict = lmodel.predict(X_test)
y_predict
```

Out[20]:
```
array([0, 0, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 0,
       0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1,
       1, 0, 1, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0,
       0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0,
       1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 1,
       0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0,
       1, 0, 1, 1, 1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0,
       0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0,
       0, 1, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0], dtype=int64)
```

In [21]:
```
lmodel.score(X_train,y_train)
```

Out[21]: 0.7899305555555556

Predict on a new sample

In [22]:
```
new_person = [[6, 200, 90, 10, 25, 23.3, 0.672, 42]]
```

In [23]:
```
print(lmodel.predict(new_person))
```

```
[1]
```

Step3. [Compute Classification Metrics]

Precision score

In [24]:
```
from sklearn.metrics import precision_score
print(precision_score(y_test, y_predict))
```

```
0.6727272727272727
```

Recall score

In [25]:
```
from sklearn.metrics import recall_score
print(recall_score(y_test, y_predict))
```

```
0.5522388059701493
```

Accuracy score

Which is 75% Accurate

In [26]:
```
from sklearn.metrics import accuracy_score
lor_ascore=accuracy_score(y_test, y_predict)
```

In [27]:
```
lor_ascore
```

Out[27]:
```
0.75
```

AUC score

AUC is the percentage of the ROC plot that is underneath the curve:

In [28]:
```
from sklearn.metrics import roc_auc_score
```

In [29]:
```
print(roc_auc_score(y_test, y_predict))
```

