Final Project

November 19, 2020

1 Final Project

[1]:
```
import pandas as pd
import geopandas as gpd
import numpy as np
import matplotlib.pyplot as plt
import scipy.io as io
import libsvm
from libsvm import svmutil
from svmutil import svm_predict
from libsvm.svmutil import *
%matplotlib inline
import seaborn as sns
import time
from scipy import stats
from datetime import datetime
import sklearn
from sklearn import preprocessing, svm
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import cross_val_score, KFold
from sklearn.model_selection import train_test_split
```

1.0.1 Training data

[2]:
```
# load training data
data = pd.read_csv('train.csv')
print(data.shape)
```

```
(9681, 25)
```

[3]:
```
# see what features do we have
data.columns
```

[3]:
```
Index(['id', 'neighbourhood', 'room_type', 'minimum_nights',
       'number_of_reviews', 'last_review', 'reviews_per_month',
       'calculated_host_listings_count', 'availability_365', 'host_since',
       'host_is_superhost', 'bathrooms', 'bedrooms', 'beds', 'bed_type',
```

```
       'cleaning_fee', 'guests_included', 'extra_people', 'maximum_nights',
       'instant_bookable', 'is_business_travel_ready', 'cancellation_policy',
       'require_guest_profile_picture', 'require_guest_phone_verification',
       'price'],
      dtype='object')
```

[4]:
```
# drop id
data.drop(columns = 'id', inplace = True)

# change datetime to number of days from 10/8/2020
data['last_review'] = pd.to_datetime(data['last_review'])
data['host_since'] = pd.to_datetime(data['host_since'])
data['days_since_last_review'] = (datetime(2020, 10, 8) - data.last_review).
 ↪astype('timedelta64[D]')
data['days_since_host'] = (datetime(2020, 10, 8) - data.host_since).
 ↪astype('timedelta64[D]')
data.drop(columns=['last_review', 'host_since'], inplace = True)

# replace f/t with 0 and 1
data.replace({'f':0, 't':1}, inplace = True)
```

1.0.2 Test data

[5]:
```
# load test data
data_test =pd.read_csv('test.csv')

# replace f/t with 0 and 1
data_test.replace({'f':0, 't':1}, inplace = True)

# converting date to number
data_test['last_review'] = pd.to_datetime(data_test['last_review'])
data_test['host_since'] = pd.to_datetime(data_test['host_since'])
data_test['days_since_last_review'] = (datetime(2020, 10, 8) - data_test.
 ↪last_review).astype('timedelta64[D]')
data_test['days_since_host'] = (datetime(2020, 10, 8) - data_test.host_since).
 ↪astype('timedelta64[D]')
data_test.drop(columns=['last_review', 'host_since'], inplace = True)

# drop id
ID = data_test.id
data_test.drop(columns = ['id'], inplace = True)
```

1.0.3 Distribution

[6]:
```python
print("Training data:", data.shape)
print('Test data:', data_test.shape)
```

```
Training data: (9681, 24)
Test data: (4149, 23)
```

[7]:
```python
# a quick view of the test data
fig_t = data_test.hist(figsize  = (20,20))
plt.suptitle('Histogram of Numerical Test Data')
plt.savefig('test_his.png')
```

[8]:
```python
# a quick view of the training data
fig = data.hist(figsize  = (20,20))
plt.suptitle('Histogram of Numerical Traning Data')
plt.savefig('train_his.png')
```

1.0.4 Features

Is_business_travel ready

[9]:
```
# drop is_business_travel_ready
data.drop(columns = ['is_business_travel_ready'], inplace = True)
data_test.drop(columns = ['is_business_travel_ready'], inplace = True)
```

Bed type

[10]:
```
# create table counts each type of bed and the average price of each type in␣
↪training data
k = data['bed_type'].value_counts().to_frame()
k = k.rename(columns = {'bed_type': 'counts'})
a = data.groupby('bed_type').price.mean().to_frame()
k = k.join(a,lsuffix='_caller', rsuffix='_other')
k
```

[10]:

	counts	price
Real Bed	9641	2.496836
Pull-out Sofa	23	2.652174
Futon	12	1.833333
Couch	3	2.000000
Airbed	2	1.000000

[11]:
```
# create table counts each type of bed and the average price of each type in␣
↪test data
k1 = data_test['bed_type'].value_counts().to_frame()
k1.rename(columns = {'bed_type': 'counts'})
```

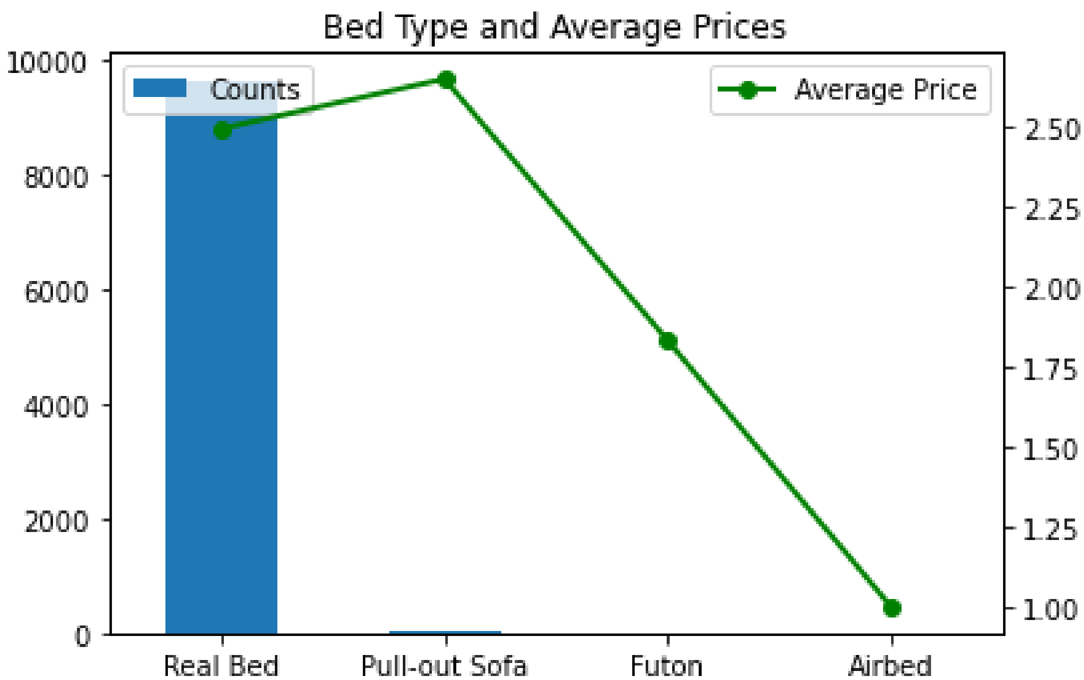
[11]:

	counts
Real Bed	4131
Pull-out Sofa	10
Futon	5
Airbed	3

[12]:
```
# remove listings that have Couch as bed type in the training data
data = data[data.bed_type != 'Couch']
# re-create the table about type and prices
k = data['bed_type'].value_counts().to_frame()
k = k.rename(columns = {'bed_type': 'counts'})
a = data.groupby('bed_type').price.mean().to_frame()
k = k.join(a,lsuffix='_caller', rsuffix='_other')
```

[13]:
```
# plot bed type and average prices for each type in training data
fig = plt.figure()
ax = k['counts'].plot(kind='bar', use_index= True ,label = 'Counts')
ax2 = ax.twinx()
ax2.plot(ax.get_xticks(),
         k['price'],
         linestyle='-',
```

```
        marker='o',color = 'g', linewidth=2.0, label = 'Average Price')
ax.set_xticklabels(
    ax.get_xticklabels(),
    rotation=0,
)
ax.legend(loc='upper left')
ax2.legend(loc = 'upper right')
ax.set_title('Bed Type and Average Prices')
plt.show()
fig.savefig('bedtype.png')
```



