In [1]:

```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
from sklearn import metrics
from sklearn.metrics import roc_auc_score


from sklearn.model_selection import train_test_split

from sklearn.metrics import confusion_matrix,classification_report,accuracy_score
from sklearn.metrics import roc_curve, roc_auc_score
```

In [2]:

```
data = pd.read_csv("bank/bank.csv",sep=';' )
data.head()
```

Out[2]:

	age	job	marital	education	default	balance	housing	loan	contact	day	month	duration	campaign	pdays
0	30	unemployed	married	primary	no	1787	no	no	cellular	19	oct	79	1	-1
1	33	services	married	secondary	no	4789	yes	yes	cellular	11	may	220	1	339
2	35	management	single	tertiary	no	1350	yes	no	cellular	16	apr	185	1	330
3	30	management	married	tertiary	no	1476	yes	yes	unknown	3	jun	199	4	-1
4	59	blue-collar	married	secondary	no	0	yes	no	unknown	5	may	226	1	-1

In [3]:

```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 4521 entries, 0 to 4520
Data columns (total 17 columns):
age           4521 non-null int64
job           4521 non-null object
marital       4521 non-null object
education     4521 non-null object
default       4521 non-null object
balance       4521 non-null int64
housing       4521 non-null object
loan          4521 non-null object
contact       4521 non-null object
day           4521 non-null int64
month         4521 non-null object
duration      4521 non-null int64
campaign      4521 non-null int64
pdays         4521 non-null int64
previous      4521 non-null int64
poutcome      4521 non-null object
y             4521 non-null object
dtypes: int64(7), object(10)
memory usage: 600.5+ KB
```

In [4]:

```
#Categorical Data
print(data.job.unique())
print(data.marital.unique())
print(data.education.unique())
print(data.default.unique())
print(data.housing.unique())
```

```
print(data.loan.unique())
print(data.contact.unique())
print(data.month.unique())
print(data.poutcome.unique())
```

```
['unemployed' 'services' 'management' 'blue-collar' 'self-employed'
 'technician' 'entrepreneur' 'admin.' 'student' 'housemaid' 'retired'
 'unknown']
['married' 'single' 'divorced']
['primary' 'secondary' 'tertiary' 'unknown']
['no' 'yes']
['no' 'yes']
['no' 'yes']
['cellular' 'unknown' 'telephone']
['oct' 'may' 'apr' 'jun' 'feb' 'aug' 'jan' 'jul' 'nov' 'sep' 'mar' 'dec']
['unknown' 'failure' 'other' 'success']
```

In [5]:

```
#CALCULATING DUMMY VALUES FOR CATEGORICAL DATA
```

In [6]:

```
job_dummy = pd.get_dummies(data['job'])
marital_dummy = pd.get_dummies(data['marital'])
education_dummy = pd.get_dummies(data['education'])
default_dummy = pd.get_dummies(data['default'])
housing_dummy = pd.get_dummies(data['housing'])
loan_dummy = pd.get_dummies(data['loan'])
contact_dummy = pd.get_dummies(data['contact'])
# day_dummy = pd.get_dummies(data['day'])
month_dummy = pd.get_dummies(data['month'])
poutcome_dummy = pd.get_dummies(data['poutcome'])
# y_dummy = pd.get_dummies(data['y'])
```

In [7]:

```
#ADDING DUMMY VALUES TO THE DATA
```

In [8]:

```
data = pd.concat([data,job_dummy], axis=1, sort=False)
data = pd.concat([data,marital_dummy], axis=1, sort=False)
data = pd.concat([data,education_dummy], axis=1, sort=False)
data = pd.concat([data,default_dummy], axis=1, sort=False)
data = pd.concat([data,housing_dummy], axis=1, sort=False)
data = pd.concat([data,loan_dummy], axis=1, sort=False)
data = pd.concat([data,contact_dummy], axis=1, sort=False)
# data = pd.concat([data,day_dummy], axis=1, sort=False)
data = pd.concat([data,month_dummy], axis=1, sort=False)
data = pd.concat([data,poutcome_dummy], axis=1, sort=False)
# data = pd.concat([data,y_dummy], axis=1, sort=False)
```

