lab03_partB

September 23, 2024

[88]:
```
import pandas as pd
housing = pd.read_csv('housing.csv')
```

0.1 Question 1

[89]:
```
## 1. split data to get train and test set
from sklearn.model_selection import train_test_split
train_set, test_set = train_test_split(housing, test_size=0.2, random_state=10)

## 2. clean the missing values
train_set_clean = train_set.dropna(subset=["total_bedrooms"])
train_set_clean

## 3. derive training features and training labels
train_labels = train_set_clean["median_house_value"].copy() # get labels for␣
↪output label Y
train_features = train_set_clean.drop("median_house_value", axis=1) # drop␣
↪labels to get features X for training set


## 4. scale the numeric features in training set
from sklearn.preprocessing import MinMaxScaler
scaler = MinMaxScaler() ## define the transformer
scaler.fit(train_features) ## call .fit() method to calculate the min and max␣
↪value for each column in dataset

train_features_normalized = scaler.transform(train_features)
train_features_normalized
```

[89]:
```
array([[0.77988048, 0.1360255 , 0.39215686, …, 0.10146024, 0.28498602,
        0.13939808],
       [0.14043825, 0.63336876, 0.88235294, …, 0.02253426, 0.06002302,
        0.14701177],
       [0.18525896, 0.54091392, 0.58823529, …, 0.04117268, 0.10146358,
        0.32103695],
       …,
       [0.25498008, 0.50797024, 0.09803922, …, 0.06045573, 0.09537905,
```

```
        0.34714694],
       [0.60956175, 0.15302869, 0.66666667, …, 0.06045573, 0.08156553,
        0.11765355],
       [0.24601594, 0.50584485, 0.29411765, …, 0.04683427, 0.11182371,
        0.15009448]])
```

[90]:
```
## 1. split data to get train and test set
from sklearn.model_selection import train_test_split
train_set, test_set = train_test_split(housing, test_size=0.2, random_state=10)
```

[91]:
```
## 2. clean the missing values
test_set_clean = test_set.dropna(subset=["total_bedrooms"])
test_set_clean
```

[91]:
```
       longitude  latitude  housing_median_age  total_rooms  total_bedrooms  \
20303    -119.18     34.16                12.0        460.0           101.0
16966    -122.31     37.55                27.0       3931.0           933.0
10623    -117.77     33.67                12.0       4329.0          1068.0
6146     -117.95     34.11                29.0       1986.0           448.0
2208     -119.87     36.81                 6.0       1891.0           341.0
…            …         …                  …           …              …
3263     -122.88     39.14                20.0       1125.0           231.0
11694    -117.98     33.89                18.0       2939.0           437.0
1729     -122.34     37.98                33.0       2014.0           410.0
5087     -118.28     33.98                45.0       1720.0           416.0
6581     -118.20     34.21                40.0       1477.0           228.0

       population  households  median_income  median_house_value
20303       405.0       103.0         5.2783            167400.0
16966      1877.0       851.0         3.9722            354100.0
10623      1913.0       978.0         4.5094            160200.0
6146       2013.0       432.0         3.1034            140800.0
2208        969.0       330.0         4.6726            107800.0
…             …           …             …                  …
3263        521.0       196.0         2.2188            106300.0
11694      1278.0       435.0         7.1425            393700.0
1729       1354.0       427.0         3.9773            131300.0
5087       1382.0       365.0         0.9337             92300.0
6581        609.0       224.0         7.8375            500001.0

[4087 rows x 9 columns]
```

[92]:
```
## 3. derive training features and training labels
test_labels = test_set_clean["median_house_value"].copy() # get labels for
 ↪output label Y
test_features = test_set_clean.drop("median_house_value", axis=1) # drop labels
 ↪to get features X for training set
```

[93]:
```
## 4. scale the numeric features in training set
from sklearn.preprocessing import MinMaxScaler
scaler = MinMaxScaler() ## define the transformer
scaler.fit(test_features) ## call .fit() method to calculate the min and max␣
↪value for each column in dataset


test_features_normalized = scaler.transform(test_features) ## call .transform()␣
↪method to scale the features
```