Room type

[14]:
```
# create table counts each type of room and the average price of each type in␣
↪training data
k = data['room_type'].value_counts().to_frame()
k = k.rename(columns = {'room_type': 'counts'})
a = data.groupby('room_type').price.mean().to_frame()
k = k.join(a,lsuffix='_caller', rsuffix='_other')
k
```

[14]:

	counts	price
Entire home/apt	8363	2.663996
Private room	1183	1.402367
Shared room	67	1.104478

```
Hotel room           65  2.230769
```

[15]:

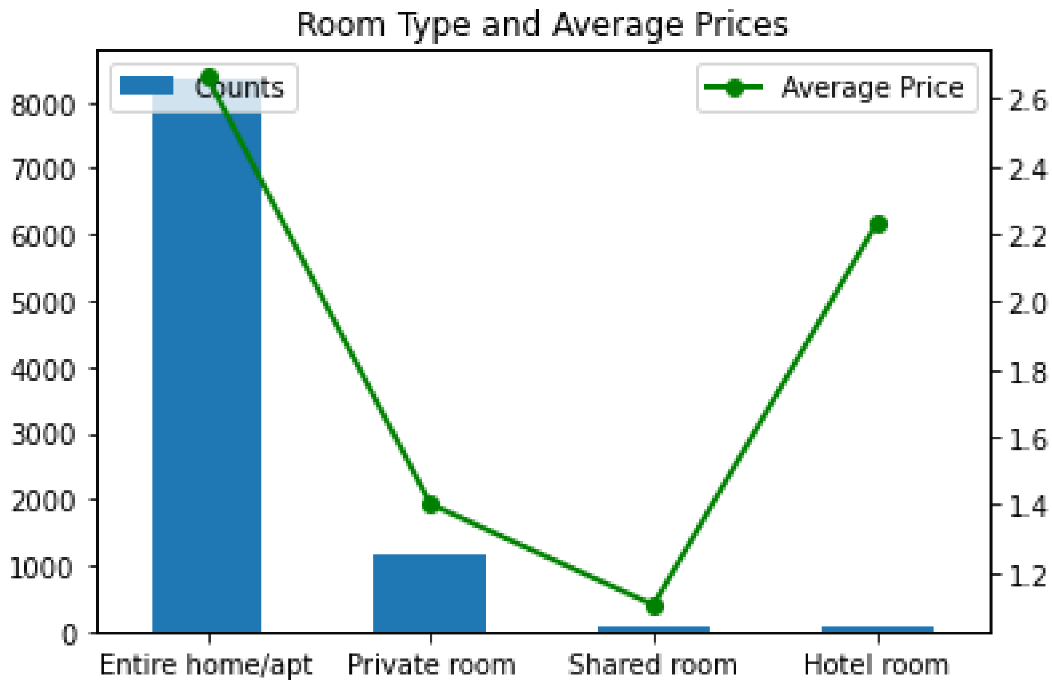
```
# create table counts each type of room and the average price of each type in␣
 ↪test data
k1 = data_test['room_type'].value_counts().to_frame()
k1.rename(columns = {'room_type': 'counts'})
```

[15]:

	counts
Entire home/apt	3585
Private room	503
Shared room	32
Hotel room	29

[16]:

```
# plot room type and average prices for each type in training data
fig = plt.figure()
ax = k['counts'].plot(kind='bar', use_index= True ,label = 'Counts')
ax2 = ax.twinx()
ax2.plot(ax.get_xticks(),
         k['price'],
         linestyle='-',
         marker='o',color = 'g', linewidth=2.0, label = 'Average Price')
ax.legend(loc='upper left')
ax2.legend(loc = 'upper right')
ax.set_xticklabels(
    ax.get_xticklabels(),
    rotation=0,
)
ax.set_title('Room Type and Average Prices')
plt.show()
fig.savefig('roomtype.png')
```



Cancellation policy

[17]:
```
k = data['cancellation_policy'].value_counts().to_frame()
k = k.rename(columns = {'cancellation_policy': 'counts'})
a = data.groupby('cancellation_policy').price.mean().to_frame()
k = k.join(a,lsuffix='_caller', rsuffix='_other')
k
```

[17]:

	counts	price
strict_14_with_grace_period	3394	2.659104
flexible	3160	2.344304
moderate	3095	2.462682
super_strict_30	26	3.500000
super_strict_60	3	3.666667

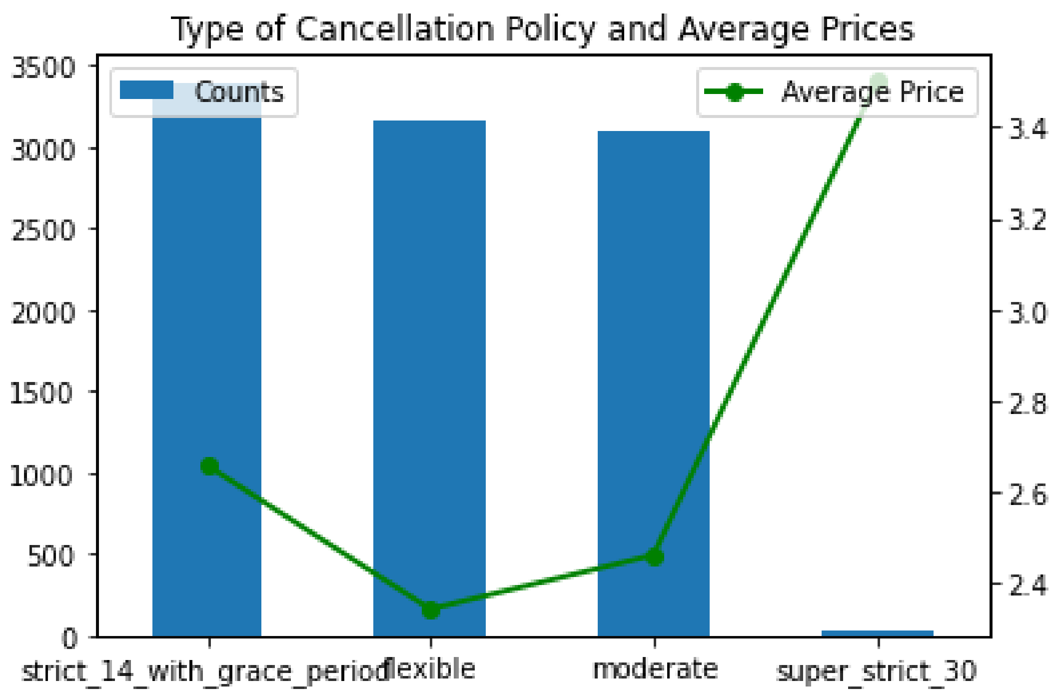
[18]:
```
k1 = data_test['cancellation_policy'].value_counts().to_frame()
k1.rename(columns = {'cancellation_policy': 'counts'})
```

[18]:

	counts
strict_14_with_grace_period	1464
moderate	1368
flexible	1313
super_strict_30	4

[19]:
```
# remove listings in the training data that has super_strict_60 cancellation␣
↪policy
data = data[data.cancellation_policy != 'super_strict_60']

# re-create the table about type and prices
k = data['cancellation_policy'].value_counts().to_frame()
k = k.rename(columns = {'cancellation_policy': 'counts'})
a = data.groupby('cancellation_policy').price.mean().to_frame()
k = k.join(a,lsuffix='_caller', rsuffix='_other')
```

[20]:
```
# plot type of cancellation policy and average prices for each type in the␣
↪training data
fig = plt.figure(figsize = (6,4))
ax = k['counts'].plot(kind='bar', use_index= True ,label = 'Counts')
ax2 = ax.twinx()
ax2.plot(ax.get_xticks(),
         k['price'],
         linestyle='-',
         marker='o',color = 'g', linewidth=2.0, label = 'Average Price')
ax.legend(loc='upper left')
ax2.legend(loc = 'upper right')
ax.set_xticklabels(
    ax.get_xticklabels(),
    rotation=0,
)
ax.set_title('Type of Cancellation Policy and Average Prices')
plt.show()
fig.savefig('cancel.png')
```