```
0.7041194029850747
```

Step4. [Understand Correlation]

Create confusion matrix between y_test and y_pred and plot confusion matrix values in a Heatmap. Explain the meaning of the 4 numbers you get.

In [30]:
```
from sklearn.metrics import confusion_matrix
cnf_matrix=confusion_matrix(y_test, y_predict)
cnf_matrix
```

Out[30]:
```
array([[107,  18],
       [ 30,  37]], dtype=int64)
```

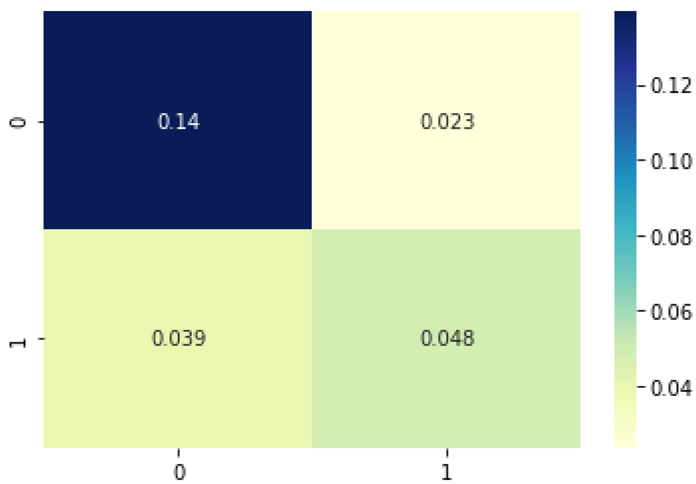
In [31]:
```
cf_ac_score = accuracy_score(y_test, y_predict)
```

In [32]:
```
cf_ac_score
```

Out[32]:
```
0.75
```

In [33]:
```
import seaborn as sns
sns.heatmap(confusion_matrix(y_test,y_predict) / len(y), cmap='YlGnBu', annot=Tru
```

Out[33]:
```
<AxesSubplot:>
```



X-axis is predicted value

Y-axis is real value

Step5. [Normalization using MinmaxScaler and rebuild LoR]

Now, normalize your X_train and X_test values using MinmaxScaler

In [34]:
```
from sklearn.preprocessing import MinMaxScaler
scaler = MinMaxScaler()
X_trained = scaler.fit_transform(X_train)
X_tested = scaler.transform(X_test)
```

In [35]:
```
X_trained.shape
```
Out[35]:
```
(576, 8)
```

In [36]:
```
X_tested.shape
```
Out[36]:
```
(192, 8)
```

Create a new LogisticRegression model, fit on normalized training set and predict on the normalized test set

In [37]:
```
from sklearn.linear_model import LogisticRegression
lmodel1 = LogisticRegression()
```

In [38]:
```
lmodel1.fit(X_trained, y_train)
```
Out[38]:
```
LogisticRegression()
```

In [39]:
```
yn_predict = lmodel1.predict(X_tested)
yn_predict
```
Out[39]:
```
array([0, 0, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 0,
       0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1,
       1, 0, 1, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0,
       0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0,
       1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 1,
       0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0,
       1, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0,
       0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0,
       0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0], dtype=int64)
```

In [40]:
```
lmodel1.score(X_trained, y_train)
```
Out[40]:
```
0.7899305555555556
```

Precision score

In [41]:
```
from sklearn.metrics import precision_score
print(precision_score(y_test, yn_predict))
```
```
0.673469387755102
```

Recall score

In [42]:
```
from sklearn.metrics import recall_score
print(recall_score(y_test, yn_predict))
```
```
0.4925373134328358
```

Accuracy score

Which is 72% Accurate

In [43]:
```
from sklearn.metrics import accuracy_score
minmax_ascore=accuracy_score(y_test, yn_predict)
```

In [44]:
```