0.2 Question 2

0.2.1 Step 10b

[94]:
```
from sklearn.neighbors import KNeighborsRegressor
```

[95]:
```
import time
start_time = time.time()

KNN_Regeressor = KNeighborsRegressor(n_neighbors=10, metric='euclidean')
KNN_Regeressor.fit(test_features_normalized, test_labels)

end_time = time.time()
elapsed_time = end_time - start_time
print("Training time: ", elapsed_time)
```

```
Training time:  0.0034983158111572266
```

0.3 Question 3

0.3.1 Step 10c

[96]:
```
training_predicttions = KNN_Regeressor.predict(test_features_normalized)
shape=training_predicttions.shape
print("Shape of testing_predictions: ", shape)
label_shape=test_labels.shape
print("Shape of test_labels: ", label_shape)
```

```
Shape of testing_predictions:  (4087,)
Shape of test_labels:  (4087,)
```

0.4 Question 4

0.4.1 Step 10d

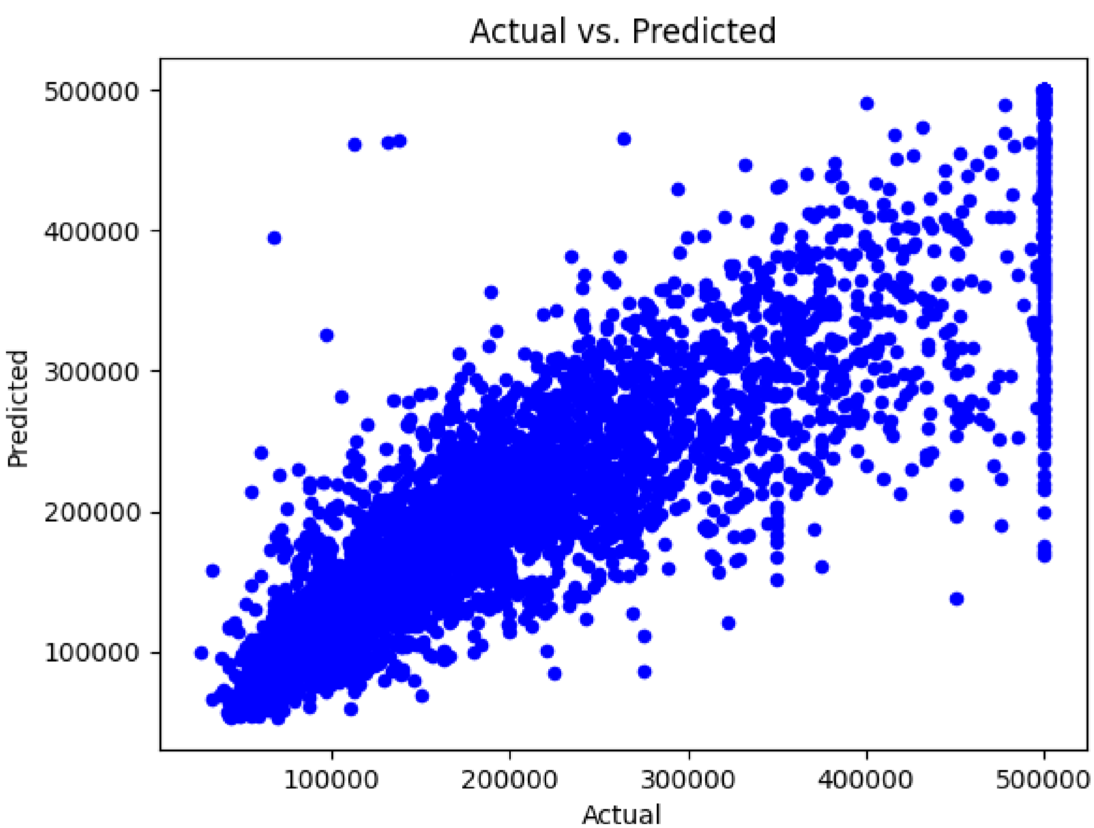
task 1

[97]:
```
prediction_summary = pd.DataFrame({'Actual': train_labels, 'Predicted':␣
↪training_predicttions})
print(prediction_summary)
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
Cell In[97], line 1
----> 1 prediction_summary =␣
 ↪pd.DataFrame({'Actual': train_labels, 'Predicted': training_predicttions})
      2 print(prediction_summary)

File c:
 ↪\Users\Julian\AppData\Local\Programs\Python\Python311\Lib\site-packages\pandas\core\frame.
 ↪py:778, in DataFrame.__init__(self, data, index, columns, dtype, copy)
    772     mgr = self._init_mgr(
    773         data, axes={"index": index, "columns": columns}, dtype=dtype,␣
 ↪copy=copy
    774     )
    776 elif isinstance(data, dict):
    777     # GH#38939 de facto copy defaults to False only in non-dict cases
--> 778     mgr =␣
 ↪dict_to_mgr(data, index, columns, dtype=dtype, copy=copy, typ=manager)
    779 elif isinstance(data, ma.MaskedArray):
    780     from numpy.ma import mrecords

File c:
 ↪\Users\Julian\AppData\Local\Programs\Python\Python311\Lib\site-packages\pandas\core\interna
 ↪py:503, in dict_to_mgr(data, index, columns, dtype, typ, copy)
    499     else:
    500         # dtype check to exclude e.g. range objects, scalars
    501         arrays = [x.copy() if hasattr(x, "dtype") else x for x in arrays]