Neighbourhood

[21]:
```
k = data['neighbourhood'].value_counts().to_frame()
k = k.rename(columns = {'neighbourhood': 'counts'})
a = data.groupby('neighbourhood').price.mean().to_frame()
k.join(a,lsuffix='_caller', rsuffix='_other')
```

[21]:

	counts	price
Palermo	3299	2.791755
Recoleta	1660	2.685542
San Nicolás	595	2.265546
Retiro	495	2.602020
Belgrano	416	2.413462
Monserrat	390	2.243590
San Telmo	389	2.421594
Almagro	379	1.849604
Balvanera	365	1.939726
Villa Crespo	310	1.951613
Colegiales	182	2.368132
Núñez	175	2.302857
Chacarita	168	2.303571
Caballito	142	1.866197
Puerto Madero	112	3.553571
Villa Urquiza	84	2.000000
Barracas	58	2.120690

```
Constitución            57  1.877193
Saavedra                41  1.926829
La Boca                 39  2.000000
Boedo                   35  1.685714
Flores                  30  1.533333
Coghlan                 28  2.035714
Villa Ortúzar           26  1.500000
Parque Patricios        24  1.666667
Villa Devoto            22  2.090909
Villa del Parque        19  1.947368
San Cristóbal           19  2.052632
Parque Chacabuco        18  1.888889
Parque Chas             17  1.588235
Agronomía               15  2.066667
Villa General Mitre     10  1.200000
Villa Pueyrredón         9  2.000000
Liniers                  8  1.750000
Floresta                 6  2.333333
Vélez Sársfield          6  2.000000
Villa Luro               6  1.166667
La Paternal              4  1.750000
Villa Santa Rita         4  1.750000
Mataderos                3  1.333333
Nueva Pompeya            2  2.500000
Villa Real               2  2.000000
Parque Avellaneda        2  1.000000
Versalles                2  2.500000
Monte Castro             2  1.000000
```

[22]:
```
k = data_test['neighbourhood'].value_counts().to_frame()
k.rename(columns = {'neighbourhood': 'counts'})
```

[22]:

	counts
Palermo	1372
Recoleta	707
San Nicolás	247
Retiro	204
Belgrano	199
Balvanera	178
Monserrat	175
San Telmo	164
Almagro	153
Villa Crespo	148
Colegiales	79
Núñez	77
Chacarita	71
Caballito	64

```
Puerto Madero            39
Villa Urquiza            38
Barracas                 31
Constitución             31
Saavedra                 22
San Cristóbal            18
La Boca                  15
Boedo                    13
Parque Chas              13
Villa Devoto             12
Villa Ortúzar            11
Villa del Parque         10
Flores                    8
Parque Patricios          7
Agronomía                 7
La Paternal               6
Floresta                  6
Villa Pueyrredón          5
Coghlan                   4
Parque Avellaneda         3
Monte Castro              2
Villa Luro                2
Nueva Pompeya             2
Parque Chacabuco          2
Versalles                 1
Villa Santa Rita          1
Liniers                   1
Villa General Mitre       1
```

[23]:
```
# neighbourhoods not included in the test data
cols = []
for i in set(data["neighbourhood"]):
    if i not in set(data_test["neighbourhood"]):
        print(i)
        cols.append(i)
```

```
Vélez Sársfield
Villa Real
Mataderos
```

[24]:
```
# remove listings in the training data that is in neighbourhoods above
data = data[data.neighbourhood != 'Mataderos']
data = data[data.neighbourhood != 'Vélez Sársfield']
data = data[data.neighbourhood != 'Villa Real']
```

[25]:
```
print("Training data:", data.shape)
print('Test data:', data_test.shape)
```

```
Training data: (9664, 23)
Test data: (4149, 22)
```

[26]:
```python
# one-hot encoded categorical features
data_test = pd.get_dummies(data_test)
Xdata = pd.get_dummies(data)
print("Training data:", Xdata.shape)
print('Test data:', data_test.shape)
```

```
Training data: (9664, 73)
Test data: (4149, 72)
```

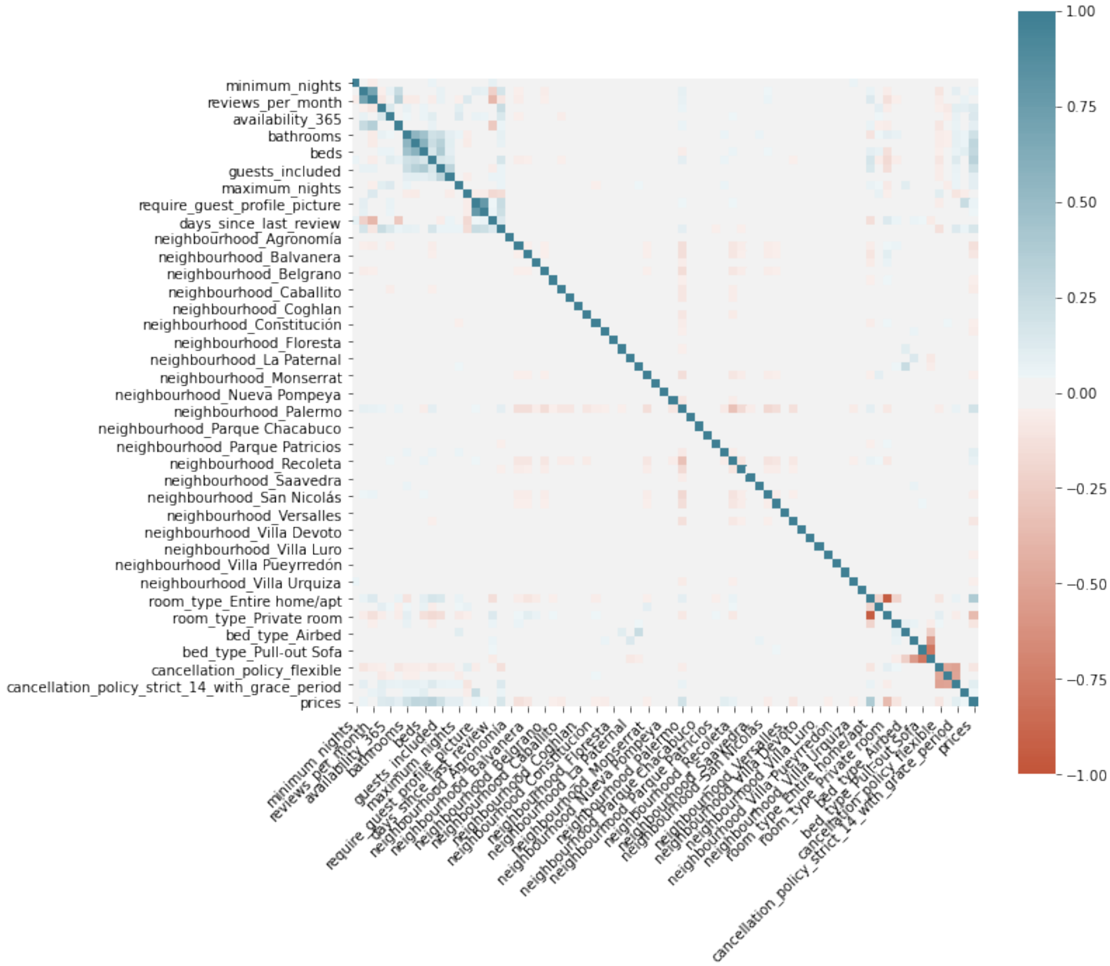
[27]:
```python
# seperate price from features
Y = Xdata.price
Xdata.drop(columns = 'price', inplace = True)
print("Training data:", Xdata.shape)
```

```
Training data: (9664, 72)
```

1.1 Exploratory Analysis

[28]:
```python
# add prices in the last column for visualization
Xdata['prices'] = Y
```

