House_prices

August 21, 2022

1 Predicting House Prices

1.1 Imports

[2]:
```
import pandas as pd
import numpy as np
import math
import sys
import matplotlib.pyplot as plt

# Make numpy values easier to read.
np.set_printoptions(precision=3, suppress=True)

import tensorflow as tf
from tensorflow.keras import layers
import keras
from sklearn.ensemble import RandomForestRegressor
from sklearn.preprocessing import OneHotEncoder
from sklearn.model_selection import RandomizedSearchCV
```

1.2 Data preprocessing

Get data as pandas array and make a dict of keras inputs

[5]:
```
full_data = pd.read_csv("./Data/train.csv")
cutoff = 7 * len(full_data) // 10

#Separate training and test data
train_data = full_data[:cutoff]
features = train_data.copy()
labels = np.array(features.pop('SalePrice')) / 100000
features.pop('Id')

test_data = full_data[cutoff:]
test_features = test_data.copy()
test_labels = np.array(test_features.pop('SalePrice')) / 100000
test_features.pop('Id')
```

```
#Change the data type of the years to strings
inputs = {}
year_cols=['YearBuilt', 'YearRemodAdd', 'GarageYrBlt', 'YrSold']

for col in year_cols:
    features[col] = features[col].astype(str)
    test_features[col] = test_features[col].astype(str)

#Deal with the missing data, either with a unique name for strings or the mean␣
↪of the column for numbers
for name, column in features.items():
    dtype = column.dtype
    if dtype == object:
        dtype = tf.string
        features[name] = features[name].fillna('NO INFO')
    else:
        dtype = tf.float32
        features[name] = features[name].fillna(features[name].mean(axis=0))

    inputs[name] = tf.keras.Input(shape=(1,), name=name, dtype=dtype)

test_inputs = {}

#Do the same processing for the test data
for name, column in test_features.items():
    dtype = column.dtype
    if dtype == object:
        dtype = tf.string
        test_features[name] = test_features[name].fillna('NO INFO')
    else:
        dtype = tf.float32
        test_features[name] = test_features[name].fillna(test_features[name].
↪mean(axis=0))

    test_inputs[name] = tf.keras.Input(shape=(1,), name=name, dtype=dtype)
```

Concatenate and normalize the float/integer inputs through appropriate layers to normalize them

[6]:
```
numeric_inputs = {name:input for name,input in inputs.items()
                  if input.dtype==tf.float32}

x = layers.Concatenate()(list(numeric_inputs.values()))
norm = layers.Normalization()
norm.adapt(np.array(features[numeric_inputs.keys()]))
all_numeric_inputs = norm(x)
```

```
preprocessed_inputs = [all_numeric_inputs]
```

Process the string inputs, by passing through a StringLookup and CategoryEncoding layer, for one hot encoding

[7]:
```
for name, inpt in inputs.items():
    if inpt.dtype == tf.float32:
        continue
    lookup = layers.StringLookup(vocabulary=np.unique(features[name]))
    one_hot = layers.CategoryEncoding(num_tokens=lookup.vocabulary_size())

    x = lookup(inpt)
    x = one_hot(x)
    preprocessed_inputs.append(x)
```

[8]:
```
preprocessed_inputs_cat = layers.Concatenate()(preprocessed_inputs)
preprocessing_model = tf.keras.Model(inputs, preprocessed_inputs_cat)
```

[9]:
```
features_dict = {name: np.array(value)
                for name, value in features.items()}
test_features_dict = {name: np.array(value)
                     for name, value in test_features.items()}
```

1.3 Building the first model: Keras neural network

Start with a simple model, with one hidden layer of 40 nodes (more complex models were tried without much success)

[10]:
```
def first_model(preprocessing, inputs):
    main = tf.keras.Sequential([
        layers.Dense(40, activation='relu'),
        layers.Dropout(.2, input_shape=(2,)),
        layers.Dense(1)
    ])
    preprocessed_inputs = preprocessing(inputs)
    result = main(preprocessed_inputs)
    model = tf.keras.Model(inputs, result)

    #The loss function will be based on the mean absolute percentage error
    model.compile(loss=tf.losses.MeanSquaredLogarithmicError(),
                 optimizer=tf.optimizers.Adam(),
                  metrics=['MeanAbsolutePercentageError', 'MSLE'])
    return model
```