In [9]:

```
#DROP ROWS WHOSE CATEGORICAL DATA HAS BEEN ADDED
```

In [10]:

```
data = data.drop('job',axis=1)
data = data.drop('marital',axis=1)
data = data.drop('education',axis=1)
data = data.drop('default',axis=1)
data = data.drop('housing',axis=1)
data = data.drop('loan',axis=1)
data = data.drop('contact',axis=1)
data = data.drop('month',axis=1)
data = data.drop('poutcome',axis=1)
```

In [11]:

In [11]:

```
data.head()
```

Out[11]:

	age	balance	day	duration	campaign	pdays	previous	y	admin.	blue-collar	...	jun	mar	may	nov	oct	sep	failure	other
0	30	1787	19	79	1	-1	0	no	0	0	...	0	0	0	0	1	0	0	0
1	33	4789	11	220	1	339	4	no	0	0	...	0	0	1	0	0	0	1	0
2	35	1350	16	185	1	330	1	no	0	0	...	0	0	0	0	0	0	1	0
3	30	1476	3	199	4	-1	0	no	0	0	...	1	0	0	0	0	0	0	0
4	59	0	5	226	1	-1	0	no	0	1	...	0	0	1	0	0	0	0	0

5 rows × 52 columns

In [12]:

```
#SEPARATING PREDICTORS AND RESPONSE
```

In [13]:

```
df = data
df = df.drop('y',axis=1);
```

In [14]:

```
# y IS THE RESPONSE IN THIS DATASET
y=data['y']
y.head()
```

Out[14]:

```
0    no
1    no
2    no
3    no
4    no
Name: y, dtype: object
```

In [15]:

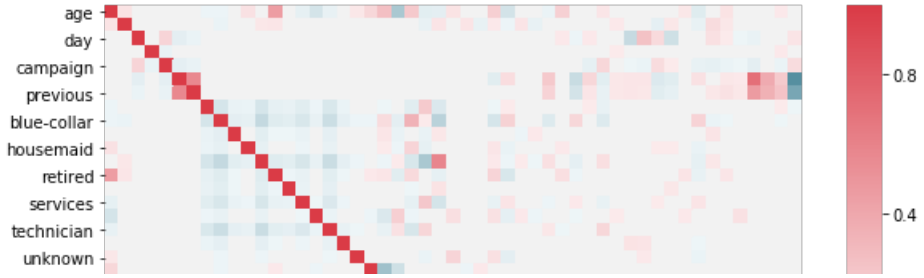
```
#PLOT CORRELATION BETWEEN ATTRIBUTES
```

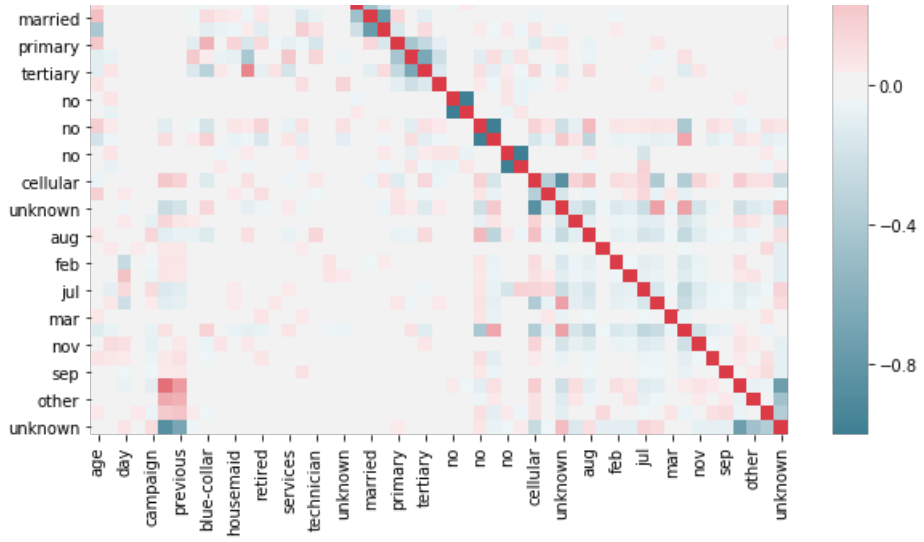
In [16]:

```
f, ax = plt.subplots(figsize=(10, 8))
corr = data.corr()
sns.heatmap(corr, mask=np.zeros_like(corr, dtype=np.bool), cmap=sns.diverging_palette(220, 10,
as_cmap=True),
            square=True, ax=ax)
```