--> 503 return␣
 ↪arrays_to_mgr(arrays, columns, index, dtype=dtype, typ=typ, consolidate=copy)

File c:
 ↪\Users\Julian\AppData\Local\Programs\Python\Python311\Lib\site-packages\pandas\core\interna
 ↪py:114, in arrays_to_mgr(arrays, columns, index, dtype, verify_integrity, typ,␣
 ↪consolidate)
    111 if verify_integrity:
    112     # figure out the index, if necessary
    113     if index is None:
--> 114         index = _extract_index(arrays)
    115     else:
    116         index = ensure_index(index)

File c:
 ↪\Users\Julian\AppData\Local\Programs\Python\Python311\Lib\site-packages\pandas\core\interna
 ↪py:690, in _extract_index(data)
    685     if lengths[0] != len(index):
    686         msg = (
    687             f"array length {lengths[0]} does not match index "
    688             f"length {len(index)}"
```

```
    689         )
--> 690         raise ValueError(msg)
    691 else:
    692     index = default_index(lengths[0])

ValueError: array length 4087 does not match index length 16346
```

[51]:
```
#Write codes to make a scatter plot for both variable 'testing_predictions' and␣
 ↪variable 'test_label'
import matplotlib.pyplot as plt
prediction_summary.plot(kind='scatter', x='Actual', y='Predicted',␣
 ↪title='Actual vs. Predicted', color='blue')
plt.xlabel('Actual')
plt.ylabel('Predicted')
plt.title('Actual vs. Predicted')
plt.show()
```



task 2

[52]:
```
import numpy as np
np.corrcoef(train_labels, training_predicttions)
```

[52]:
```
array([[1.        , 0.86191378],
       [0.86191378, 1.        ]])
```

0.5 Question 5

0.5.1 Step 10e

[53]:
```
prediction_summary['error'] = prediction_summary['Actual'] -␣
↪prediction_summary['Predicted']
```

[54]:
```
from sklearn.metrics import mean_squared_error
lin_mse = mean_squared_error(train_labels, training_predicttions)
lin_rmse = np.sqrt(lin_mse)
lin_rmse
```

[54]:
```
59804.04517062825
```

0.6 Question 6

0.6.1 Step 10f

0.7 task 2

[55]:
```
# practice 10f.1: Define one KNN model
from sklearn.neighbors import KNeighborsRegressor
KNN_regressor = KNeighborsRegressor(n_neighbors=7, metric = 'euclidean') # pick␣
↪one configuration K=7
```

