kfold-kd_tree

October 14, 2018

```
In [8]: # ============================= loading libraries ==================================
        import numpy as np
        import pandas as pd
        import matplotlib.pyplot as plt
        from sklearn.cross_validation import train_test_split
        from sklearn.neighbors import KNeighborsClassifier
        from sklearn.metrics import accuracy_score
        from sklearn.cross_validation import cross_val_score
        from collections import Counter
        from sklearn.metrics import accuracy_score
        from sklearn import cross_validation

        from sklearn import datasets, neighbors
        from sklearn.model_selection import TimeSeriesSplit
        import pickle
        import scipy
        import time
        # ==================================================================================
```

```
In [9]: #Function to pickle in an object.
        def openPickleFile(name): #name = the pickle file name, this should be passed as a str
            global temp
            temp = pickle.load(open(name + ".pickle","rb"))
            return temp
```

```
In [10]: openPickleFile("y_train")
         y_train = temp
         print(y_train.shape)
         print(y_train.dtype)
```

```
(33334,)
object
```

```
In [11]: y_train[y_train == 'positive'] = 1
         y_train[y_train == 'negative'] = 0
         y_train = y_train.astype(float)
         print(y_train.dtype)
```

```
float64
```

```
In [12]: openPickleFile("y_test")
         y_test = temp
         print(y_test.shape)
         print(y_test.dtype)
```

```
(16666,)
object
```

```
In [13]: y_test[y_test == 'positive'] = 1
         y_test[y_test == 'negative'] = 0
         y_test = y_test.astype(float)
         print(y_test.dtype)
```

```
float64
```

```
In [14]: #Function to count no. of unique values in variable of any datatype.
         def unique_count(a):
             unique, inverse = np.unique(a, return_inverse=True)
             count = np.zeros(len(unique), np.int)
             np.add.at(count, inverse, 1)
             return np.vstack(( unique, count)).T
```

1 Dataset splitting strategies:

1. Time based splitting:-

```
In [9]: #Splitting data to Train and test based on time. Here the dataset is split to Train an
        #and the (k+1)th fold alloted to Test. k= no. of splits.
        def timeBasedSplit(X,y,splits):
            tscv = TimeSeriesSplit(n_splits=splits)
            print(tscv)
            global X_train, X_test, y_train, y_test
            for train_index, test_index in tscv.split(X):
               print("TRAIN:", train_index, "TEST:", test_index)
               X_train, X_test = X[train_index], X[test_index]
               y_train, y_test = y[train_index], y[test_index]

        timeBasedSplit(tsne_data_unigram,labels_20k_float,splits=3)
```

```
TimeSeriesSplit(max_train_size=None, n_splits=3)
TRAIN: [   0    1    2 ... 4997 4998 4999] TEST: [5000 5001 5002 ... 9997 9998 9999]
TRAIN: [   0    1    2 ... 9997 9998 9999] TEST: [10000 10001 10002 ... 14997 14998 14999]
TRAIN: [    0     1     2 ... 14997 14998 14999] TEST: [15000 15001 15002 ... 19997 19998 1999
```

2 CV using kd_tree algorithm.

3 1. CV on Standardized data for Unigrams

3.0.1 Simple Cross Validation

```
In [15]: openPickleFile("X_train_BOW_unigram")
         X_train = temp
         print(X_train.shape)
         print(X_train.dtype)
```

```
(33334, 50)
float64
```

```
In [16]: openPickleFile("X_test_BOW_unigram")
         X_test = temp
         print(X_test.shape)
         print(X_test.dtype)
```

```
(16666, 50)
float64
```

```
In [17]: def unique(a):
             unique, counts = np.unique(a, return_counts=True)
             return np.asarray((unique, counts)).T

         unique(y_test)
```

```
Out[17]: array([[0.000e+00, 8.440e+02],
                [1.000e+00, 4.156e+03]])
```

```
In [17]: # split the train data set into cross validation train and cross validation test
         time_start = time.time()

         X_tr, X_cv, y_tr, y_cv = cross_validation.train_test_split(X_train, y_train, test_size

         for i in range(1,30,2):
             # instantiate learning model (k = 30)
             knn = KNeighborsClassifier(n_neighbors=i, algorithm='kd_tree', n_jobs = 6)

             # fitting the model on crossvalidation train
             knn.fit(X_tr, y_tr)

             # predict the response on the crossvalidation train
             pred = knn.predict(X_cv)

             # evaluate CV accuracy
```