Define some callbacks, to save the training and test error on each epoch

[11]:
```
class Callbacks(keras.callbacks.Callback):
    def on_epoch_end(self, epoch, logs=None):
        train_losses.append(logs['mean_absolute_percentage_error'])
        epochs_list.append(epoch)
```

```
        test_losses.append(self.model.evaluate(test_features_dict,␣
↪test_labels)[1])
```

Train the model

[12]:
```
train_losses = []
test_losses = []
epochs_list = []
model = first_model(preprocessing_model, inputs)
model.fit(x=features_dict, y=labels, epochs=80, callbacks=[Callbacks()])
```

```
Epoch 1/80
14/14 [==============================] - 2s 3ms/step - loss: 0.0366 -
mean_absolute_percentage_error: 30.0059 - MSLE: 0.0366
32/32 [==============================] - 6s 59ms/step - loss: 0.2131 -
mean_absolute_percentage_error: 46.6095 - MSLE: 0.2131
Epoch 2/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0149 -
mean_absolute_percentage_error: 14.8521 - MSLE: 0.0149
32/32 [==============================] - 0s 12ms/step - loss: 0.0325 -
mean_absolute_percentage_error: 23.6192 - MSLE: 0.0325
Epoch 3/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0123 -
mean_absolute_percentage_error: 13.1353 - MSLE: 0.0123
32/32 [==============================] - 0s 12ms/step - loss: 0.0226 -
mean_absolute_percentage_error: 19.6082 - MSLE: 0.0226
Epoch 4/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0112 -
mean_absolute_percentage_error: 12.4073 - MSLE: 0.0112
32/32 [==============================] - 0s 13ms/step - loss: 0.0175 -
mean_absolute_percentage_error: 16.6543 - MSLE: 0.0175
Epoch 5/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0108 -
mean_absolute_percentage_error: 12.3903 - MSLE: 0.0108
32/32 [==============================] - 0s 13ms/step - loss: 0.0165 -
mean_absolute_percentage_error: 16.2498 - MSLE: 0.0165
Epoch 6/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0097 -
mean_absolute_percentage_error: 11.1066 - MSLE: 0.0097
32/32 [==============================] - 0s 13ms/step - loss: 0.0143 -
mean_absolute_percentage_error: 14.8413 - MSLE: 0.0143
Epoch 7/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0093 -
mean_absolute_percentage_error: 10.7339 - MSLE: 0.0093
32/32 [==============================] - 0s 13ms/step - loss: 0.0141 -
mean_absolute_percentage_error: 14.5747 - MSLE: 0.0141
Epoch 8/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0094 -
mean_absolute_percentage_error: 10.9514 - MSLE: 0.0094
```

```
32/32 [==============================] - 0s 13ms/step - loss: 0.0131 -
mean_absolute_percentage_error: 13.8518 - MSLE: 0.0131
Epoch 9/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0091 -
mean_absolute_percentage_error: 10.2745 - MSLE: 0.0091
32/32 [==============================] - 0s 13ms/step - loss: 0.0134 -
mean_absolute_percentage_error: 13.9027 - MSLE: 0.0134
Epoch 10/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0088 -
mean_absolute_percentage_error: 10.2404 - MSLE: 0.0088
32/32 [==============================] - 0s 13ms/step - loss: 0.0123 -
mean_absolute_percentage_error: 13.1624 - MSLE: 0.0123
Epoch 11/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0088 -
mean_absolute_percentage_error: 10.2422 - MSLE: 0.0088
32/32 [==============================] - 1s 19ms/step - loss: 0.0120 -
mean_absolute_percentage_error: 13.6223 - MSLE: 0.0120
Epoch 12/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0088 -
mean_absolute_percentage_error: 10.2483 - MSLE: 0.0088
32/32 [==============================] - 0s 14ms/step - loss: 0.0114 -
mean_absolute_percentage_error: 12.9674 - MSLE: 0.0114
Epoch 13/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0086 -
mean_absolute_percentage_error: 10.0451 - MSLE: 0.0086
32/32 [==============================] - 0s 14ms/step - loss: 0.0112 -
mean_absolute_percentage_error: 12.7427 - MSLE: 0.0112
Epoch 14/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0089 -