[56]:
```
## practice 10f.2:  Evaluate the KNN model using cross-validation on the␣
↪training set
# KNN will take ~3min set using 10-fold cross-validation
from sklearn.model_selection import cross_val_score
CV_mse_scores = cross_val_score(estimator = KNN_regressor, X =␣
↪train_features_normalized, y = train_labels, cv = 10, scoring =␣
↪'neg_mean_squared_error')
print("CV_mse_scores: ", CV_mse_scores)
```

```
CV_mse_scores:  [-3.91841608e+09 -4.10790086e+09 -3.59604082e+09 -3.81505352e+09
 -4.08762578e+09 -3.83463385e+09 -4.10664865e+09 -3.77413013e+09
 -3.73180413e+09 -4.15740833e+09]
```

Task 3

[57]:
```
# display CV scores
def display_scores(scores):
    print("CV_scores: ", scores)
    print("CV Mean: ", scores.mean())
```

```
    print("CV Standard deviation: ", scores.std())
```

[58]:
```
display_scores(CV_mse_scores)
```

```
CV_scores:  [-3.91841608e+09 -4.10790086e+09 -3.59604082e+09 -3.81505352e+09
 -4.08762578e+09 -3.83463385e+09 -4.10664865e+09 -3.77413013e+09
 -3.73180413e+09 -4.15740833e+09]
CV Mean:  -3912966215.784583
CV Standard deviation:  182773010.66517955
```

Task 4

[59]:
```
from sklearn.model_selection import cross_val_score
CV_r2_scores = cross_val_score(estimator = KNN_regressor, X =␣
 ↪train_features_normalized, y = train_labels, cv = 10, scoring = 'r2')
print("CV_r2_scores: ", CV_r2_scores)
```

```
CV_r2_scores:  [0.69080821 0.70565108 0.71749391 0.69946592 0.69684798
0.71756461
 0.69251691 0.71558565 0.72019134 0.68628121]
```

0.8 Question 7

[ ]:
```

```

[66]:
```
def evaluate_knn(k_values):
    results = []

    for k in k_values:
        knn_regressor = KNeighborsRegressor(n_neighbors=k)
        knn_regressor.fit(train_features_normalized, train_labels)

        # Training MSE
        training_predictions = knn_regressor.predict(train_features_normalized)
        training_mse = mean_squared_error(train_labels, training_predictions)

        # Training Correlation
        training_corr = np.corrcoef(train_labels, training_predictions)[0, 1]

        # Cross-validation MSE (10-fold CV)
        cv_mse_scores = cross_val_score(knn_regressor,␣
 ↪train_features_normalized, train_labels, cv=10,␣
 ↪scoring='neg_mean_squared_error')
        mean_cv_mse = -cv_mse_scores.mean()
        std_cv_mse = cv_mse_scores.std()

        # Cross-validation R² (10-fold CV)
        cv_r2_scores = cross_val_score(knn_regressor,␣
 ↪train_features_normalized, train_labels, cv=10, scoring='r2')
```

```
        mean_cv_r2 = cv_r2_scores.mean()
        std_cv_r2 = cv_r2_scores.std()

        # Append the results for this K value
        results.append({
            'K': k,
            'Training MSE': training_mse,
            'Training Correlation': training_corr,
            'Mean CV MSE': mean_cv_mse,
            'Std CV MSE': std_cv_mse,
            'Mean CV R2': mean_cv_r2,
            'Std CV R2': std_cv_r2
        })

    return pd.DataFrame(results)
```

[67]:
```
k_values = [1, 3, 5, 7, 9]
knn_results = evaluate_knn(k_values)
```

[68]:
```
print(knn_results)
```

```
   K  Training MSE  Training Correlation   Mean CV MSE    Std CV MSE  \
0  1  0.000000e+00              1.000000  5.785628e+09  2.825489e+08
1  3  2.017961e+09              0.920965  4.248065e+09  1.789400e+08
2  5  2.559006e+09              0.898736  4.013255e+09  2.132148e+08
3  7  2.856855e+09              0.886280  3.912966e+09  1.827730e+08
4  9  3.027968e+09              0.879043  3.905838e+09  1.614103e+08

   Mean CV R2  Std CV R2
0    0.562436   0.023991
1    0.678839   0.013231
2    0.696624   0.015209
3    0.704241   0.012067
4    0.704746   0.011111
```