minmax_ascore
```

Out[44]:
```
0.7395833333333334
```

AUC score

AUC is the percentage of the ROC plot that is underneath the curve

In [45]:
```
from sklearn.metrics import roc_auc_score
```

In [46]:
```
lgr_auc=roc_auc_score(y_test, yn_predict)
lgr_auc1=('LoR minmax, AUC=',lgr_auc)
lgr_auc1
```

Out[46]:
```
('LoR minmax, AUC=', 0.6822686567164179)
```

Step6. [Normalization using StandardScaler and rebuild LoR]

In [47]:
```
from sklearn.preprocessing import StandardScaler
scaler = StandardScaler()
Xs_trained = scaler.fit_transform(X_train)
Xs_tested = scaler.transform(X_test)
```

In [48]:
```
Xs_trained.shape
```

Out[48]:
```
(576, 8)
```

In [49]:
```
Xs_tested.shape
```

Out[49]:
```
(192, 8)
```

In [50]:
```
from sklearn.linear_model import LogisticRegression
lmodel2 = LogisticRegression()
```

In [51]:
```
lmodel2.fit(Xs_trained, y_train)
```

Out[51]:
```
LogisticRegression()
```

In [52]:
```
ys_predict = lmodel2.predict(Xs_tested)
ys_predict
```

Out[52]:
```
array([0, 0, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 0,
       0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1,
       1, 0, 1, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0,
       0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0,
       1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 1,
       0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0,
       1, 0, 1, 1, 1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 1, 1, 1, 0, 0, 0, 0,
       0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0,
       0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0], dtype=int64)
```

In [53]:
```
lmodel2.score(Xs_trained, y_train)
```

Out[53]:
```
0.7795138888888888
```

Precision score

In [54]:
```
from sklearn.metrics import precision_score
print(precision_score(y_test, ys_predict))
```

```
0.6851851851851852
```

Recall score

In [55]:
```
from sklearn.metrics import recall_score
print(recall_score(y_test, ys_predict))
```

```
0.5522388059701493
```

Accuracy score

Which is 75% Accurate

In [56]:
```
from sklearn.metrics import accuracy_score
ss_ascore=accuracy_score(y_test, ys_predict)
```

In [57]:
```
ss_ascore
```

Out[57]:
```
0.7552083333333334
```

AUC score

AUC is the percentage of the ROC plot that is underneath the curve

In [58]:
```
from sklearn.metrics import roc_auc_score
```

In [59]:
```
ss_auc=roc_auc_score(y_test, ys_predict)
ss_auc1=('AUC=',ss_auc)
ss_auc1
```

Out[59]:
```
('AUC=', 0.7081194029850746)
```

Among the 3 models, which model gives better classification scores?

In [60]:
```
print('StandardScaler:',ss_ascore)
print('MinmaxScaler:',minmax_ascore)
print('Logistic Regression Model:',lor_ascore)
```