[29]:
```python
# create a correlation heatmap

corr = Xdata.corr()
fig = plt.figure(figsize = (10,10))
ax = sns.heatmap(
    corr,
    vmin=-1, vmax=1, center=0,
    cmap=sns.diverging_palette(20, 220, n=200),
    square=True
)
ax.set_xticklabels(
    ax.get_xticklabels(),
    rotation=45,
    horizontalalignment='right'
);
plt.show()

fig.savefig('heatmap.png')
```



[30]:
```
# drop prices from the features
Xdata.drop(columns = 'prices', inplace = True)
```

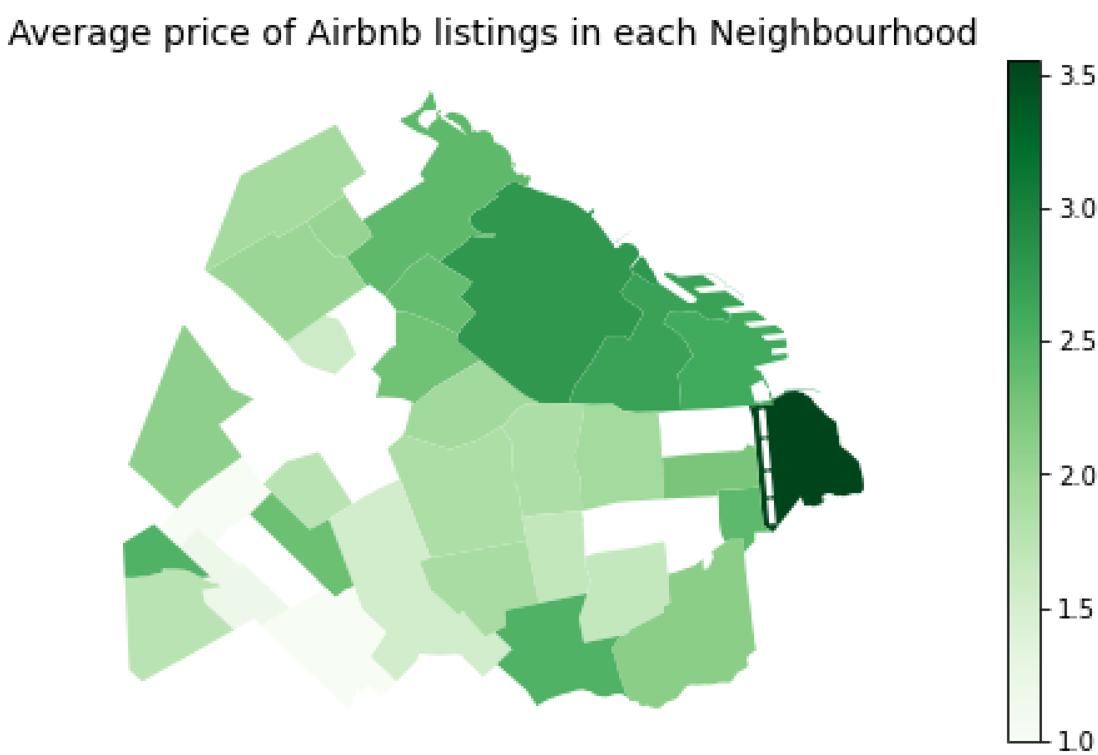
1.1.1 Neighbourhood

[31]:
```
# Use the geojson file of the Buenos Aires neighbourhood
map_neighbour = gpd.read_file('neighbourhoods.geojson')
map_neighbour.drop(columns = ['neighbourhood_group'], inplace = True)
```

Source: http://insideairbnb.com/get-the-data.html

[32]:
```
# create a dataframe with average prices and number of listings for each␣
↪neighbourhood
n = pd.DataFrame(data.groupby('neighbourhood').size())
n.rename(columns={0: 'number_of_listings'}, inplace=True)
n['avg_price'] = data.groupby('neighbourhood').price.mean().values
n['median_price'] = data.groupby('neighbourhood').price.median().values
```

```
# combine the dataframe and the geo-map
n_map = map_neighbour.set_index('neighbourhood').join(n)

# Plot the average price of listings in each borough
fig2, ax2 = plt.subplots(1, figsize=(15, 5))
n_map.plot(column='avg_price', cmap='Greens', ax=ax2)
ax2.axis('off')
ax2.set_title('Average price of Airbnb listings in each Neighbourhood',␣
↪fontsize=14)
sm = plt.cm.ScalarMappable(cmap='Greens', norm=plt.Normalize(vmin=min(n_map.
↪median_price),
                                                             vmax=max(n_map.
↪avg_price)))
sm._A = [] # Creates an empty array for the data range
cbar = fig2.colorbar(sm)
plt.show()
fig2.savefig('neigh.png')
```



2 Models

2.0.1 Prepare data for training

[33]:
```
# scale features
scaler = preprocessing.StandardScaler()
# scale training data
X = pd.DataFrame(scaler.fit_transform(Xdata), columns=list(Xdata.columns))
# scale test data
X_test = pd.DataFrame(scaler.fit_transform(data_test), columns=list(data_test.
 ↪columns))
```

[34]:
```
X.head()
```

[34]:
```
   minimum_nights  number_of_reviews  reviews_per_month  \
0       -0.195658           3.984677           1.532531
1       -0.195658          -0.353632          -0.370085
2       -0.104399          -0.599196          -0.858190
3       -0.150029          -0.626481          -0.808384
4       -0.150029           0.192068           0.596165

   calculated_host_listings_count  availability_365  host_is_superhost  \
0                       -0.145142          0.992381           1.247643
1                       -0.386370         -1.574888           1.247643
2                        1.060994          1.096259          -0.801511
3                       -0.386370          0.406212          -0.801511
4                       -0.064733          1.133358           1.247643

   bathrooms  bedrooms      beds  cleaning_fee  …  room_type_Private room  \
0  -0.438704 -1.383005 -0.663041      0.386720  …               -0.372761
1  -0.438704 -0.164427 -0.663041     -0.532227  …                2.682681
2  -0.438704 -1.383005 -0.663041     -0.236295  …               -0.372761
3  -0.438704 -0.164427  0.802900     -0.866498  …               -0.372761
4  -0.438704 -0.164427  0.802900      0.386720  …               -0.372761

   room_type_Shared room  bed_type_Airbed  bed_type_Futon  \
0              -0.083554        -0.014387        -0.03526
1              -0.083554        -0.014387        -0.03526
2              -0.083554        -0.014387        -0.03526
3              -0.083554        -0.014387        -0.03526
4              -0.083554        -0.014387        -0.03526

   bed_type_Pull-out Sofa  bed_type_Real Bed  cancellation_policy_flexible  \
0               -0.048843           0.061995                     -0.695886
1               -0.048843           0.061995                     -0.695886
2               -0.048843           0.061995                     -0.695886
3               -0.048843           0.061995                      1.437017
4               -0.048843           0.061995                     -0.695886
```

```
   cancellation_policy_moderate  \
0                     -0.685916
1                      1.457904
2                      1.457904
3                     -0.685916
4                      1.457904

   cancellation_policy_strict_14_with_grace_period  \
0                                         1.359491
1                                        -0.735569
2                                        -0.735569
3                                        -0.735569
4                                        -0.735569

   cancellation_policy_super_strict_30
0                            -0.051939
1                            -0.051939
2                            -0.051939
3                            -0.051939
4                            -0.051939

[5 rows x 72 columns]
```

[35]:

```
# define cross validation folds: 5-folds cross validation
kf = KFold(n_splits = 5, shuffle=True, random_state = 15)
```

[36]:

```
# define a function that plots cross validation results and save the plot
def plot_cross_validation_results(depths, cv_scores_mean,
                                   cv_scores_std, title):
    fig, ax = plt.subplots(1,1, figsize=(20,5))
    ax.plot(depths, cv_scores_mean, '-o',
            label='mean cross-validation accuracy', alpha=0.9)
    ax.fill_between(depths, cv_scores_mean-2*cv_scores_std,
                    cv_scores_mean+2*cv_scores_std, alpha=0.2)
    ylim = plt.ylim()
    ax.set_title(title, fontsize=16)
    ax.set_xlabel('Maximum Tree depth', fontsize=14)
    ax.set_xticks(depths)
    ax.legend()
    fig.savefig(title + '.png')
```