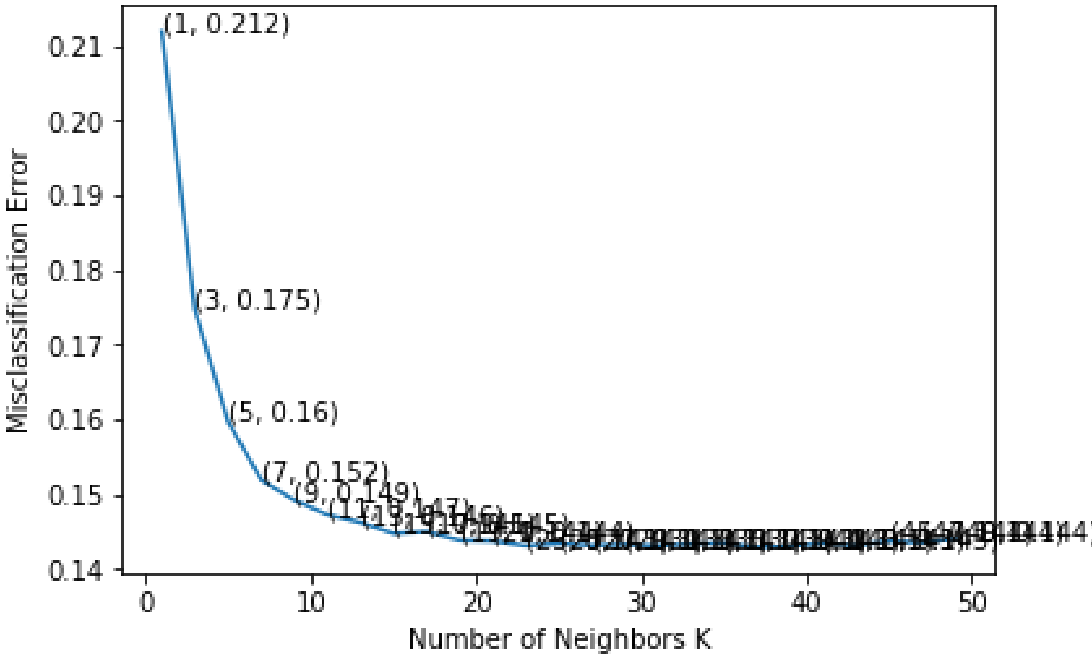
```
            acc = accuracy_score(y_cv, pred, normalize=True) * float(100)
            print('\nCV accuracy for k = %d is %d%%' % (i, acc))

        knn = KNeighborsClassifier(1)
        knn.fit(X_tr,y_tr)
        pred = knn.predict(X_test)
        acc = accuracy_score(y_test, pred, normalize=True) * float(100)
        print('\n****Test accuracy for k = 1 is %d%%' % (acc))

        print ('CV for k in range(1,30,2) done! Time elapsed: {} seconds'.format(time.time()-
```

```
CV accuracy for k = 1 is 78%

CV accuracy for k = 3 is 82%

CV accuracy for k = 5 is 83%

CV accuracy for k = 7 is 84%

CV accuracy for k = 9 is 84%

CV accuracy for k = 11 is 85%

CV accuracy for k = 13 is 85%

CV accuracy for k = 15 is 85%

CV accuracy for k = 17 is 85%

CV accuracy for k = 19 is 85%

CV accuracy for k = 21 is 85%

CV accuracy for k = 23 is 85%

CV accuracy for k = 25 is 85%

CV accuracy for k = 27 is 85%

CV accuracy for k = 29 is 85%

****Test accuracy for k = 1 is 71%
CV for k in range(1,30,2) done! Time elapsed: 191.60425472259521 seconds
```

3.0.2 10 fold cross validation

In [18]:
```
# creating odd list of K for KNN
myList = list(range(0,50))
neighbors = list(filter(lambda x: x % 2 != 0, myList))

# empty list that will hold cv scores
cv_scores = []

# perform 10-fold cross validation
for k in neighbors:
    knn = KNeighborsClassifier(n_neighbors=k, algorithm='kd_tree', n_jobs = 6)
    scores = cross_val_score(knn, X_train, y_train, cv=10, scoring='accuracy')
    cv_scores.append(scores.mean())

# changing to misclassification error
MSE = [1 - x for x in cv_scores]

# determining best k
optimal_k = neighbors[MSE.index(min(MSE))]
print('\nThe optimal number of neighbors is %d.' % optimal_k)

# plot misclassification error vs k
plt.plot(neighbors, MSE)

for xy in zip(neighbors, np.round(MSE,3)):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data')

plt.xlabel('Number of Neighbors K')
plt.ylabel('Misclassification Error')
plt.show()

print("the misclassification error for each k value is : ", np.round(MSE,3))
```

```
The optimal number of neighbors is 37.
```




```
the misclassification error for each k value is :  [0.212 0.175 0.16  0.152 0.149 0.147 0.146 0
 0.143 0.143 0.143 0.143 0.143 0.143 0.143 0.143 0.143 0.143 0.144 0.144
 0.144]
```

```
In [19]: # ============================== KNN with k = optimal_k ===============================
         # instantiate learning model k = optimal_k
         knn_optimal = KNeighborsClassifier(n_neighbors=optimal_k, algorithm='kd_tree', n_jobs

         # fitting the model
         knn_optimal.fit(X_train, y_train)

         # predict the response
         pred = knn_optimal.predict(X_test)

         # evaluate accuracy
         acc = accuracy_score(y_test, pred) * 100
         print('\nThe accuracy of the knn classifier for k = %d is %f%%' % (optimal_k, acc))
```

```
The accuracy of the knn classifier for k = 37 is 81.987279%
```