```
StandardScaler: 0.7552083333333334
MinmaxScaler: 0.7395833333333334
Logistic Regression Model: 0.75
```

Step7. [Plot ROC curve]

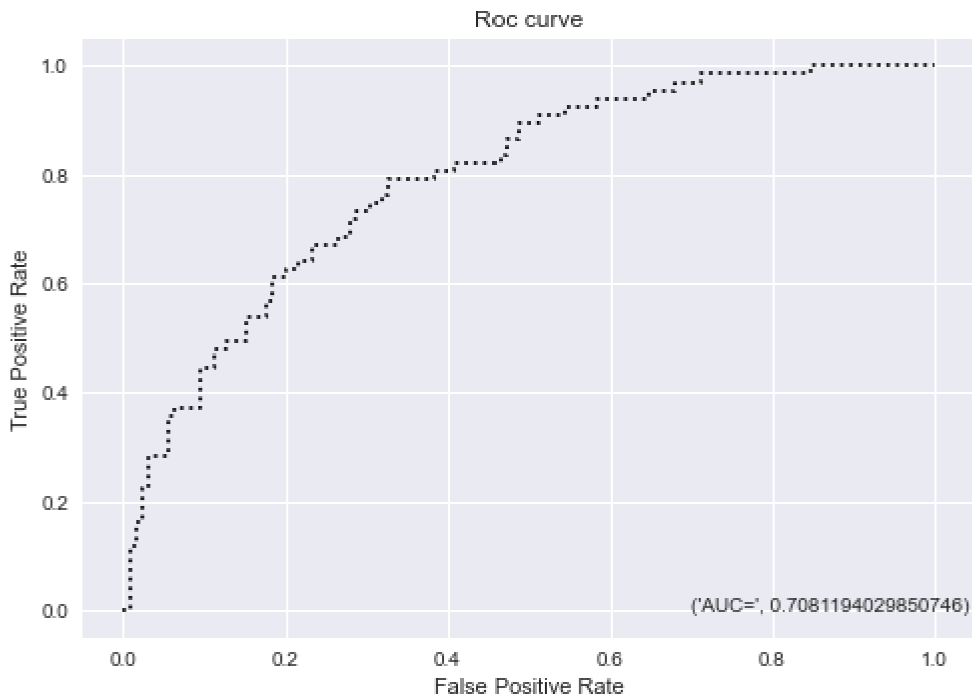
Plot ROC curve as shown below. You can use the MinmaxScaler scaled values of X_test for computing predict_proba() score.

In [61]:
```
from sklearn.metrics import roc_curve
```

In [62]:
```
predict_pb1 = lmodel1.predict_proba(X_tested)
fpr1, tpr1, threshold1 = roc_curve(y_test,predict_pb1[:,1], pos_label=1)
```

In [63]:
```
import matplotlib.pyplot as plt
plt.style.use('seaborn')
plt.annotate(xy=[0.7,0], s=ss_auc1)
plt.plot(fpr1, tpr1, linestyle=':', color='black',label='Logistic Regression')
plt.title('Roc curve')
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
```

Out[63]:
```
Text(0, 0.5, 'True Positive Rate')
```



Step8. [Comparison with KNN classifier].

Create a KNN classifier with default values, fit on the scaled X using MinmaxScaler, predict and print classification metric scores.

In [64]:
```
from sklearn.neighbors import KNeighborsClassifier
```

In [65]:
```
lmodel3 = KNeighborsClassifier(n_neighbors=3)
```

In [66]:
```
lmodel3.fit(X_trained,y_train)
```

Out[66]:
```
KNeighborsClassifier(n_neighbors=3)
```

In [67]:
```
knn_y_predict = lmodel3.predict(X_tested)
knn_y_predict
```

Out[67]:
```
array([1, 0, 1, 0, 0, 0, 1, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0,
       0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1,
       1, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 1, 0, 0,
       0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0, 1, 1, 0, 1, 0, 0, 0, 1, 0,
       1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 1, 1, 0, 0,
       0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0,
       0, 0, 1, 1, 1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0,
       0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 0, 0,
       0, 1, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1], dtype=int64)
```

Precision score

In [68]:
```
from sklearn.metrics import precision_score
print(precision_score(y_test, knn_y_predict))
```