mean_absolute_percentage_error: 10.4941 - MSLE: 0.0089
32/32 [==============================] - 0s 13ms/step - loss: 0.0111 -
mean_absolute_percentage_error: 12.7443 - MSLE: 0.0111
Epoch 15/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0087 -
mean_absolute_percentage_error: 10.0854 - MSLE: 0.0087
32/32 [==============================] - 0s 13ms/step - loss: 0.0106 -
mean_absolute_percentage_error: 12.3664 - MSLE: 0.0106
Epoch 16/80
14/14 [==============================] - 0s 4ms/step - loss: 0.0091 -
mean_absolute_percentage_error: 10.6966 - MSLE: 0.0091
32/32 [==============================] - 0s 14ms/step - loss: 0.0106 -
mean_absolute_percentage_error: 12.3592 - MSLE: 0.0106
Epoch 17/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0093 -
mean_absolute_percentage_error: 11.3200 - MSLE: 0.0093
32/32 [==============================] - 0s 14ms/step - loss: 0.0116 -
mean_absolute_percentage_error: 12.8777 - MSLE: 0.0116
Epoch 18/80
```

```
14/14 [==============================] - 0s 3ms/step - loss: 0.0087 -
mean_absolute_percentage_error: 10.2581 - MSLE: 0.0087
32/32 [==============================] - 0s 14ms/step - loss: 0.0104 -
mean_absolute_percentage_error: 12.5355 - MSLE: 0.0104
Epoch 19/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.0657 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0096 -
mean_absolute_percentage_error: 11.8239 - MSLE: 0.0096
Epoch 20/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 9.9278 - MSLE: 0.0083
32/32 [==============================] - 0s 13ms/step - loss: 0.0106 -
mean_absolute_percentage_error: 12.2472 - MSLE: 0.0106
Epoch 21/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 9.9145 - MSLE: 0.0084
32/32 [==============================] - 0s 13ms/step - loss: 0.0097 -
mean_absolute_percentage_error: 12.2773 - MSLE: 0.0097
Epoch 22/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 9.7469 - MSLE: 0.0084
32/32 [==============================] - 1s 19ms/step - loss: 0.0090 -
mean_absolute_percentage_error: 11.8887 - MSLE: 0.0090
Epoch 23/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0081 -
mean_absolute_percentage_error: 9.7039 - MSLE: 0.0081
32/32 [==============================] - 0s 13ms/step - loss: 0.0092 -
mean_absolute_percentage_error: 11.6020 - MSLE: 0.0092
Epoch 24/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.3842 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0091 -
mean_absolute_percentage_error: 11.7930 - MSLE: 0.0091
Epoch 25/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 10.3172 - MSLE: 0.0084
32/32 [==============================] - 0s 13ms/step - loss: 0.0091 -
mean_absolute_percentage_error: 11.8910 - MSLE: 0.0091
Epoch 26/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0081 -
mean_absolute_percentage_error: 9.8111 - MSLE: 0.0081
32/32 [==============================] - 0s 13ms/step - loss: 0.0086 -
mean_absolute_percentage_error: 11.6265 - MSLE: 0.0086
Epoch 27/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 9.7404 - MSLE: 0.0080
32/32 [==============================] - 0s 13ms/step - loss: 0.0089 -
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```
mean_absolute_percentage_error: 11.5924 - MSLE: 0.0089
Epoch 28/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0082 -
mean_absolute_percentage_error: 9.7387 - MSLE: 0.0082
32/32 [==============================] - 0s 13ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 11.3511 - MSLE: 0.0085
Epoch 29/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0087 -
mean_absolute_percentage_error: 10.2532 - MSLE: 0.0087
32/32 [==============================] - 0s 13ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.8931 - MSLE: 0.0085
Epoch 30/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 9.7613 - MSLE: 0.0083
32/32 [==============================] - 0s 13ms/step - loss: 0.0082 -
mean_absolute_percentage_error: 11.3349 - MSLE: 0.0082