0.9 Question 8

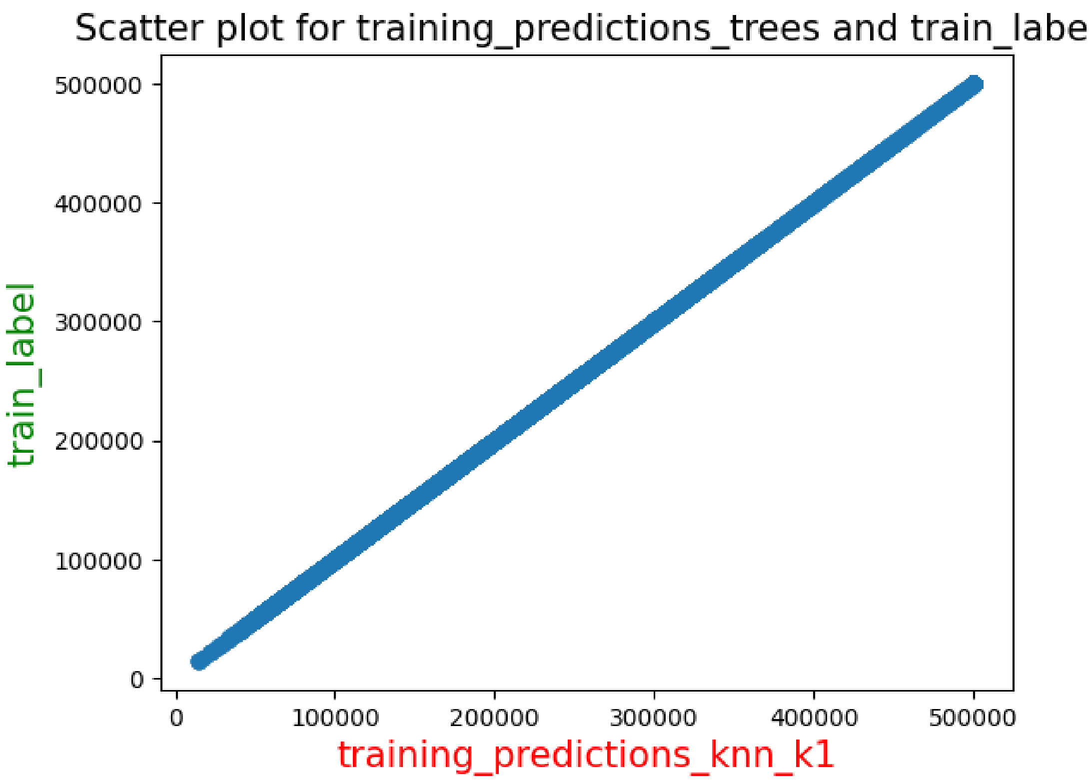
[61]:
```
from sklearn.neighbors import KNeighborsRegressor
KNN_regressor_k1 = KNeighborsRegressor(n_neighbors=1) # pick one configuration␣
↪K=1
KNN_regressor_k1.fit(train_features_normalized, train_labels)
```

[61]: KNeighborsRegressor(n_neighbors=1)

[62]:
```
training_predictions_knn_k1 = KNN_regressor_k1.
↪predict(train_features_normalized)
training_predictions_knn_k1
```

[62]: array([145200., 117000., 263900., …, 241900., 150000., 191100.])