4 2. CV on Standardized data for Bigrams

```
In [20]: openPickleFile("X_train_BOW_bigrams")
         X_train = temp
         print(X_train.shape)
         print(X_train.dtype)
```

```
(33334, 50)
float64
```

```
In [21]: openPickleFile("X_test_BOW_bigrams")
         X_test = temp
         print(X_test.shape)
         print(X_test.dtype)
```

```
(16666, 50)
float64
```

```
In [22]: # split the train data set into cross validation train and cross validation test
         time_start = time.time()

         X_tr, X_cv, y_tr, y_cv = cross_validation.train_test_split(X_train, y_train, test_size

         for i in range(1,30,2):
             # instantiate learning model (k = 30)
             knn = KNeighborsClassifier(n_neighbors=i, algorithm='kd_tree', n_jobs = 6)

             # fitting the model on crossvalidation train
             knn.fit(X_tr, y_tr)

             # predict the response on the crossvalidation train
             pred = knn.predict(X_cv)

             # evaluate CV accuracy
             acc = accuracy_score(y_cv, pred, normalize=True) * float(100)
             print('\nCV accuracy for k = %d is %d%%' % (i, acc))

         knn = KNeighborsClassifier(1)
         knn.fit(X_tr,y_tr)
         pred = knn.predict(X_test)
         acc = accuracy_score(y_test, pred, normalize=True) * float(100)
         print('\n****Test accuracy for k = 1 is %d%%' % (acc))

         print ('CV for k in range(1,30,2) done! Time elapsed: {} seconds'.format(time.time()-
```

```
CV accuracy for k = 1 is 79%
```

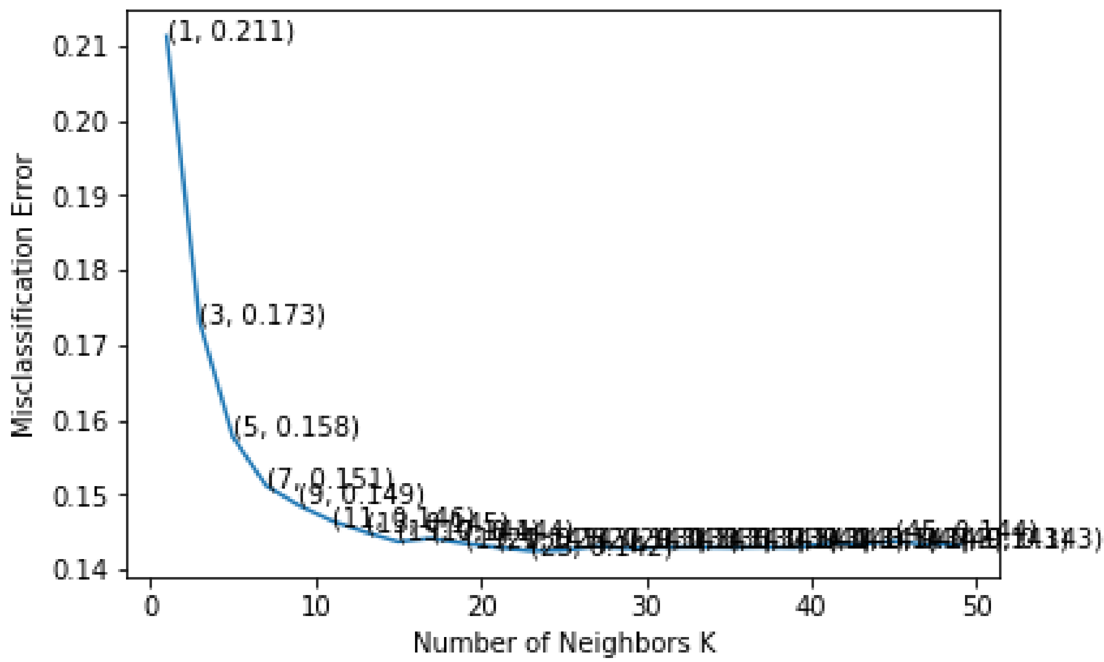
```
CV accuracy for k = 3 is 83%

CV accuracy for k = 5 is 84%

CV accuracy for k = 7 is 85%

CV accuracy for k = 9 is 85%

CV accuracy for k = 11 is 85%

CV accuracy for k = 13 is 85%

CV accuracy for k = 15 is 85%

CV accuracy for k = 17 is 85%

CV accuracy for k = 19 is 85%

CV accuracy for k = 21 is 85%

CV accuracy for k = 23 is 85%

CV accuracy for k = 25 is 85%

CV accuracy for k = 27 is 85%

CV accuracy for k = 29 is 85%

****Test accuracy for k = 1 is 72%
CV for k in range(1,30,2) done! Time elapsed: 193.7396240234375 seconds
```