Out[16]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1a145592b0>
```





In [17]:

```
#SPLITTING INTO TRAINING AND TESTING DATA
```

In [18]:

```
X_train, X_test, y_train, y_test = train_test_split(df, y, test_size=0.33, random_state=101)
```

In [19]:

```
#KNN RUNNING
```

In [20]:

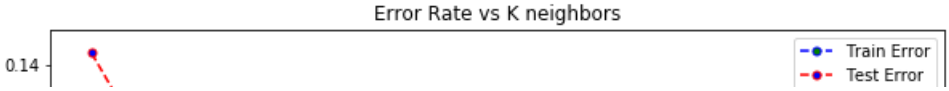
```
from sklearn.neighbors import KNeighborsClassifier
error_rate_train = []
for i in range(1,20):

    knn = KNeighborsClassifier(n_neighbors=i)
    knn.fit(X_train,y_train)
    pred_i = knn.predict(X_train)
    error_rate_train.append(np.mean(pred_i != y_train))

error_rate_test = []
for i in range(1,20):

    knn = KNeighborsClassifier(n_neighbors=i)
    knn.fit(X_train,y_train)
    pred_i = knn.predict(X_test)
    error_rate_test.append(np.mean(pred_i != y_test))
```

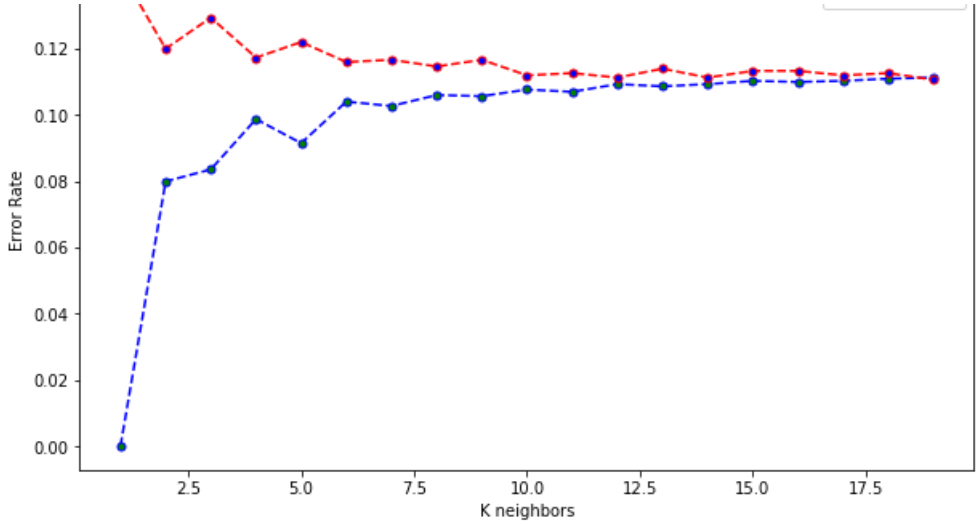
In [21]:

```
plt.figure(figsize=(10,6))
train_score,=plt.plot(range(1,20),error_rate_train,color='blue', linestyle='dashed', marker='o',
         markerfacecolor='green', markersize=5)
test_score,=plt.plot(range(1,20),error_rate_test,color='red',linestyle='dashed',  marker='o',
         markerfacecolor='blue', markersize=5)
plt.legend( [train_score,test_score],["Train Error","Test Error"])
plt.title('Error Rate vs K neighbors')
plt.xlabel('K neighbors')
plt.ylabel('Error Rate')
```

Out[21]:

```
Text(0,0.5,'Error Rate')
```





In [22]:

```
# KNN FOR 6 NEIGHBOURS
```

In [23]:

```
knn = KNeighborsClassifier(n_neighbors=6)
knn.fit(X_train,y_train)
```

Out[23]:

```
KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='minkowski',
           metric_params=None, n_jobs=1, n_neighbors=6, p=2,
           weights='uniform')
```

In [24]:

```
print('Accuracy = ',knn.score(X_test,y_test)) #Mean Accuracy
y_pred=knn.predict(X_test)


print('\nconfusion matrix\n',confusion_matrix(y_test, y_pred))
print('\nclassification report\n',classification_report(y_test, y_pred))
```