Epoch 31/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 9.8822 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0081 -
mean_absolute_percentage_error: 11.1176 - MSLE: 0.0081
Epoch 32/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 9.7546 - MSLE: 0.0083
32/32 [==============================] - 1s 19ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 11.1837 - MSLE: 0.0084
Epoch 33/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0086 -
mean_absolute_percentage_error: 10.0508 - MSLE: 0.0086
32/32 [==============================] - 0s 13ms/step - loss: 0.0078 -
mean_absolute_percentage_error: 11.2478 - MSLE: 0.0078
Epoch 34/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 9.8999 - MSLE: 0.0084
32/32 [==============================] - 0s 13ms/step - loss: 0.0074 -
mean_absolute_percentage_error: 10.5509 - MSLE: 0.0074
Epoch 35/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 9.8724 - MSLE: 0.0083
32/32 [==============================] - 0s 13ms/step - loss: 0.0074 -
mean_absolute_percentage_error: 10.8892 - MSLE: 0.0074
Epoch 36/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 9.8480 - MSLE: 0.0083
32/32 [==============================] - 0s 13ms/step - loss: 0.0087 -
mean_absolute_percentage_error: 11.2136 - MSLE: 0.0087
Epoch 37/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
```

```
mean_absolute_percentage_error: 10.1408 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 10.9390 - MSLE: 0.0080
Epoch 38/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0082 -
mean_absolute_percentage_error: 9.9143 - MSLE: 0.0082
32/32 [==============================] - 0s 13ms/step - loss: 0.0081 -
mean_absolute_percentage_error: 10.7596 - MSLE: 0.0081
Epoch 39/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 10.0903 - MSLE: 0.0083
32/32 [==============================] - 0s 13ms/step - loss: 0.0072 -
mean_absolute_percentage_error: 10.5765 - MSLE: 0.0072
Epoch 40/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0082 -
mean_absolute_percentage_error: 9.8904 - MSLE: 0.0082
32/32 [==============================] - 0s 13ms/step - loss: 0.0076 -
mean_absolute_percentage_error: 11.0586 - MSLE: 0.0076
Epoch 41/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0082 -
mean_absolute_percentage_error: 9.8943 - MSLE: 0.0082
32/32 [==============================] - 0s 13ms/step - loss: 0.0075 -
mean_absolute_percentage_error: 10.5444 - MSLE: 0.0075
Epoch 42/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0081 -
mean_absolute_percentage_error: 9.7249 - MSLE: 0.0081
32/32 [==============================] - 0s 13ms/step - loss: 0.0082 -
mean_absolute_percentage_error: 10.8932 - MSLE: 0.0082
Epoch 43/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.1161 - MSLE: 0.0085
32/32 [==============================] - 1s 19ms/step - loss: 0.0070 -
mean_absolute_percentage_error: 10.1956 - MSLE: 0.0070
Epoch 44/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 10.0913 - MSLE: 0.0084
32/32 [==============================] - 0s 13ms/step - loss: 0.0072 -
mean_absolute_percentage_error: 10.6233 - MSLE: 0.0072
Epoch 45/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 10.0812 - MSLE: 0.0083
32/32 [==============================] - 0s 13ms/step - loss: 0.0079 -
mean_absolute_percentage_error: 11.1280 - MSLE: 0.0079
Epoch 46/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0087 -
mean_absolute_percentage_error: 10.3466 - MSLE: 0.0087
32/32 [==============================] - 0s 13ms/step - loss: 0.0071 -
mean_absolute_percentage_error: 10.4538 - MSLE: 0.0071
```

```
Epoch 47/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0086 -
mean_absolute_percentage_error: 10.2407 - MSLE: 0.0086
32/32 [==============================] - 0s 13ms/step - loss: 0.0076 -
mean_absolute_percentage_error: 10.6463 - MSLE: 0.0076
Epoch 48/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 9.9546 - MSLE: 0.0083
32/32 [==============================] - 0s 12ms/step - loss: 0.0070 -