[63]:
```
import matplotlib.pyplot as plt
plt.scatter(training_predictions_knn_k1, train_labels )
plt.xlabel('training_predictions_knn_k1', fontsize=15, color="red")
plt.ylabel('train_label', fontsize=15,color="green")
plt.title('Scatter plot for training_predictions_trees and train_label',␣
↪fontsize=15)
plt.show()
```



[65]:
```
from sklearn.metrics import mean_squared_error
knn_k1_mse = mean_squared_error(train_labels, training_predictions_knn_k1)
print("Training MSE of model: ",knn_k1_mse)
```

```
Training MSE of model:  0.0
```

0.10 Question 10

[69]:
```
# Practice 13.1: define a ML model to finetune the hyper-parameters
from sklearn.neighbors import KNeighborsRegressor
KNN_regressor = KNeighborsRegressor()
# leave the hyper-parameters empty inside the method classs
```

[72]:
```
# parameter 1: n_neighbors
n_neighbors_list = [1, 3, 5, 7, 9]
```

[73]:
```
# parameter 2: weighting strategies
metrics_list = ["uniform", "distance"]
```

[74]:
```
# Practice 13.2: Define the hyper-parameter combination
KNN_param_grid = {
'n_neighbors': n_neighbors_list,
'weights': metrics_list
}
```

[75]:
```
# Practice 13.3: define grid_search
from sklearn.model_selection import GridSearchCV
grid_search = GridSearchCV(estimator = KNN_regressor, param_grid =␣
 ↪KNN_param_grid, cv = 10, scoring = 'r2', return_train_score = True)
## we use 'r2' as evaluation metrics for this example
## check what does return_train_score = True mean
```

[76]:
```
# Practice 13.4: fit grid-searchcv on training data
grid_search.fit(X = train_features_normalized, y = train_labels)
```

[76]:
```
GridSearchCV(cv=10, estimator=KNeighborsRegressor(),
             param_grid={'n_neighbors': [1, 3, 5, 7, 9],
                         'weights': ['uniform', 'distance']},
             return_train_score=True, scoring='r2')
```

0.11 Question 11

[77]:
```
# practice 13c.1: get best parameters
grid_search.best_params_
```

[77]:
```
{'n_neighbors': 9, 'weights': 'distance'}
```

[78]:
```
# practice 13c.2: get best estimator
best_knn_model = grid_search.best_estimator_
best_knn_model
```

[78]:
```
KNeighborsRegressor(n_neighbors=9, weights='distance')
```

[79]:
```
# Create a df from the cv_resuetls
df_cv = pd.DataFrame(grid_search.cv_results_)
df_cv.head()
```

[79]:
```
   mean_fit_time  std_fit_time  mean_score_time  std_score_time  \
0       0.009519      0.000231         0.008628        0.000473
1       0.009242      0.000225         0.008370        0.000327
2       0.009432      0.000270         0.011961        0.001824
```

```
3       0.009071      0.000268         0.011555        0.000535
4       0.009189      0.000249         0.013176        0.000828

   param_n_neighbors param_weights                                    params  \
0                  1       uniform   {'n_neighbors': 1, 'weights': 'uniform'}
1                  1      distance  {'n_neighbors': 1, 'weights': 'distance'}
2                  3       uniform   {'n_neighbors': 3, 'weights': 'uniform'}
3                  3      distance  {'n_neighbors': 3, 'weights': 'distance'}
4                  5       uniform   {'n_neighbors': 5, 'weights': 'uniform'}

   split0_test_score  split1_test_score  split2_test_score  …  \
0           0.519702           0.603715           0.573019  …
1           0.519702           0.603715           0.573019  …
2           0.665652           0.689578           0.684602  …
3           0.669229           0.697347           0.692106  …
4           0.684007           0.699685           0.705688  …

   split2_train_score  split3_train_score  split4_train_score  \
0            1.000000            1.000000            1.000000
1            1.000000            1.000000            1.000000
2            0.845155            0.845877            0.847110
3            1.000000            1.000000            1.000000
4            0.803992            0.804432            0.805589

   split5_train_score  split6_train_score  split7_train_score  \
0            1.000000            1.000000            1.000000
1            1.000000            1.000000            1.000000
2            0.845713            0.845675            0.843759
3            1.000000            1.000000            1.000000
4            0.804018            0.805180            0.802353

   split8_train_score  split9_train_score  mean_train_score  std_train_score
0            1.000000            1.000000          1.000000         0.000000
1            1.000000            1.000000          1.000000         0.000000
2            0.845161            0.846836          0.845660         0.001091
3            1.000000            1.000000          1.000000         0.000000
4            0.802877            0.806684          0.804357         0.001389

[5 rows x 32 columns]
```