4.0.1 10 fold cross validation

In [23]:
```python
time_start = time.time()

# creating odd list of K for KNN
myList = list(range(0,50))
neighbors = list(filter(lambda x: x % 2 != 0, myList))

# empty list that will hold cv scores
cv_scores = []

# perform 10-fold cross validation
for k in neighbors:
    knn = KNeighborsClassifier(n_neighbors=k, algorithm='kd_tree', n_jobs = 6)
    scores = cross_val_score(knn, X_train, y_train, cv=10, scoring='accuracy')
```

```
    cv_scores.append(scores.mean())

# changing to misclassification error
MSE = [1 - x for x in cv_scores]

# determining best k
optimal_k = neighbors[MSE.index(min(MSE))]
print('\nThe optimal number of neighbors is %d.' % optimal_k)

# plot misclassification error vs k
plt.plot(neighbors, MSE)

for xy in zip(neighbors, np.round(MSE,3)):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data')

plt.xlabel('Number of Neighbors K')
plt.ylabel('Misclassification Error')
plt.show()

print("the misclassification error for each k value is : ", np.round(MSE,3))

print (' 10-fold CV for k in range(1,50,2) done! Time elapsed: {} seconds'.format(time
```

```
The optimal number of neighbors is 23.
```



```
the misclassification error for each k value is :  [0.211 0.173 0.158 0.151 0.149 0.146 0.145 0
 0.143 0.143 0.143 0.143 0.143 0.143 0.143 0.143 0.143 0.143 0.144 0.143
 0.143]
 10-fold CV for k in range(1,50,2) done! Time elapsed: 991.4597065448761 seconds
```

In [24]:
```
# ============================== KNN with k = optimal_k ==============================
# instantiate learning model k = optimal_k
time_start = time.time()

knn_optimal = KNeighborsClassifier(n_neighbors=optimal_k, algorithm='kd_tree', n_jobs

# fitting the model
knn_optimal.fit(X_train, y_train)

# predict the response
pred = knn_optimal.predict(X_test)

# evaluate accuracy
acc = accuracy_score(y_test, pred) * 100
print('\nThe accuracy of the knn classifier for k = %d is %f%%' % (optimal_k, acc))

print (' CV for optimal k on Test data done! Time elapsed: {} seconds'.format(time.ti
```

```
The accuracy of the knn classifier for k = 23 is 81.747270%
 CV for optimal k on Test data done! Time elapsed: 25.197612762451172 seconds
```

5 3. CV on Standardized data for TF IDF

In [25]:
```
openPickleFile("X_train_tf_idf")
X_train = temp
print(X_train.shape)
print(X_train.dtype)
```

```
(33334, 50)
float64
```

In [26]:
```
openPickleFile("X_test_tf_idf")
X_test = temp
print(X_test.shape)
print(X_test.dtype)
```

```
(16666, 50)
float64
```

In [27]:
```
# split the train data set into cross validation train and cross validation test
time_start = time.time()

X_tr, X_cv, y_tr, y_cv = cross_validation.train_test_split(X_train, y_train, test_size

for i in range(1,30,2):
    # instantiate learning model (k = 30)
    knn = KNeighborsClassifier(n_neighbors=i, algorithm='kd_tree', n_jobs = 6)

    # fitting the model on crossvalidation train
    knn.fit(X_tr, y_tr)

    # predict the response on the crossvalidation train
    pred = knn.predict(X_cv)

    # evaluate CV accuracy
    acc = accuracy_score(y_cv, pred, normalize=True) * float(100)
    print('\nCV accuracy for k = %d is %d%%' % (i, acc))

knn = KNeighborsClassifier(1)
knn.fit(X_tr,y_tr)
pred = knn.predict(X_test)
acc = accuracy_score(y_test, pred, normalize=True) * float(100)
print('\n****Test accuracy for k = 1 is %d%%' % (acc))

print ('CV for k in range(1,30,2) done! Time elapsed: {} seconds'.format(time.time()-
```

```
CV accuracy for k = 1 is 78%

CV accuracy for k = 3 is 83%

CV accuracy for k = 5 is 84%

CV accuracy for k = 7 is 85%

CV accuracy for k = 9 is 86%

CV accuracy for k = 11 is 86%

CV accuracy for k = 13 is 86%

CV accuracy for k = 15 is 86%

CV accuracy for k = 17 is 86%

CV accuracy for k = 19 is 86%
```