```
Accuracy =  0.8840482573726541

confusion matrix
 [[1301   23]
 [ 150   18]]

classification report
              precision    recall  f1-score   support

          no       0.90      0.98      0.94      1324
         yes       0.44      0.11      0.17       168

avg / total       0.85      0.88      0.85      1492
```

In [25]:

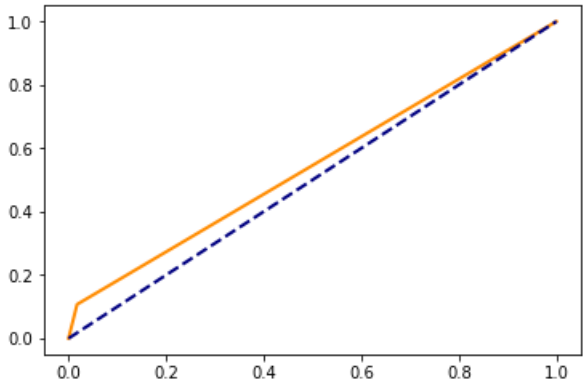
```
y_test_bin = y_test
y_test_bin = y_test_bin.map({'no':0,'yes':1})
y_pred_bin = y_pred
y_pred_bin = pd.Series(data=y_pred)
y_pred_bin = y_pred_bin.map({'no':0,'yes':1})
```

In [26]:

```
#AUC GRAPH

fpr, tpr, _ = roc_curve(y_test_bin, y_pred_bin)
```

```
plt.plot(fpr,tpr, color='darkorange',lw=2)
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
roc_auc = roc_auc_score(y_test_bin, y_pred_bin)
print('Area under graph = ',roc_auc)
```

```
Area under graph =  0.544885627967199
```



In [27]:

```
# DECISION TREE
```

In [28]:

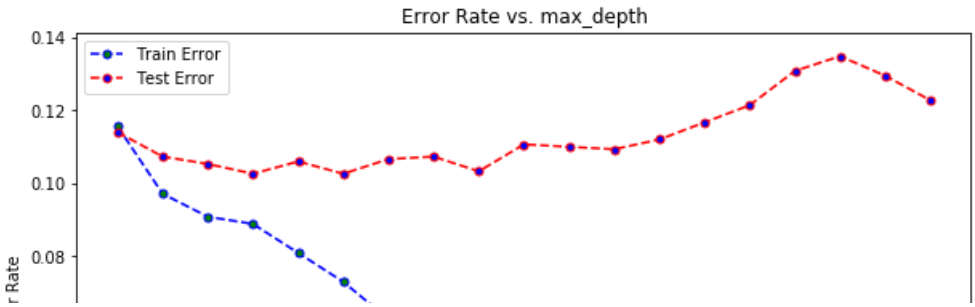
```
from sklearn.tree import DecisionTreeClassifier
error_rate_train = []
for i in range(1,20):

    dTree = DecisionTreeClassifier(max_depth=i)
    dTree.fit(X_train,y_train)
    pred_i = dTree.predict(X_train)
    error_rate_train.append(np.mean(pred_i != y_train))

error_rate_test = []
for i in range(1,20):

    dTree = DecisionTreeClassifier(max_depth=i)
    dTree.fit(X_train,y_train)
    pred_i = dTree.predict(X_test)
    error_rate_test.append(np.mean(pred_i != y_test))
```

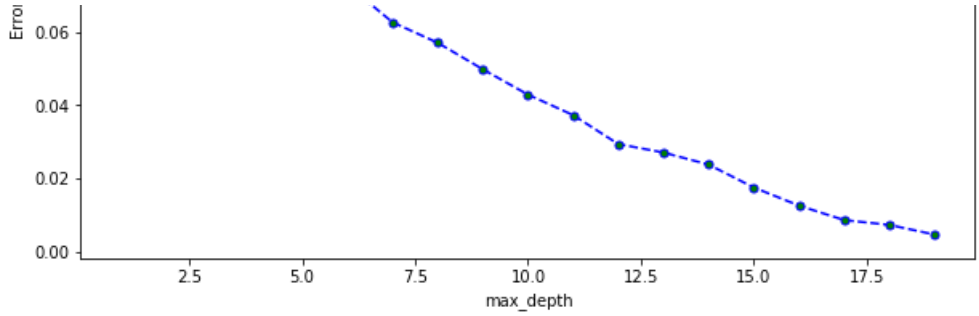
In [29]:

```
plt.figure(figsize=(10,6))
train_score,=plt.plot(range(1,20),error_rate_train,color='blue', linestyle='dashed', marker='o',
         markerfacecolor='green', markersize=5)
test_score,=plt.plot(range(1,20),error_rate_test,color='red',linestyle='dashed',  marker='o',
         markerfacecolor='blue', markersize=5)
plt.legend( [train_score,test_score],["Train Error","Test Error"])
plt.title('Error Rate vs. max_depth')
plt.xlabel('max_depth')
plt.ylabel('Error Rate')
```

Out[29]:

```
Text(0,0.5,'Error Rate')
```





In [30]:

```
dTree = DecisionTreeClassifier(max_depth=6)
dTree.fit(X_train,y_train)
```

Out[30]:

```
DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=6,
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=None,
            splitter='best')
```

In [31]:

```
print('Mean Accuracy\n',dTree.score(X_test,y_test))
print('\nconfusion matrix\n',confusion_matrix(y_test, y_pred))
print('\nclassification report\n',classification_report(y_test, y_pred))
```

```
Mean Accuracy
 0.8981233243967829

confusion matrix
 [[1301   23]
 [ 150   18]]

classification report
              precision    recall  f1-score   support

          no       0.90      0.98      0.94      1324
         yes       0.44      0.11      0.17       168

avg / total       0.85      0.88      0.85      1492
```

In [32]:

```
y_pred=dTree.predict(X_test)
```

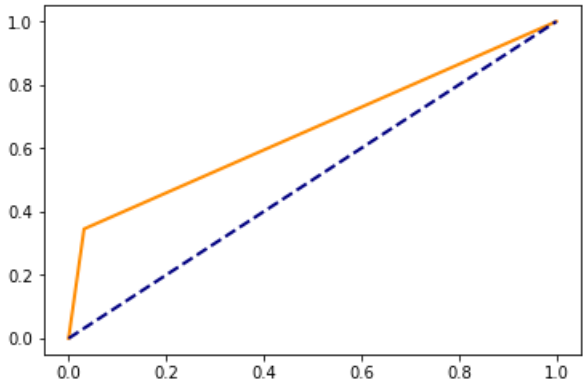
In [33]:

```
y_test_bin = y_test
y_test_bin = y_test_bin.map({'no':0,'yes':1})
y_pred_bin = y_pred
y_pred_bin = pd.Series(data=y_pred)
y_pred_bin = y_pred_bin.map({'no':0,'yes':1})
```

In [34]:

```
#AUC GRAPH

fpr, tpr, _ = roc_curve(y_test_bin, y_pred_bin)
plt.plot(fpr,tpr, color='darkorange',lw=2)
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
roc_auc = roc_auc_score(y_test_bin, y_pred_bin)
print('Area under graph = ',roc_auc)
```

```
Area under graph =  0.6567580204287153
```



In [35]:

```
# RANDOM FOREST
```

In [36]:

```
from sklearn.ensemble import RandomForestClassifier
rf = RandomForestClassifier(n_estimators=200,criterion="entropy")
rf.fit(X_train, y_train)
```

Out[36]:

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='entropy',
            max_depth=None, max_features='auto', max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, n_estimators=200, n_jobs=1,
            oob_score=False, random_state=None, verbose=0,
            warm_start=False)
```

In [37]:

```
print('Accuracy\n',rf.score(X_test,y_test))
y_pred=rf.predict(X_test)
print('\nConfusion Matrix\n',confusion_matrix(y_test, y_pred))
print('\nClassification Report\n',classification_report(y_test, y_pred))
```

```
Accuracy
 0.8981233243967829

Confusion Matrix
 [[1302   22]
 [ 130   38]]

Classification Report
              precision    recall  f1-score   support

          no       0.91      0.98      0.94      1324
         yes       0.63      0.23      0.33       168

avg / total       0.88      0.90      0.88      1492
```

In [38]:

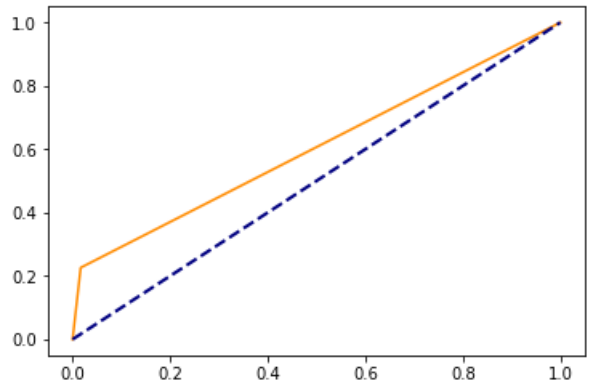
```
y_test_bin = y_test
y_test_bin = y_test_bin.map({'no':0,'yes':1})
y_pred_bin = y_pred
y_pred_bin = pd.Series(data=y_pred)
y_pred_bin = y_pred_bin.map({'no':0,'yes':1})
```

In [39]:

```
#AUC GRAPH
fpr, tpr, _ = roc_curve(y_test_bin, y_pred_bin)
```

```
plt.plot(fpr,tpr, color='darkorange')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
roc_auc = roc_auc_score(y_test_bin, y_pred_bin)
print('Area under graph = ',roc_auc)
```

```
Area under graph =  0.6047870809955402
```



In [40]:

```
#BAGGING
from sklearn.ensemble import BaggingClassifier
```

In [41]:

```
bag_depth5 = BaggingClassifier(base_estimator=DecisionTreeClassifier(max_depth=5 , criterion =
'entropy'), n_estimators=10, n_jobs=-1, random_state=1)
```

In [42]:

```
bag_depth5.fit(X_train,y_train)
```

Out[42]:

```
BaggingClassifier(base_estimator=DecisionTreeClassifier(class_weight=None, criterion='entropy', ma
x_depth=5,
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=None,
            splitter='best'),
         bootstrap=True, bootstrap_features=False, max_features=1.0,
         max_samples=1.0, n_estimators=10, n_jobs=-1, oob_score=False,
         random_state=1, verbose=0, warm_start=False)
```

In [43]:

```
print('Mean Accuracy\n',bag_depth5.score(X_test,y_test))
y_pred=bag_depth5.predict(X_test)
print('\nconfusion matrix\n',confusion_matrix(y_test, y_pred))
print('\nclassification report\n',classification_report(y_test, y_pred))
```

```
Mean Accuracy
 0.8927613941018767

confusion matrix
 [[1285   39]
 [ 121   47]]

classification report
             precision    recall  f1-score   support

         no       0.91      0.97      0.94      1324
        yes       0.55      0.28      0.37       168

avg / total       0.87      0.89      0.88      1492
```

In [44]:

```
bag_depth40 = BaggingClassifier(base_estimator=DecisionTreeClassifier(max_depth=40 , criterion =
'entropy'), n_estimators=10, n_jobs=-1, random_state=1)
```

In [45]:

```
bag_depth40.fit(X_train,y_train)
```

Out[45]:

```
BaggingClassifier(base_estimator=DecisionTreeClassifier(class_weight=None, criterion='entropy', ma
x_depth=40,
            max_features=None, max_leaf_nodes=None,
            min_impurity_decrease=0.0, min_impurity_split=None,
            min_samples_leaf=1, min_samples_split=2,
            min_weight_fraction_leaf=0.0, presort=False, random_state=None,
            splitter='best'),
         bootstrap=True, bootstrap_features=False, max_features=1.0,
         max_samples=1.0, n_estimators=10, n_jobs=-1, oob_score=False,
         random_state=1, verbose=0, warm_start=False)
```

In [46]:

```
print('Mean Accuracy\n',bag_depth40.score(X_test,y_test))
y_pred=bag_depth40.predict(X_test)
print('\nconfusion matrix\n',confusion_matrix(y_test, y_pred))
print('\nclassification report\n',classification_report(y_test, y_pred))
```

```
Mean Accuracy
 0.8967828418230563

confusion matrix
 [[1273   51]
 [ 103   65]]

classification report
              precision    recall  f1-score   support

         no       0.93      0.96      0.94      1324
        yes       0.56      0.39      0.46       168

avg / total       0.88      0.90      0.89      1492
```