2.1 Random Forest

2.1.1 All Features

Tuning max_depth

[54]:
```python
# define a function that runs cross validation on trees
def cross_val_trees(x, y, kf, depths):

    """

    This function runs cross validation on random forest with differnt␣
↪max_depth, given cross validation split
    Input: x - data, y - label, kf - k fold cv spliting, depths - range of␣
↪max_depth
    Output: mean cross validation accuracy, cross validation standard␣
↪deviation, run time of this function

    """

    # record run time
    start = time.time()

    cv_scores_mean, cv_scores_std = [], []

    for depth in depths:
        clf = RandomForestClassifier(n_estimators=2000, criterion='entropy',␣
↪max_depth = depth, oob_score = True,
                                    random_state=0,verbose=0)
        scores_clf = cross_val_score(clf, x, y, scoring='accuracy', cv=kf)

        # cv results
        cv_scores_mean.append(scores_clf.mean())
        cv_scores_std.append(scores_clf.std())
        print(depth, scores_clf.mean())


    cv_scores_mean = np.array(cv_scores_mean)
    cv_scores_std = np.array(cv_scores_std)

    run_time = time.time()-start

    return cv_scores_mean, cv_scores_std, run_time
```

[55]:
```python
# possible max_depth
depths = range(1,30)
```

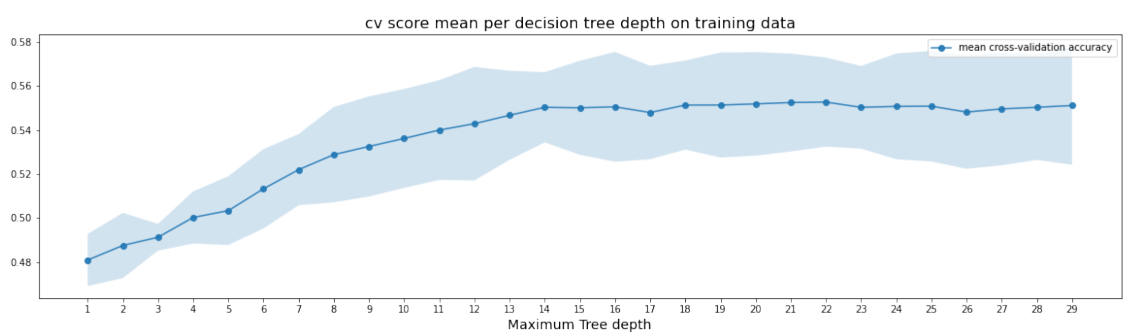
[56]:
```python
# run the cross validation function
rdf_mean, rdf_std, rdf_time = cross_val_trees(X, Y, kf, depths)
print(rdf_time)
```

```
1 0.48085775122932956
2 0.48748038588790743
```

```
3 0.4912049518068547
4 0.5002074677685916
5 0.5033122545223583
6 0.5132461797332801
7 0.5219378689193575
8 0.5287679177926371
9 0.5324930192504812
10 0.5361149759168158
11 0.5399437041511762
12 0.5428413444596896
13 0.5466696442629324
14 0.5502911189442601
15 0.550084561591793
16 0.5504989615900792
17 0.5479116125183288
18 0.5513258872005132
19 0.5513264762932997
20 0.5518435390980883
21 0.5524644428949519
22 0.5526715357863157
23 0.5502911724981497
24 0.5507053047269876
25 0.550808770841835
26 0.5481188660713616
27 0.5495668561403283
28 0.5502916544831568
29 0.5511196511713843
3469.4145352840424
```

[57]:
```python
# plot the cv score mean for each max_depth
fig = plt.figure()
plot_cross_validation_results(depths, rdf_mean, rdf_std,
                              'cv score mean per decision tree depth on␣
 ↪training data')
plt.show()
```

```
<Figure size 432x288 with 0 Axes>
```



[77]:
```
# choose the best max_depth and train on the whole trainging set
max_dep = 22
s = time.time()
clf_rdf = RandomForestClassifier(n_estimators=2000, criterion='gini', max_depth␣
↪= max_dep, random_state=0)
clf_rdf.fit(X, Y)
print('training acc:', clf_rdf.score(X, Y), 'time:', time.time()-s)
```

```
training acc: 0.9995860927152318 time: 27.356616020202637
```

Tuning n_estimators

[82]:
```
# define a function that runs cross validation on trees
def cross_val_trees_nestimator(x, y, kf, n):

    """

    This function runs cross validation on random forest with differnt␣
↪n_estimators, given cross validation split
    Input: x - data, y - label, kf - k fold cv spliting, depths - range of␣
↪max_depth
    Output: mean cross validation accuracy, cross validation standard␣
↪deviation, run time of this function

    """

    # record run time
    start = time.time()

    cv_scores_mean, cv_scores_std = [], []

    for num in n:
        clf = RandomForestClassifier(n_estimators=num, criterion='entropy',␣
↪max_depth = 22, oob_score = True,
                                     random_state=0,verbose=0)
        scores_clf = cross_val_score(clf, x, y, scoring='accuracy', cv=kf)

        # cv results
        cv_scores_mean.append(scores_clf.mean())
        cv_scores_std.append(scores_clf.std())
        print(depth, scores_clf.mean())


    cv_scores_mean = np.array(cv_scores_mean)
    cv_scores_std = np.array(cv_scores_std)
```

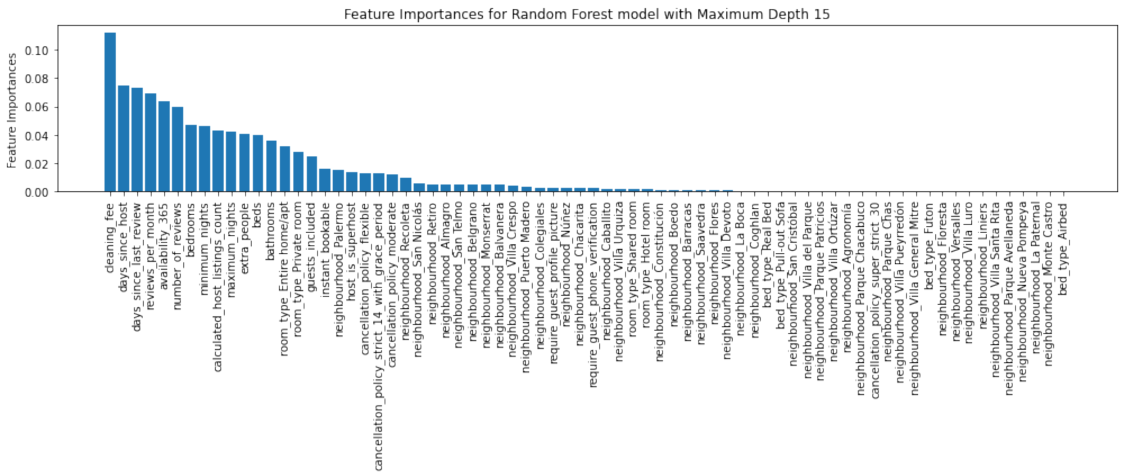
```
    run_time = time.time()-start

    return cv_scores_mean, cv_scores_std, run_time
```

[84]:
```
# possible number of trees in the forest
n = [100, 500, 1000, 1500, 2000]
# run the cross validation function
rdf_n_mean, rdf_n_std, rdf_n_time = cross_val_trees(X, Y, kf, n)
print(rdf_n_time)
```

```
100 0.5493599239106335
500 0.5493599239106335
1000 0.5493599239106335
1500 0.5493599239106335
2000 0.5493599239106335
703.7198657989502
```