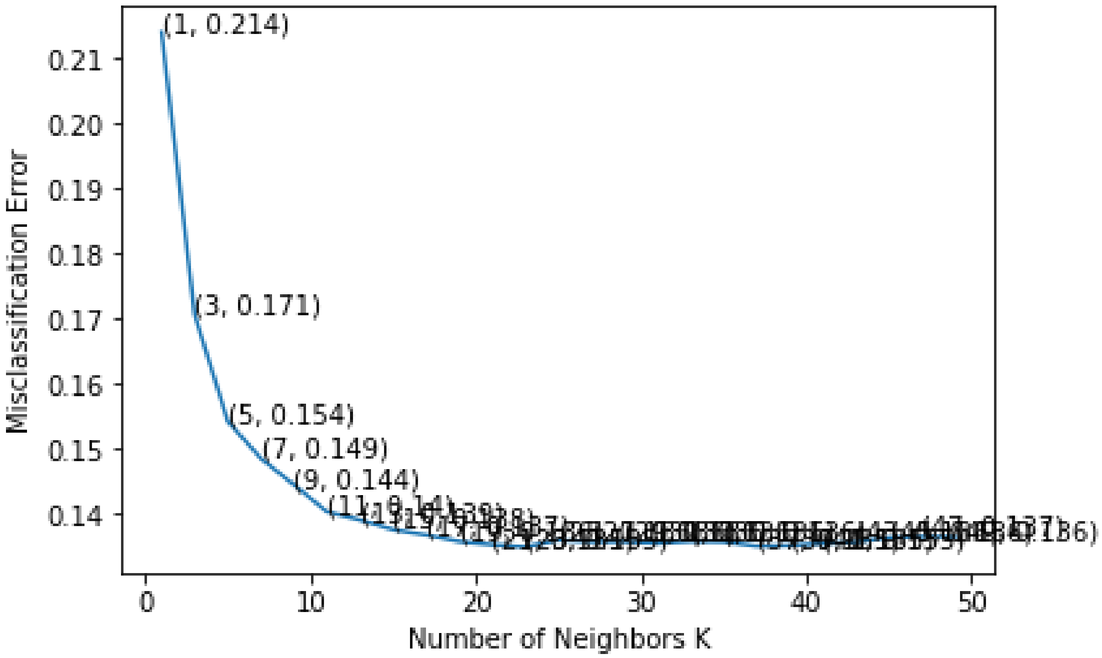
```
CV accuracy for k = 21 is 86%

CV accuracy for k = 23 is 86%

CV accuracy for k = 25 is 86%

CV accuracy for k = 27 is 86%

CV accuracy for k = 29 is 86%

****Test accuracy for k = 1 is 73%
CV for k in range(1,30,2) done! Time elapsed: 195.3687767982483 seconds
```

5.0.1 10 fold cross validation

In [28]:
```
time_start = time.time()

# creating odd list of K for KNN
myList = list(range(0,50))
neighbors = list(filter(lambda x: x % 2 != 0, myList))

# empty list that will hold cv scores
cv_scores = []

# perform 10-fold cross validation
for k in neighbors:
    knn = KNeighborsClassifier(n_neighbors=k, algorithm='kd_tree', n_jobs = 6)
    scores = cross_val_score(knn, X_train, y_train, cv=10, scoring='accuracy')
    cv_scores.append(scores.mean())

# changing to misclassification error
MSE = [1 - x for x in cv_scores]

# determining best k
optimal_k = neighbors[MSE.index(min(MSE))]
print('\nThe optimal number of neighbors is %d.' % optimal_k)

# plot misclassification error vs k
plt.plot(neighbors, MSE)

for xy in zip(neighbors, np.round(MSE,3)):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data')

plt.xlabel('Number of Neighbors K')
plt.ylabel('Misclassification Error')
plt.show()
```

```
print("the misclassification error for each k value is : ", np.round(MSE,3))

print (' 10-fold CV for k in range(1,50,2) done! Time elapsed: {} seconds'.format(time
```

```
The optimal number of neighbors is 23.
```




```
the misclassification error for each k value is :  [0.214 0.171 0.154 0.149 0.144 0.14  0.139 0
 0.136 0.136 0.136 0.136 0.136 0.136 0.135 0.135 0.135 0.136 0.136 0.137
 0.136]
 10-fold CV for k in range(1,50,2) done! Time elapsed: 1010.0943915843964 seconds
```

In [29]:
```
# ============================== KNN with k = optimal_k ==============================
# instantiate learning model k = optimal_k
time_start = time.time()

knn_optimal = KNeighborsClassifier(n_neighbors=optimal_k, algorithm='kd_tree', n_jobs

# fitting the model
knn_optimal.fit(X_train, y_train)

# predict the response
pred = knn_optimal.predict(X_test)
```

```
# evaluate accuracy
acc = accuracy_score(y_test, pred) * 100
print('\nThe accuracy of the knn classifier for k = %d is %f%%' % (optimal_k, acc))

print (' CV for optimal k on Test data done! Time elapsed: {} seconds'.format(time.ti
```

```
The accuracy of the knn classifier for k = 23 is 81.915277%
 CV for optimal k on Test data done! Time elapsed: 26.98582887649536 seconds
```