mean_absolute_percentage_error: 10.1156 - MSLE: 0.0070
Epoch 49/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.0094 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0067 -
mean_absolute_percentage_error: 9.9604 - MSLE: 0.0067
Epoch 50/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 9.8451 - MSLE: 0.0084
32/32 [==============================] - 0s 13ms/step - loss: 0.0067 -
mean_absolute_percentage_error: 10.0968 - MSLE: 0.0067
Epoch 51/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 9.9640 - MSLE: 0.0084
32/32 [==============================] - 0s 13ms/step - loss: 0.0067 -
mean_absolute_percentage_error: 10.0568 - MSLE: 0.0067
Epoch 52/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0086 -
mean_absolute_percentage_error: 10.3479 - MSLE: 0.0086
32/32 [==============================] - 0s 13ms/step - loss: 0.0073 -
mean_absolute_percentage_error: 10.5902 - MSLE: 0.0073
Epoch 53/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.1397 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0066 -
mean_absolute_percentage_error: 10.0401 - MSLE: 0.0066
Epoch 54/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0088 -
mean_absolute_percentage_error: 10.3291 - MSLE: 0.0088
32/32 [==============================] - 1s 19ms/step - loss: 0.0070 -
mean_absolute_percentage_error: 10.3628 - MSLE: 0.0070
Epoch 55/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0091 -
mean_absolute_percentage_error: 10.6405 - MSLE: 0.0091
32/32 [==============================] - 0s 13ms/step - loss: 0.0063 -
mean_absolute_percentage_error: 9.5311 - MSLE: 0.0063
Epoch 56/80
14/14 [==============================] - 0s 4ms/step - loss: 0.0087 -
mean_absolute_percentage_error: 10.3654 - MSLE: 0.0087
```

```
32/32 [==============================] - 0s 14ms/step - loss: 0.0061 -
mean_absolute_percentage_error: 9.6973 - MSLE: 0.0061
Epoch 57/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 9.9273 - MSLE: 0.0084
32/32 [==============================] - 0s 13ms/step - loss: 0.0059 -
mean_absolute_percentage_error: 9.4370 - MSLE: 0.0059
Epoch 58/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0088 -
mean_absolute_percentage_error: 10.4824 - MSLE: 0.0088
32/32 [==============================] - 0s 13ms/step - loss: 0.0066 -
mean_absolute_percentage_error: 10.0065 - MSLE: 0.0066
Epoch 59/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.1980 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0066 -
mean_absolute_percentage_error: 9.8280 - MSLE: 0.0066
Epoch 60/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0081 -
mean_absolute_percentage_error: 9.8996 - MSLE: 0.0081
32/32 [==============================] - 0s 14ms/step - loss: 0.0067 -
mean_absolute_percentage_error: 9.7629 - MSLE: 0.0067
Epoch 61/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0081 -
mean_absolute_percentage_error: 9.9628 - MSLE: 0.0081
32/32 [==============================] - 0s 13ms/step - loss: 0.0065 -
mean_absolute_percentage_error: 9.8961 - MSLE: 0.0065
Epoch 62/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 9.8193 - MSLE: 0.0080
32/32 [==============================] - 0s 13ms/step - loss: 0.0065 -
mean_absolute_percentage_error: 9.9715 - MSLE: 0.0065
Epoch 63/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0079 -
mean_absolute_percentage_error: 9.8682 - MSLE: 0.0079
32/32 [==============================] - 0s 13ms/step - loss: 0.0061 -
mean_absolute_percentage_error: 9.3947 - MSLE: 0.0061
Epoch 64/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 9.9791 - MSLE: 0.0080
32/32 [==============================] - 0s 13ms/step - loss: 0.0057 -
mean_absolute_percentage_error: 9.4112 - MSLE: 0.0057
Epoch 65/80
14/14 [==============================] - 0s 5ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 9.9516 - MSLE: 0.0080
32/32 [==============================] - 1s 23ms/step - loss: 0.0060 -
mean_absolute_percentage_error: 9.6250 - MSLE: 0.0060
Epoch 66/80
```