2.1.2 Feature importances

[61]:
```
# sort the importances from high to low and  plot importance for each feature
imp=[]
for i,j in zip(X.columns, range(len(clf_rdf.feature_importances_))):
    imp.append((i,clf_rdf.feature_importances_[j]))
imp.sort(key = lambda x: -x[1])

fig = plt.figure(figsize = (14,6))
plt.bar([x[0] for x in imp], np.abs([x[1] for x in imp]))
plt.xticks(rotation=90)
plt.title('Feature Importances for Random Forest model with Maximum Depth 15')
plt.ylabel('Feature Importances')
plt.tight_layout() # make room for xlabels
plt.show()
fig.savefig('feature_importances_rdf.png')
```



```
[62]: # drop features which importance is less than 0.01
delfe = []
for i in range(len(X.columns)):
    if clf_rd.feature_importances_[i]<0.01:
        delfe.append(X.columns[i])

new_X = X.copy()
new_X.drop(columns = delfe, inplace = True)
```

```
[63]: new_X.shape
```

```
[63]: (9664, 22)
```

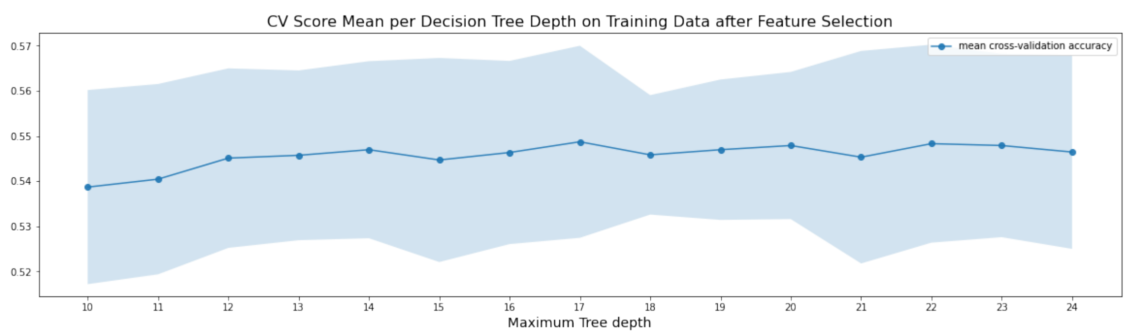
```
[65]: # run cross validation on the selected features

# possible max_depth
new_depths = range(10,25)

# run the cross validation function
new_rdf_mean, new_rdf_std, new_rdf_time = cross_val_trees(new_X, Y, kf,␣
↪new_depths)
print(new_rdf_time)
```

```
10 0.5387013610185521
11 0.5404607669559647
12 0.5451170634474353
13 0.5457380743520783
14 0.5469799890535849
15 0.5447039487425012
16 0.5463591923645007
17 0.5487392343293286
```

18 0.5458412726974773
19 0.546979667730247
20 0.5479108627638734
21 0.5453245312160268
22 0.5483253698699391
23 0.547911076979432
24 0.5464624442637893
1837.7601029872894

[66]:
```
# plot the cv score mean for each max_depth
fig = plt.figure()
plot_cross_validation_results(new_depths, new_rdf_mean, new_rdf_std,
                               'CV Score Mean per Decision Tree Depth on␣
 ↪Training Data after Feature Selection')
plt.show()
```

<Figure size 432x288 with 0 Axes>



2.2 CNN

[37]:
```
import tensorflow as tf
import keras
from tensorflow.python.keras import backend as K
from keras.models import Sequential
from keras.layers import Conv1D, MaxPooling1D, Flatten, Dense, Activation,␣
 ↪Dropout
from keras.layers.advanced_activations import LeakyReLU
```

Using TensorFlow backend.

[38]:
```
# define a function that reset tensorflow session
def reset_tf_session():
    """
    A function that clears tf session/graph
```

```
    """
    curr_session = tf.compat.v1.get_default_session()
    # close current session
    if curr_session is not None:
        curr_session.close()
    # reset graph
    K.clear_session()
    # create new session
    config = tf.compat.v1.ConfigProto()
    config.gpu_options.allow_growth = True
    s = tf.compat.v1.InteractiveSession(config=config)
    K.set_session(s)
    return s
```

[39]:
```
# one-hot encode price levels
Y_oh = pd.get_dummies(Y)
print("Train samples:", X.shape, Y_oh.shape)
```

```
Train samples: (9664, 72) (9664, 4)
```

[40]:
```
# split data into training and validation set
X_tr, X_val, Y_tr, Y_val = train_test_split(X, Y_oh, test_size=0.2, shuffle =␣
↪True)
X_tr = X_tr.to_numpy()
X_val = X_val.to_numpy()
Y_tr = Y_tr.to_numpy()
Y_val = Y_val.to_numpy()
# add 1 dim to the array
X_tr=np.expand_dims(X_tr,axis=1)
X_val=np.expand_dims(X_val,axis=1)
```

2.2.1 Learning Rate

[43]:
```
# define possible learning rate
eta = [5e-4, 1e-3, 5e-3, 0.01, 0.05, 0.1]
```

[44]:
```
# first try relu as activation function
def make_cnnmodel():
    """
    Define the model architecture.

    """
    model = Sequential()

    model.add(Conv1D(filters = 16, kernel_size = 3, padding = 'same',␣
↪input_shape=(1,72)))
    model.add(Activation('relu'))
```

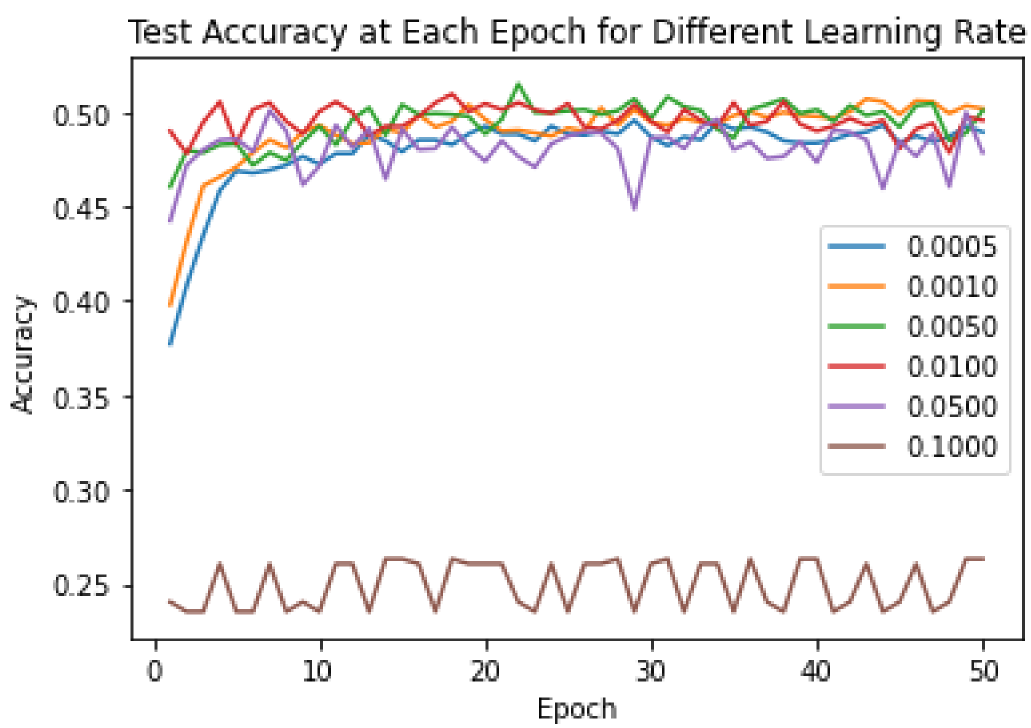
```
    model.add(Conv1D(filters = 32, kernel_size = 3, padding = 'same'))
    model.add(Activation('relu'))
    model.add(Dropout(0.25))


    model.add(Flatten(input_shape=(1,72)))
    model.add(Dense(128, activation = 'relu'))
    model.add(Dropout(0.25))
    model.add(Dense(256, activation = 'relu'))
    model.add(Dropout(0.25))
    model.add(Dense(512, activation = 'relu'))
    model.add(Dropout(0.25))
    model.add(Dense(4))
    model.add(Activation('softmax'))

    return model
```