6 4. CV on Standardized data for Avg w2v

```
In [30]: openPickleFile("X_train_sent_vectors")
         X_train = temp
         print(X_train.shape)
         print(X_train.dtype)
```

```
(33334, 50)
float64
```

```
In [31]: openPickleFile("X_test_sent_vectors_array")
         X_test = temp
         print(X_test.shape)
         print(X_test.dtype)
```

```
(16666, 50)
float64
```

```
In [32]: # split the train data set into cross validation train and cross validation test
         time_start = time.time()

         X_tr, X_cv, y_tr, y_cv = cross_validation.train_test_split(X_train, y_train, test_siz

         for i in range(1,30,2):
             # instantiate learning model (k = 30)
             knn = KNeighborsClassifier(n_neighbors=i, algorithm='kd_tree', n_jobs = 6)

             # fitting the model on crossvalidation train
             knn.fit(X_tr, y_tr)

             # predict the response on the crossvalidation train
             pred = knn.predict(X_cv)

             # evaluate CV accuracy
```

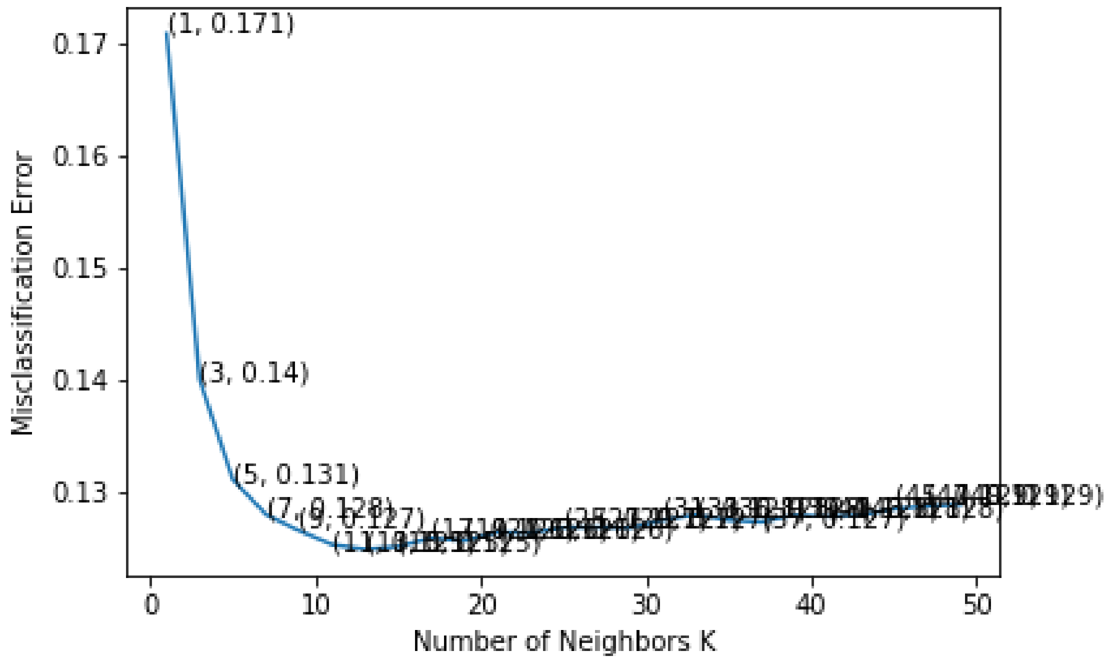
```
            acc = accuracy_score(y_cv, pred, normalize=True) * float(100)
            print('\nCV accuracy for k = %d is %d%%' % (i, acc))

        knn = KNeighborsClassifier(1)
        knn.fit(X_tr,y_tr)
        pred = knn.predict(X_test)
        acc = accuracy_score(y_test, pred, normalize=True) * float(100)
        print('\n****Test accuracy for k = 1 is %d%%' % (acc))

        print ('CV for k in range(1,30,2) done! Time elapsed: {} seconds'.format(time.time()-
```

```
CV accuracy for k = 1 is 82%

CV accuracy for k = 3 is 85%

CV accuracy for k = 5 is 86%

CV accuracy for k = 7 is 86%

CV accuracy for k = 9 is 86%

CV accuracy for k = 11 is 86%

CV accuracy for k = 13 is 87%

CV accuracy for k = 15 is 87%

CV accuracy for k = 17 is 87%

CV accuracy for k = 19 is 87%

CV accuracy for k = 21 is 87%

CV accuracy for k = 23 is 87%

CV accuracy for k = 25 is 86%

CV accuracy for k = 27 is 87%

CV accuracy for k = 29 is 86%

****Test accuracy for k = 1 is 72%
CV for k in range(1,30,2) done! Time elapsed: 203.44471192359924 seconds
```