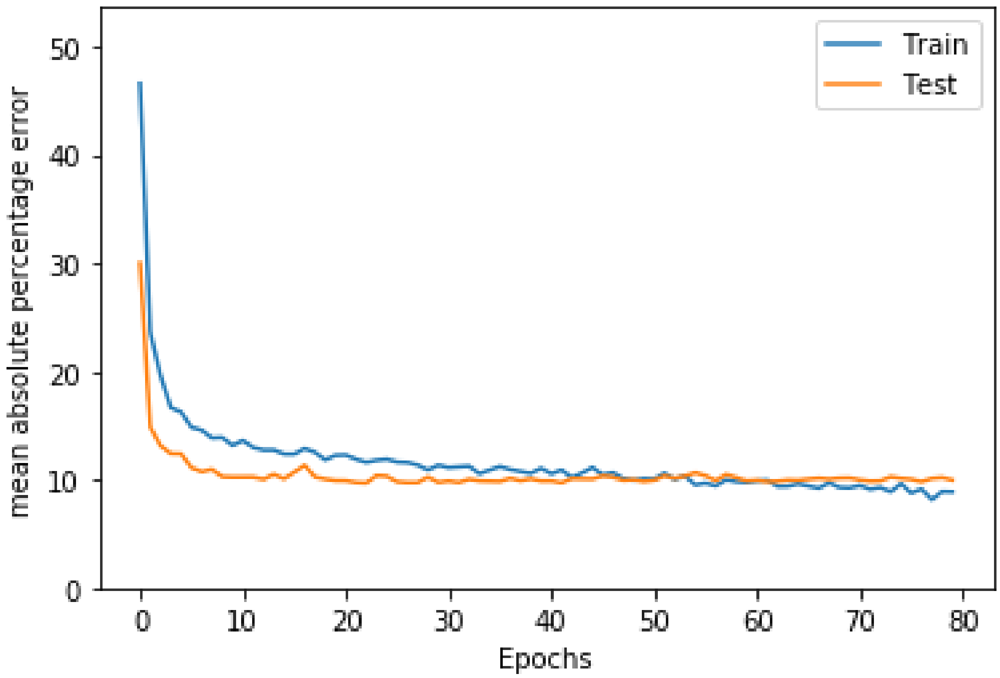
```
14/14 [==============================] - 0s 3ms/step - loss: 0.0081 -
mean_absolute_percentage_error: 10.0619 - MSLE: 0.0081
32/32 [==============================] - 0s 14ms/step - loss: 0.0058 -
mean_absolute_percentage_error: 9.4256 - MSLE: 0.0058
Epoch 67/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 10.1495 - MSLE: 0.0080
32/32 [==============================] - 0s 13ms/step - loss: 0.0058 -
mean_absolute_percentage_error: 9.2195 - MSLE: 0.0058
Epoch 68/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0082 -
mean_absolute_percentage_error: 10.0611 - MSLE: 0.0082
32/32 [==============================] - 0s 13ms/step - loss: 0.0066 -
mean_absolute_percentage_error: 9.7287 - MSLE: 0.0066
Epoch 69/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 10.1521 - MSLE: 0.0083
32/32 [==============================] - 0s 13ms/step - loss: 0.0055 -
mean_absolute_percentage_error: 9.2937 - MSLE: 0.0055
Epoch 70/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.1658 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0059 -
mean_absolute_percentage_error: 9.2548 - MSLE: 0.0059
Epoch 71/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 9.9894 - MSLE: 0.0080
32/32 [==============================] - 0s 13ms/step - loss: 0.0061 -
mean_absolute_percentage_error: 9.4749 - MSLE: 0.0061
Epoch 72/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0079 -
mean_absolute_percentage_error: 9.8720 - MSLE: 0.0079
32/32 [==============================] - 0s 13ms/step - loss: 0.0059 -
mean_absolute_percentage_error: 9.1275 - MSLE: 0.0059
Epoch 73/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 9.8960 - MSLE: 0.0080
32/32 [==============================] - 0s 13ms/step - loss: 0.0061 -
mean_absolute_percentage_error: 9.2919 - MSLE: 0.0061
Epoch 74/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 10.2665 - MSLE: 0.0083
32/32 [==============================] - 0s 13ms/step - loss: 0.0054 -
mean_absolute_percentage_error: 8.8899 - MSLE: 0.0054
Epoch 75/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0085 -
mean_absolute_percentage_error: 10.1265 - MSLE: 0.0085
32/32 [==============================] - 0s 13ms/step - loss: 0.0062 -
```

```
mean_absolute_percentage_error: 9.6401 - MSLE: 0.0062
Epoch 76/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0083 -
mean_absolute_percentage_error: 10.0494 - MSLE: 0.0083
32/32 [==============================] - 1s 19ms/step - loss: 0.0054 -
mean_absolute_percentage_error: 8.7724 - MSLE: 0.0054
Epoch 77/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0079 -
mean_absolute_percentage_error: 9.8198 - MSLE: 0.0079
32/32 [==============================] - 0s 13ms/step - loss: 0.0054 -
mean_absolute_percentage_error: 9.1521 - MSLE: 0.0054
Epoch 78/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0082 -
mean_absolute_percentage_error: 10.1223 - MSLE: 0.0082
32/32 [==============================] - 0s 13ms/step - loss: 0.0046 -
mean_absolute_percentage_error: 8.1604 - MSLE: 0.0046
Epoch 79/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0084 -
mean_absolute_percentage_error: 10.2004 - MSLE: 0.0084
32/32 [==============================] - 0s 13ms/step - loss: 0.0055 -
mean_absolute_percentage_error: 8.9147 - MSLE: 0.0055
Epoch 80/80
14/14 [==============================] - 0s 3ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 9.9773 - MSLE: 0.0080
32/32 [==============================] - 0s 13ms/step - loss: 0.0058 -
mean_absolute_percentage_error: 8.8866 - MSLE: 0.0058
```