```
0.6271186440677966
```

Recall score

In [69]:
```
from sklearn.metrics import recall_score
print(recall_score(y_test, knn_y_predict))
```

```
0.5522388059701493
```

Accuracy score

In [70]:
```
from sklearn.metrics import accuracy_score
kn_ascore=accuracy_score(y_test, knn_y_predict)
kn_ascore
```

Out[70]:
```
0.7291666666666666
```

AUC score

In [71]:
```
from sklearn.metrics import roc_auc_score
kn_auc=roc_auc_score(y_test, knn_y_predict)
kn_auc1=('KNN minmax, AUC=',kn_auc)
kn_auc1
```

Out[71]:
```
('KNN minmax, AUC=', 0.6881194029850747)
```

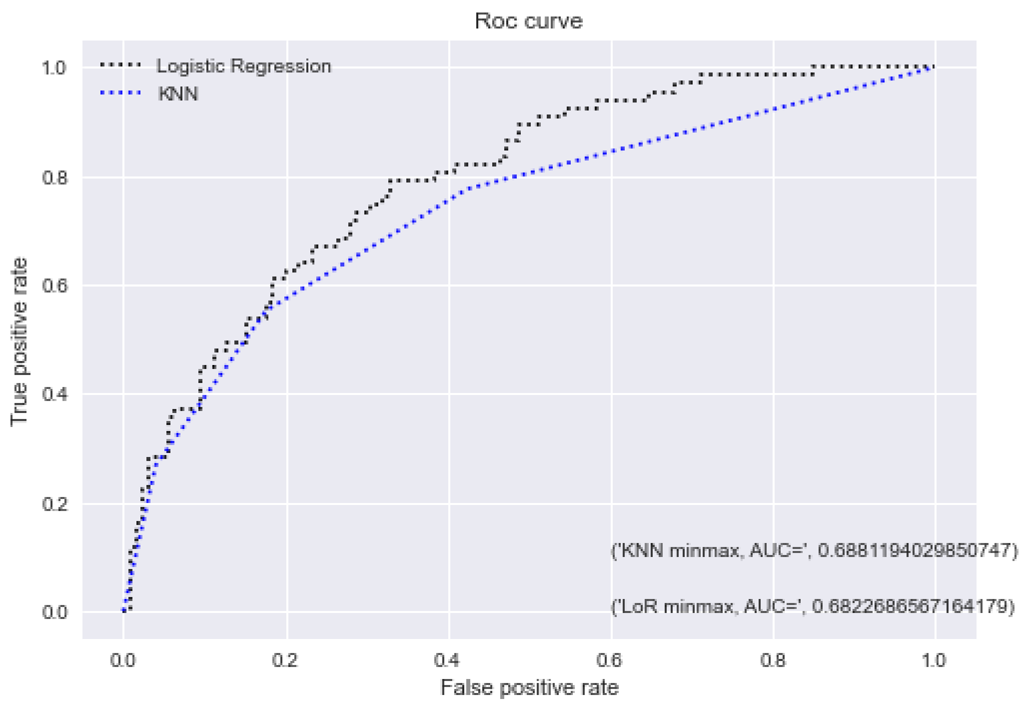
Step9. [Update ROC curve]

Update your ROC curve, this time, with one more curve of KNN classifier,

In [72]:
```
predict_pb2 = lmodel3.predict_proba(X_tested)
fpr1,tpr1,threshold1 = roc_curve(y_test, predict_pb1[:,1],pos_label=1)
fpr2,tpr2,threshold2 = roc_curve(y_test, predict_pb2[:,1],pos_label=1)
```

In [73]:
```
plt.plot(fpr1,tpr1,linestyle=':',color='black',label='Logistic Regression')
plt.plot(fpr2,tpr2,linestyle=':',color ='blue',label='KNN')
plt.annotate(xy=[0.6,0.1], s=kn_auc1)
plt.annotate(xy=[0.6,0], s=lgr_auc1)
plt.legend(loc='best')
plt.title('Roc curve')
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')
```

Out[73]:
```
Text(0, 0.5, 'True positive rate')
```



Step10. [Regularization]

In order to reduce overfitting of your data, you will use LogisticRegressionCV model with L1 and L2 regularization parameters. Create both models using the following statements

In [74]:
```
from sklearn.linear_model import LogisticRegressionCV
```

In [75]:
```
lmodel4 = LogisticRegressionCV(Cs=10, cv=4, penalty='l1', solver='liblinear')
lmodel5 = LogisticRegressionCV(Cs=10, cv=4, penalty='l2')
```

Perform fit using MinmaxScaler scaled values and predict

In [76]:
```
print(lmodel4.fit(X_trained,y_train))
print(lmodel5.fit(X_trained,y_train))
```