0.12 Question 12

[80]:
```
## 1. clean the missing values in test set
test_set_clean = test_set.dropna(subset=["total_bedrooms"])
test_set_clean
```

```
## 2. derive test features and test labels. In this case, test labels are only␣
↪used for evaluation
test_labels = test_set_clean["median_house_value"].copy() # get labels for␣
↪output label Y
test_features = test_set_clean.drop("median_house_value", axis=1) # drop labels␣
↪to get features X for training set


## 4. scale the numeric features in test set. The scaler is derived from Step 10
## important note: do not apply fit function on the test set, using same scalar␣
↪from training set
test_features_normalized = scaler.transform(test_features)
test_features_normalized
```

[80]:
```
array([[0.52191641, 0.17241379, 0.21568627, …, 0.02481851, 0.01928268,
         0.32954028],
        [0.20285423, 0.53771552, 0.50980392, …, 0.11615065, 0.16351716,
         0.23946566],
        [0.6656473 , 0.11961207, 0.21568627, …, 0.11838431, 0.18800617,
         0.27651343],
        …,
        [0.19979613, 0.58405172, 0.62745098, …, 0.08370044, 0.08175858,
         0.23981738],
        [0.61365953, 0.15301724, 0.8627451 , …, 0.08543774, 0.06980332,
         0.02991683],
        [0.62181448, 0.17780172, 0.76470588, …, 0.03747596, 0.04261473,
         0.5060344 ]])
```

[81]:
```
### Step 5: make a prediction using the best model from the hyper-parameter␣
↪tuning
# practice 13c.2: get best estimator
best_knn_model = grid_search.best_estimator_
test_predictions_knn = best_knn_model.predict(test_features_normalized)
test_predictions_knn
```

[81]:
```
array([322741.00801447, 250409.67942524, 191558.03474468, …,
       260163.42618696, 129864.63337078, 467212.33086968])
```

[82]:
```
from sklearn.metrics import mean_squared_error
from sklearn.metrics import r2_score
test_knn_mse = mean_squared_error(test_labels, test_predictions_knn)
test_knn_correlation = np.corrcoef(test_labels, test_predictions_knn)
test_knn_R2 = r2_score(test_labels, test_predictions_knn)
print("MSE: ", test_knn_mse)
print("Correlation: ", test_knn_correlation)
print("R2-score: ", test_knn_R2)
```

```
MSE:  4364782631.990618
```

```
Correlation:  [[1.         0.83272273]
 [0.83272273 1.        ]]
R2-score:  0.6803241320815888
```

[83]:
```python
from joblib import dump, load

dump(scaler, 'scaler.joblib')
```

[83]:
```
['scaler.joblib']
```

[84]:
```python
dump(best_knn_model, 'best_knn_model.joblib')
```

[84]:
```
['best_knn_model.joblib']
```

[85]:
```python
scaler_reload = load('scaler.joblib')
```

[86]:
```python
print("Scaler Min: ",scaler_reload.data_min_)

print("Scaler Max: ",scaler_reload.data_max_)
```

```
Scaler Min:  [-124.3      32.56      1.        16.         3.         5.         3.
    0.4999]
Scaler Max:  [-1.14490e+02  4.18400e+01  5.20000e+01  3.79370e+04  5.47100e+03
  1.61220e+04  5.18900e+03  1.50001e+01]
```

[87]:
```python
KNN_model_reload = load('best_knn_model.joblib')

KNN_model_reload
```

[87]:
```
KNeighborsRegressor(n_neighbors=9, weights='distance')
```