6.0.1 10 fold cross validation

```
In [33]: time_start = time.time()

         # creating odd list of K for KNN
         myList = list(range(0,50))
         neighbors = list(filter(lambda x: x % 2 != 0, myList))

         # empty list that will hold cv scores
         cv_scores = []

         # perform 10-fold cross validation
         for k in neighbors:
             knn = KNeighborsClassifier(n_neighbors=k, algorithm='kd_tree', n_jobs = 6)
             scores = cross_val_score(knn, X_train, y_train, cv=10, scoring='accuracy')
             cv_scores.append(scores.mean())

         # changing to misclassification error
         MSE = [1 - x for x in cv_scores]

         # determining best k
         optimal_k = neighbors[MSE.index(min(MSE))]
         print('\nThe optimal number of neighbors is %d.' % optimal_k)

         # plot misclassification error vs k
         plt.plot(neighbors, MSE)

         for xy in zip(neighbors, np.round(MSE,3)):
             plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data')

         plt.xlabel('Number of Neighbors K')
         plt.ylabel('Misclassification Error')
         plt.show()

         print("the misclassification error for each k value is : ", np.round(MSE,3))

         print (' 10-fold CV for k in range(1,50,2) done! Time elapsed: {} seconds'.format(time
```

```
The optimal number of neighbors is 13.
```




```
the misclassification error for each k value is :  [0.171 0.14  0.131 0.128 0.127 0.125 0.125 0
 0.127 0.127 0.127 0.128 0.128 0.128 0.127 0.128 0.128 0.128 0.129 0.129
 0.129]
 10-fold CV for k in range(1,50,2) done! Time elapsed: 1057.9436614513397 seconds
```

In [34]:
```
# ============================== KNN with k = optimal_k ==============================
# instantiate learning model k = optimal_k
time_start = time.time()

knn_optimal = KNeighborsClassifier(n_neighbors=optimal_k, algorithm='kd_tree', n_jobs

# fitting the model
knn_optimal.fit(X_train, y_train)

# predict the response
pred = knn_optimal.predict(X_test)

# evaluate accuracy
acc = accuracy_score(y_test, pred) * 100
print('\nThe accuracy of the knn classifier for k = %d is %f%%' % (optimal_k, acc))

print (' CV for optimal k on Test data done! Time elapsed: {} seconds'.format(time.ti
```

```
The accuracy of the knn classifier for k = 13 is 80.451218%
```

```
CV for optimal k on Test data done! Time elapsed: 26.140099048614502 seconds
```

7 6. CV on TSNE data for TFIDF Avg w2v

```
In [35]: openPickleFile("X_train_tfidf_sent_vectors")
         X_train = temp
         print(X_train.shape)
         print(X_train.dtype)
```

```
(33334, 50)
float64
```

```
In [36]: openPickleFile("X_test_tfidf_sent_vectors_array")
         X_test = temp
         print(X_test.shape)
         print(X_test.dtype)
```

```
(16666, 50)
float64
```

```
In [37]: # split the train data set into cross validation train and cross validation test
         time_start = time.time()

         X_tr, X_cv, y_tr, y_cv = cross_validation.train_test_split(X_train, y_train, test_size

         for i in range(1,30,2):
             # instantiate learning model (k = 30)
             knn = KNeighborsClassifier(n_neighbors=i, algorithm='kd_tree', n_jobs = 6)

             # fitting the model on crossvalidation train
             knn.fit(X_tr, y_tr)

             # predict the response on the crossvalidation train
             pred = knn.predict(X_cv)

             # evaluate CV accuracy
             acc = accuracy_score(y_cv, pred, normalize=True) * float(100)
             print('\nCV accuracy for k = %d is %d%%' % (i, acc))

         knn = KNeighborsClassifier(1)
         knn.fit(X_tr,y_tr)
         pred = knn.predict(X_test)
         acc = accuracy_score(y_test, pred, normalize=True) * float(100)
         print('\n****Test accuracy for k = 1 is %d%%' % (acc))

         print ('CV for k in range(1,30,2) done! Time elapsed: {} seconds'.format(time.time()-
```