```
LogisticRegressionCV(cv=4, penalty='l1', solver='liblinear')
LogisticRegressionCV(cv=4)
```

In [77]:
```
lr_y_predict1 = lmodel4.predict(X_tested)
lr_y_predict2 = lmodel5.predict(X_tested)
print('Logistic RegressionCV L1:\n',lr_y_predict1)
print('---------------------------------------------------------------------------
print('Logistic RegressionCV L2:\n',lr_y_predict2)
```

```
Logistic RegressionCV L1:
 [0 0 1 1 0 1 1 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 1 0 1 0 0 1 0 0 0 0 0 0
 0 0 0 0 1 0 1 1 0 1 0 1 0 0 0 1 0 0 1 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0
 1 0 0 0 0 1 1 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 1 0
 0 0 1 1 0 0 0 0 0 1 0 0 1 1 0 0 0 0 0 0 0 1 0 1 1 1 1 0 0 0 0 0 0 1 0 0 0
 1 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 1 0 0 0 0 0 1 0 0 1 1 0 0
 0 0 0 1 0 0 0]
---------------------------------------------------------------------------
Logistic RegressionCV L2:
 [0 0 1 1 0 1 1 0 0 1 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0 1 0 1 0 0 1 0 0 0 0 0 0
 0 0 0 0 1 0 1 1 0 1 0 1 0 0 0 1 0 0 1 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 1
 1 0 0 0 0 1 1 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 1 0
 0 0 1 1 0 0 0 0 0 1 0 0 1 1 0 0 0 0 0 0 0 1 0 1 1 1 1 0 0 0 1 0 0 1 0 0 0
 1 1 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 1 0 1 0 0 1 0 0 0 0 0 1 0 0 1 1 0 0
 0 0 0 1 0 0 0]
```

In [78]:
```
from sklearn.metrics import roc_auc_score
lrp_auc=roc_auc_score(y_test, lr_y_predict1)
lrp1_auc=('LoR L1 minmax, AUC=',lrp_auc)
lrp1_auc
```

Out[78]:
```
('LoR L1 minmax, AUC=', 0.6748059701492537)
```

In [79]:
```
from sklearn.metrics import roc_auc_score
lrp_auc2=roc_auc_score(y_test, lr_y_predict2)
lrp2_auc=('LoR L2 minmax, AUC=',lrp_auc2)
lrp2_auc
```

Out[79]:
```
('LoR L2 minmax, AUC=', 0.6931940298507463)
```

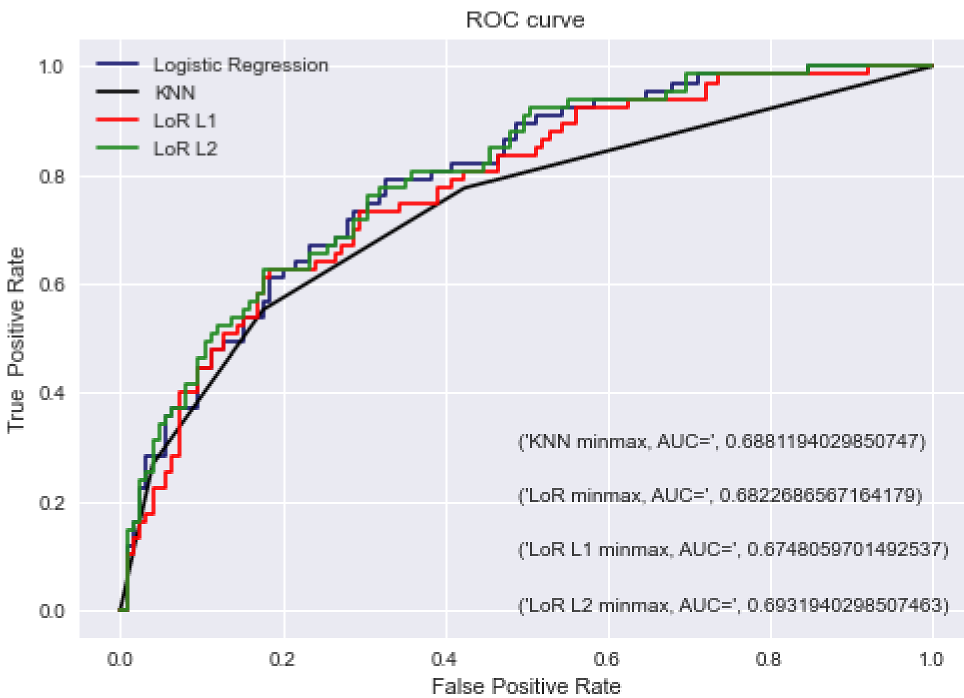
Step11. [Update ROC curve]

Update your ROC curve, this time, with two more curves

In [80]:
```
predict_pb3 = lmodel4.predict_proba(X_tested)
predict_pb4 = lmodel5.predict_proba(X_tested)
fpr1,tpr1,thresh1 = roc_curve(y_test, predict_pb1[:,1], pos_label=1)
fpr2,tpr2,thresh2 = roc_curve(y_test, predict_pb2[:,1], pos_label=1)
fpr3,tpr3,thresh3 = roc_curve(y_test, predict_pb3[:,1], pos_label=1)
fpr4,tpr4,thresh4 = roc_curve(y_test, predict_pb4[:,1], pos_label=1)
```

In [90]:
```
plt.plot(fpr1,tpr1,linestyle='-',color='midnightblue', label='Logistic Regression
plt.plot(fpr2,tpr2,linestyle='-',color='black', label='KNN')
plt.plot(fpr3,tpr3,linestyle='-',color='red', label='LoR L1')
plt.plot(fpr4,tpr4,linestyle='-',color='forestgreen', label='LoR L2')
plt.annotate(xy=[0.49,0.3], s=kn_auc1)
plt.annotate(xy=[0.49,0.2], s=lgr_auc1)
plt.annotate(xy=[0.49,0.1], s=lrp1_auc)
plt.annotate(xy=[0.49,0], s=lrp2_auc)
plt.legend(loc='best')
plt.title('ROC curve')
plt.xlabel('False Positive Rate')
plt.ylabel('True  Positive Rate')
```

Out[90]:
```
Text(0, 0.5, 'True  Positive Rate')
```



Logistic Regression L2 Minmax gives 69% of AUC score so this shows it is the best score