[57]:
```
# store results
val_acc_lr = []
start = time.time()
for e in eta:
    # initial learning rate
    init_lr = e
    batch = 128
    epoch = 50

    # clear default graph
    s = reset_tf_session()

    # define the model
    model = make_cnnmodel()

    # prepare model for fitting
    model.compile(
        loss='categorical_crossentropy',  # train 4-way classification
        optimizer=keras.optimizers.adamax(lr = init_lr),
        metrics=['accuracy']  # report accuracy during training
    )

    # fit the model
    model.fit(
    X_tr, Y_tr,
    batch_size = batch,
    epochs = epoch,
    validation_data=(X_val, Y_val),
    shuffle=True,
    verbose=0,
```

```
    initial_epoch=0
    )

    # get validation results
    val = model.history.history['val_accuracy']
    val_acc_lr.append(val)
t = time.time()-start
print('run time:', t)
```

```
run time: 362.9908571243286
```

[58]:
```
# plot the result
fig = plt.figure()
for i in range(len(eta)):
    plt.plot(range(1,epoch+1), val_acc_lr[i], label = '%.4f'%eta[i])

plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.title('Test Accuracy at Each Epoch for Different Learning Rate')
plt.show()
fig.savefig('Learning Rate.png')
```



2.2.2 Activation functions

ReLu

[59]:
```
# describe model
s = reset_tf_session()
model = make_cnnmodel()

model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv1d_1 (Conv1D)            (None, 1, 16)             3472
_________________________________________________________________
activation_1 (Activation)    (None, 1, 16)             0
_________________________________________________________________
conv1d_2 (Conv1D)            (None, 1, 32)             1568
_________________________________________________________________
activation_2 (Activation)    (None, 1, 32)             0
_________________________________________________________________
dropout_1 (Dropout)          (None, 1, 32)             0
_________________________________________________________________
flatten_1 (Flatten)          (None, 32)                0
_________________________________________________________________
dense_1 (Dense)              (None, 128)               4224
_________________________________________________________________
dropout_2 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_2 (Dense)              (None, 256)               33024
_________________________________________________________________
dropout_3 (Dropout)          (None, 256)               0
_________________________________________________________________
dense_3 (Dense)              (None, 512)               131584
_________________________________________________________________
dropout_4 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_4 (Dense)              (None, 4)                 2052
_________________________________________________________________
activation_3 (Activation)    (None, 4)                 0
=================================================================
Total params: 175,924
Trainable params: 175,924
Non-trainable params: 0
_________________________________________________________________
```

[60]:
```
# initial learning rate
init_lr = 5e-3
```

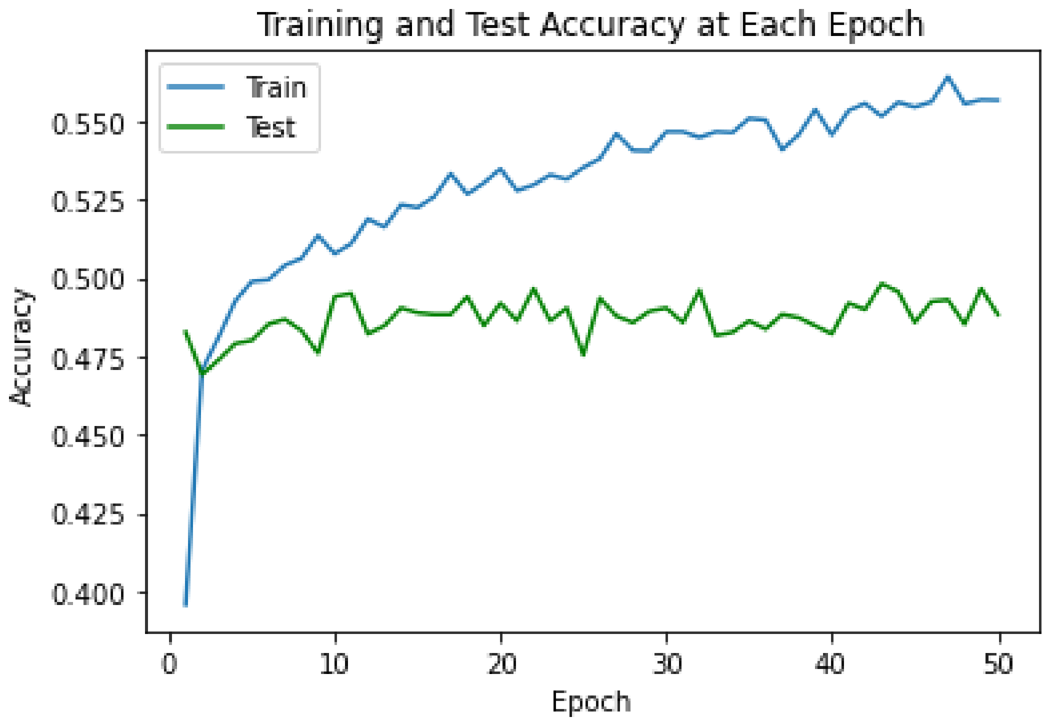
```
batch = 128
epoch = 50

# clear default graph
s = reset_tf_session()

# define the model
model = make_cnnmodel()

# prepare model for fitting
model.compile(
    loss='categorical_crossentropy',  # train 4-way classification
    optimizer=keras.optimizers.adamax(lr = init_lr),
    metrics=['accuracy']  # report accuracy during training
)
```

[61]:
```
# fit the model
start = time.time()
model.fit(
    X_tr, Y_tr,
    batch_size = batch,
    epochs = epoch,
    validation_data=(X_val, Y_val),
    shuffle=True,
    verbose=0,
    initial_epoch=0
)
end = time.time()
cnn_time = end - start # record the run time
```

[62]:
```
print('run time:', cnn_time)
```

```
run time: 62.177632093429565
```

[63]:
```
# plot training and validation accuracy

model_results = model.history.history
fig = plt.figure()
plt.plot(range(1,epoch+1), model_results['accuracy'], label='Train')
plt.plot(range(1,epoch+1), model_results['val_accuracy'], label='Test',␣
 ↪color='green')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.title('Training and Test Accuracy at Each Epoch')
plt.show()
fig.savefig('Training and Test Accuracy at Each Epoch.png')
```



Sigmoid

[64]:
```
def make_cnnmodel_sig():
    """
    Define the model architecture.

    """
    model = Sequential()

    model.add(Conv1D(filters = 16, kernel_size = 3, padding = 'same',␣
↪input_shape=(1,72)))
    model.add(Activation('sigmoid'))
    model.add(Conv1D(filters = 32, kernel_size = 3, padding = 'same'))
    model.add(Activation('sigmoid'))
    model.add(Dropout(0.25))


    model.add(Flatten(input_shape=(1,72)))
    model.add(Dense(128, activation = 'sigmoid'))
    model.add(Dropout(0.25))
    model.add(Dense(256, activation = 'sigmoid'))
    model.add(Dropout(0.25))

    model.add(Dense(512, activation = 'sigmoid'))
```

```
    model.add(Dropout(0.25))
    model.add(Dense(4))
    model.add(Activation('softmax'))

    return model
```

[65]:
```
# initial learning rate
init_lr = 5e-3
batch = 128
epoch = 50

# clear default graph
s = reset_tf_session()

# define the model
model_1 = make_cnnmodel_sig()

# prepare model for fitting
model_1.compile(
    loss='categorical_crossentropy',  # train 4-way classification
    optimizer=keras.optimizers.adamax(lr = init_lr),  # for SGD
    metrics=['accuracy']  # report accuracy during training
)

# fit the model
start = time.time()
model_1.fit(
    X_tr, Y_tr,
    batch_size = batch,
    epochs = epoch,
    validation_data=(X_val, Y_val),
    shuffle=True,
    verbose=0,
    initial_epoch=0
)
end = time.time()
cnn_time_1 = end - start # record the run time
```