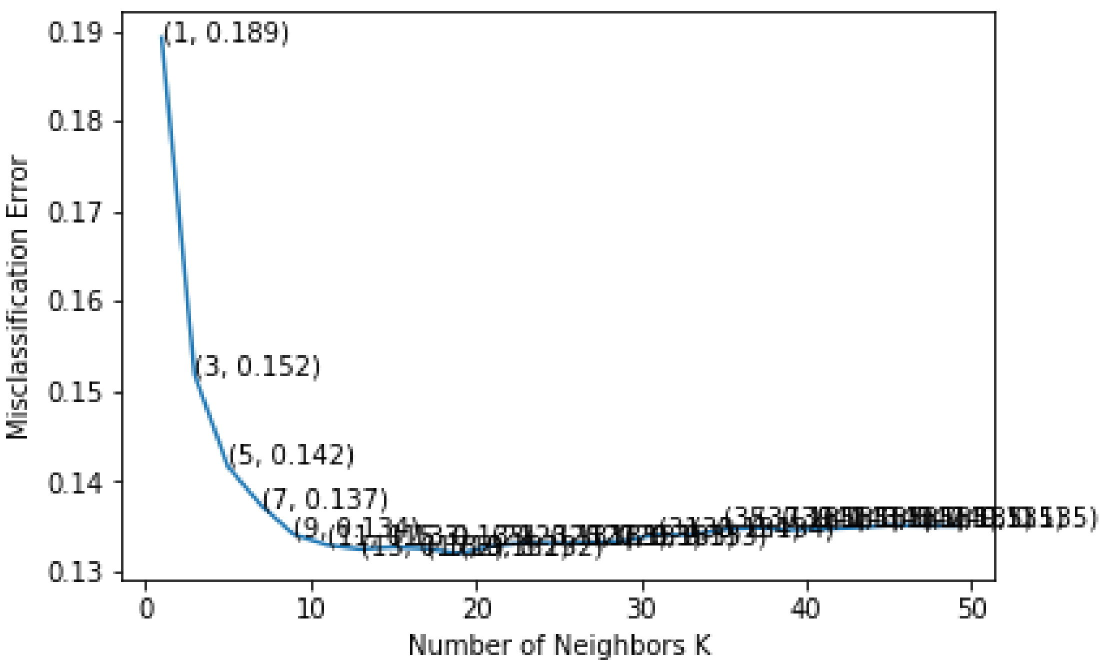
```
CV accuracy for k = 1 is 80%

CV accuracy for k = 3 is 84%

CV accuracy for k = 5 is 86%

CV accuracy for k = 7 is 86%

CV accuracy for k = 9 is 86%

CV accuracy for k = 11 is 86%

CV accuracy for k = 13 is 86%

CV accuracy for k = 15 is 86%

CV accuracy for k = 17 is 86%

CV accuracy for k = 19 is 86%

CV accuracy for k = 21 is 86%

CV accuracy for k = 23 is 86%

CV accuracy for k = 25 is 86%

CV accuracy for k = 27 is 86%

CV accuracy for k = 29 is 86%

****Test accuracy for k = 1 is 71%
CV for k in range(1,30,2) done! Time elapsed: 190.40722560882568 seconds
```

7.0.1 10 fold cross validation

In [38]:
```
time_start = time.time()

# creating odd list of K for KNN
myList = list(range(0,50))
neighbors = list(filter(lambda x: x % 2 != 0, myList))

# empty list that will hold cv scores
cv_scores = []

# perform 10-fold cross validation
for k in neighbors:
```

```
    knn = KNeighborsClassifier(n_neighbors=k, algorithm='kd_tree', n_jobs = 6)
    scores = cross_val_score(knn, X_train, y_train, cv=10, scoring='accuracy')
    cv_scores.append(scores.mean())

# changing to misclassification error
MSE = [1 - x for x in cv_scores]

# determining best k
optimal_k = neighbors[MSE.index(min(MSE))]
print('\nThe optimal number of neighbors is %d.' % optimal_k)

# plot misclassification error vs k
plt.plot(neighbors, MSE)

for xy in zip(neighbors, np.round(MSE,3)):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data')

plt.xlabel('Number of Neighbors K')
plt.ylabel('Misclassification Error')
plt.show()

print("the misclassification error for each k value is : ", np.round(MSE,3))

print (' 10-fold CV for k in range(1,50,2) done! Time elapsed: {} seconds'.format(time
```

```
The optimal number of neighbors is 19.
```



```
the misclassification error for each k value is :  [0.189 0.152 0.142 0.137 0.134 0.133 0.132 0
 0.133 0.133 0.133 0.134 0.134 0.135 0.135 0.135 0.135 0.135 0.135 0.135
 0.135]
 10-fold CV for k in range(1,50,2) done! Time elapsed: 898.2963585853577 seconds
```

In [39]:
```
# ============================== KNN with k = optimal_k ===============================
# instantiate learning model k = optimal_k
time_start = time.time()

knn_optimal = KNeighborsClassifier(n_neighbors=optimal_k, algorithm='kd_tree', n_jobs

# fitting the model
knn_optimal.fit(X_train, y_train)

# predict the response
pred = knn_optimal.predict(X_test)

# evaluate accuracy
acc = accuracy_score(y_test, pred) * 100
print('\nThe accuracy of the knn classifier for k = %d is %f%%' % (optimal_k, acc))

print (' CV for optimal k on Test data done! Time elapsed: {} seconds'.format(time.tim
```

```
The accuracy of the knn classifier for k = 19 is 81.723269%
 CV for optimal k on Test data done! Time elapsed: 25.183132886886597 seconds
```