[12]:
```
<keras.callbacks.History at 0x7fa53014c0f0>
```

Plot the learning curves (the hyperparameters were tuned to minimize bias and variance based on this plot)

[13]:
```
plt.figure()
plt.plot(epochs_list, train_losses, label='Train')
plt.plot(epochs_list, test_losses, label='Test')
plt.legend()
plt.ylim([0,1.15 * max(train_losses[0], test_losses[0])])
plt.xlabel('Epochs')
plt.ylabel('mean absolute percentage error')
plt.show()
```



[17]:
```
model.evaluate(test_features_dict, test_labels)
```

```
14/14 [==============================] - 0s 3ms/step - loss: 0.0080 -
mean_absolute_percentage_error: 9.9773 - MSLE: 0.0080
```

[17]:
```
[0.008023053407669067, 9.977315902709961, 0.008023053407669067]
```

[18]:
```
preds = model.predict(test_features_dict) * 100000
actual = test_labels * 100000
```

Compute the mean squared logarithmic error

[19]:
```
tot_sum = 0
for i in range(len(preds)):
    tot_sum += (np.log(preds[i] + 1) - np.log(actual[i] + 1)) ** 2
np.sqrt(tot_sum / len(preds))
```

[19]:
```
array([0.141])
```

2 New model: Random Forest

Since it seems like it will be hard to reduce our bias with a neural network, we will turn to another model: random forests. We will do the same date pre-processing, but this time using pandas, since we will Scikit learn and not keras.

[20]:
```
#Do the same preprocessing as with the other model
```

```
full_data = pd.read_csv("./Data/train.csv")

year_cols=['YearBuilt', 'YearRemodAdd', 'GarageYrBlt', 'YrSold']

for col in year_cols:
    full_data[col] = full_data[col].astype(str)

cutoff = 7 * len(full_data) // 10

train_data = full_data[:cutoff]
features = train_data.copy()
labels = np.array(features.pop('SalePrice'))
features.pop('Id')

test_data = full_data[cutoff:]
test_features = test_data.copy()
test_labels = np.array(test_features.pop('SalePrice'))
test_features.pop('Id')
print()
```

For this we do the preprocessing only using pandas, rather than the keras layers

[21]:
```
def PandasPreprocessing(features, train_data):
    year_cols=['YearBuilt', 'YearRemodAdd', 'GarageYrBlt', 'YrSold']
    #Get years as strings
    for col in year_cols:
        train_data[col] = train_data[col].astype(str)
    #Deal with missing data as before
    for name, column in features.items():
        dtype = column.dtype
        if dtype == object:
            features[name] = features[name].fillna('NO INFO')
            train_data[name] = train_data[name].fillna('NO INFO')
            enc = OneHotEncoder(handle_unknown='ignore')
            enc.fit(train_data[name].to_numpy().reshape(-1, 1))
            encoded_col = enc.transform(column.to_numpy().reshape(-1, 1)).
↪toarray()
            encoded_col = list(map(list, zip(*encoded_col)))
            features.pop(name)
            for i, col in enumerate(encoded_col):
                features[name + '_' + str(i)] = col
        else:
            #No real need to normalize for tree based algorithms, just fill the␣
↪nans with column mean
            features[name] = features[name].fillna(features[name].mean(axis=0))
    return features
```

[23]:
```
features = PandasPreprocessing(features, train_data)
test_features = PandasPreprocessing(test_features, train_data)
```

```
/home/mathieu/anaconda3/lib/python3.7/site-packages/ipykernel_launcher.py:4:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: http://pandas.pydata.org/pandas-
docs/stable/indexing.html#indexing-view-versus-copy
  after removing the cwd from sys.path.
```

[24]:
```
# Set values for the parameter grid we want to train our model over
n_estimators = [int(x) for x in np.linspace(start = 200, stop = 2000, num = 10)]
max_features = ['auto', 'sqrt']
max_depth = [int(x) for x in np.linspace(10, 110, num = 11)]
max_depth.append(None)
min_samples_split = [2, 5, 10]
min_samples_leaf = [1, 2, 4]
bootstrap = [True, False]
random_grid = {'n_estimators': n_estimators,
               'max_features': max_features,
               'max_depth': max_depth,
               'min_samples_split': min_samples_split,
               'min_samples_leaf': min_samples_leaf,
               'bootstrap': bootstrap}
```