Tanh

[66]:
```
def make_cnnmodel_tanh():
    """
    Define the model architecture.

    """
    model = Sequential()
```

```
    model.add(Conv1D(filters = 16, kernel_size = 3, padding = 'same',␣
↪input_shape=(1,72)))
    model.add(Activation('tanh'))
    model.add(Conv1D(filters = 32, kernel_size = 3, padding = 'same'))
    model.add(Activation('tanh'))
    model.add(Dropout(0.25))


    model.add(Flatten(input_shape=(1,72)))
    model.add(Dense(128, activation = 'tanh'))
    model.add(Dropout(0.25))
    model.add(Dense(256, activation = 'tanh'))
    model.add(Dropout(0.25))
    model.add(Dense(512, activation = 'tanh'))
    model.add(Dropout(0.25))
    model.add(Dense(4))
    model.add(Activation('softmax'))

    return model
```

[67]:
```
# initial learning rate
init_lr = 5e-3
batch = 128
epoch = 50

# clear default graph
s = reset_tf_session()

# define the model
model_2 = make_cnnmodel_tanh()

# prepare model for fitting
model_2.compile(
    loss='categorical_crossentropy',  # train 4-way classification
    optimizer=keras.optimizers.adamax(lr = init_lr),  # for SGD
    metrics=['accuracy']  # report accuracy during training
)

# fit the model
start = time.time()
model_2.fit(
    X_tr, Y_tr,
    batch_size = batch,
    epochs = epoch,
    validation_data=(X_val, Y_val),
    shuffle=True,
    verbose=0,
```

```
    initial_epoch=0
)
end = time.time()
cnn_time_2 = end - start # record the run time
```

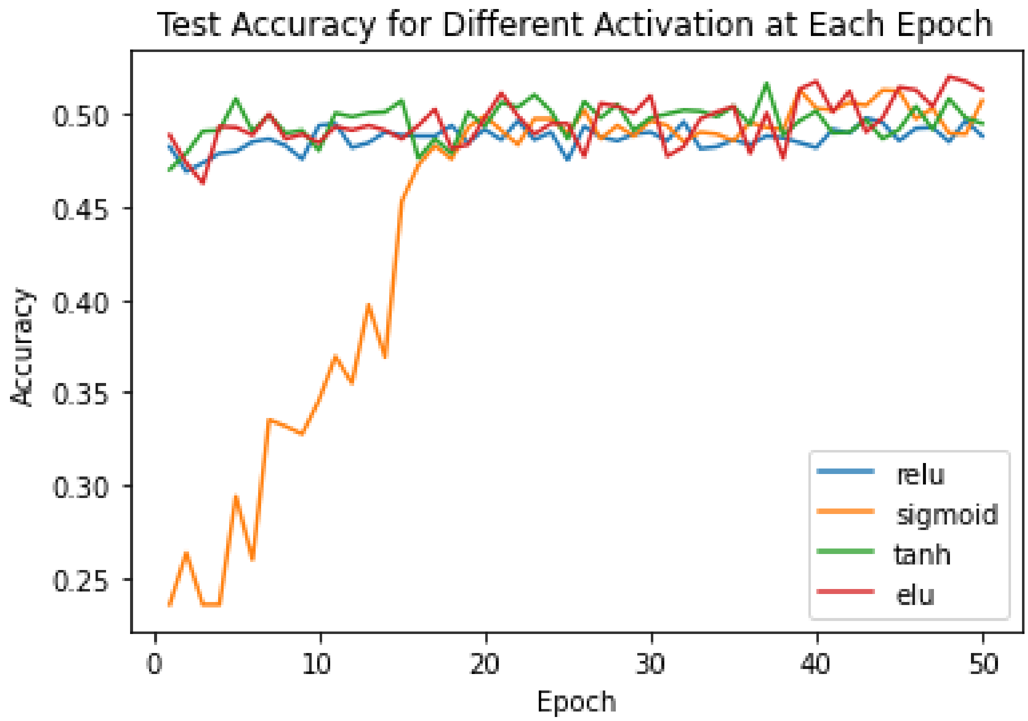
elu

[68]:
```
def make_cnnmodel_elu():
    """
    Define the model architecture.

    """
    model = Sequential()

    model.add(Conv1D(filters = 16, kernel_size = 3, padding = 'same',␣
 ↪input_shape=(1,72)))
    model.add(Activation('elu'))
    model.add(Conv1D(filters = 32, kernel_size = 3, padding = 'same'))
    model.add(Activation('elu'))
    model.add(Dropout(0.25))


    model.add(Flatten(input_shape=(1,72)))
    model.add(Dense(128, activation = 'elu'))
    model.add(Dropout(0.25))
    model.add(Dense(256, activation = 'elu'))
    model.add(Dropout(0.25))
    model.add(Dense(512, activation = 'elu'))
    model.add(Dropout(0.25))
    model.add(Dense(4))
    model.add(Activation('softmax'))

    return model
```

[69]:
```
# initial learning rate
init_lr = 5e-3
batch = 128
epoch = 50

# clear default graph
s = reset_tf_session()

# define the model
model_3 = make_cnnmodel_elu()

# prepare model for fitting
model_3.compile(
```

```
    loss='categorical_crossentropy',  # train 4-way classification
    optimizer=keras.optimizers.adamax(lr = init_lr),  # for SGD
    metrics=['accuracy']  # report accuracy during training
)

# fit the model
start = time.time()
model_3.fit(
    X_tr, Y_tr,
    batch_size = batch,
    epochs = epoch,
    validation_data=(X_val, Y_val),
    shuffle=True,
    verbose=0,
    initial_epoch=0
)
end = time.time()
cnn_time_3 = end - start # record the run time
```

[70]:
```
# plot the results for activation functions
results = model.history.history
results_1 = model_1.history.history
results_2 = model_2.history.history
results_3 = model_3.history.history
fig = plt.figure()
plt.plot(range(1,epoch+1), results['val_accuracy'], label='relu')
plt.plot(range(1,epoch+1), results_1['val_accuracy'], label='sigmoid')
plt.plot(range(1,epoch+1), results_2['val_accuracy'], label='tanh')
plt.plot(range(1,epoch+1), results_3['val_accuracy'], label='elu')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.title('Test Accuracy for Different Activation at Each Epoch')
plt.show()
fig.savefig('Test Accuracy for Different Activation at Each Epoch.png')
```



[71]:
```
# total time for tuning
cnn_time + cnn_time_1 + cnn_time_2 + cnn_time_3
```

[71]: 272.16894793510437

2.2.3 Run the whole training set

[73]:
```
# preprocess the data
Y_cnn = Y_oh.to_numpy()
X_cnn = X.to_numpy()
# add 1 dim to the array
X_cnn=np.expand_dims(X_cnn,axis=1)
```

[75]:
```
# initial learning rate
init_lr = 5e-3
batch = 128
epoch = 50

# clear default graph
s = reset_tf_session()

# define the model
model = make_cnnmodel()
```

```
# prepare model for fitting
model.compile(
    loss='categorical_crossentropy',  # train 4-way classification
    optimizer=keras.optimizers.adamax(lr = init_lr),
    metrics=['accuracy']  # report accuracy during training
)
# fit the model
start = time.time()
model.fit(
    X_cnn, Y_cnn,
    batch_size = batch,
    epochs = epoch,
    shuffle=True,
    verbose=0,
    initial_epoch=0
)
end = time.time()
cnn_time = end - start # record the run time

print('run time:', cnn_time)
```

```
run time: 69.4025490283966
```

3 Prediction

[80]:
```
# use test data to make prediction
pred_rdf = pd.DataFrame({'price':clf_rdf.predict(X_test)})
ID = pd.DataFrame(ID)
pred = ID.join(pred_rdf,lsuffix='_caller', rsuffix='_other')
pred = pred.set_index('id')
display(pred)
```

```
       price
id
7715       2
13196      2
13194      2
4673       2
11325      1
...      ...
12921      3
7174       2
9240       3
11663      1
4513       1
```

[4149 rows x 1 columns]

[81]:
```
# save to csv file
pred.to_csv('pred.csv')
```

[ ]:
```
```