Train the model over our random grid

[26]:
```
regr = RandomForestRegressor()
regr_random = RandomizedSearchCV(estimator = regr, param_distributions =␣
 ↪random_grid, n_iter = 100, cv = 3, verbose=2, random_state=42, n_jobs = -1)
regr_random.fit(features, labels)
```

```
Fitting 3 folds for each of 100 candidates, totalling 300 fits

/home/mathieu/anaconda3/lib/python3.7/site-
packages/sklearn/model_selection/_split.py:442: DeprecationWarning: `np.int` is
a deprecated alias for the builtin `int`. To silence this warning, use `int` by
itself. Doing this will not modify any behavior and is safe. When replacing
`np.int`, you may wish to use e.g. `np.int64` or `np.int32` to specify the
precision. If you wish to review your current use, check the release note link
for additional information.
Deprecated in NumPy 1.20; for more details and guidance:
https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations
  fold_sizes = np.full(n_splits, n_samples // n_splits, dtype=np.int)
/home/mathieu/anaconda3/lib/python3.7/site-
packages/sklearn/model_selection/_split.py:102: DeprecationWarning: `np.bool` is
```

```
a deprecated alias for the builtin `bool`. To silence this warning, use `bool`
by itself. Doing this will not modify any behavior and is safe. If you
specifically wanted the numpy scalar type, use `np.bool_` here.
Deprecated in NumPy 1.20; for more details and guidance:
https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations
  test_mask = np.zeros(_num_samples(X), dtype=np.bool)
/home/mathieu/anaconda3/lib/python3.7/site-
packages/sklearn/model_selection/_split.py:102: DeprecationWarning: `np.bool` is
a deprecated alias for the builtin `bool`. To silence this warning, use `bool`
by itself. Doing this will not modify any behavior and is safe. If you
specifically wanted the numpy scalar type, use `np.bool_` here.
Deprecated in NumPy 1.20; for more details and guidance:
https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations
  test_mask = np.zeros(_num_samples(X), dtype=np.bool)
/home/mathieu/anaconda3/lib/python3.7/site-
packages/sklearn/model_selection/_split.py:102: DeprecationWarning: `np.bool` is
a deprecated alias for the builtin `bool`. To silence this warning, use `bool`
by itself. Doing this will not modify any behavior and is safe. If you
specifically wanted the numpy scalar type, use `np.bool_` here.
Deprecated in NumPy 1.20; for more details and guidance:
https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations
  test_mask = np.zeros(_num_samples(X), dtype=np.bool)
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 8 concurrent workers.
[Parallel(n_jobs=-1)]: Done  25 tasks      | elapsed:   56.1s
[Parallel(n_jobs=-1)]: Done 146 tasks      | elapsed:  3.8min
[Parallel(n_jobs=-1)]: Done 300 out of 300 | elapsed:  9.4min finished
/home/mathieu/anaconda3/lib/python3.7/site-
packages/sklearn/model_selection/_search.py:793: DeprecationWarning: `np.int` is
a deprecated alias for the builtin `int`. To silence this warning, use `int` by
itself. Doing this will not modify any behavior and is safe. When replacing
`np.int`, you may wish to use e.g. `np.int64` or `np.int32` to specify the
precision. If you wish to review your current use, check the release note link
for additional information.
Deprecated in NumPy 1.20; for more details and guidance:
https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations
  dtype=np.int)
```

[26]:
```
RandomizedSearchCV(cv=3, error_score='raise-deprecating',
                   estimator=RandomForestRegressor(bootstrap=True,
                                                   criterion='mse',
                                                   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='warn',
                                          n_jobs=None, oob_score=False,
                                          random_sta...
                   param_distributions={'bootstrap': [True, False],
                                        'max_depth': [10, 20, 30, 40, 50, 60,
                                                      70, 80, 90, 100, 110,
                                                      None],
                                        'max_features': ['auto', 'sqrt'],
                                        'min_samples_leaf': [1, 2, 4],
                                        'min_samples_split': [2, 5, 10],
                                        'n_estimators': [200, 400, 600, 800,
                                                         1000, 1200, 1400, 1600,
                                                         1800, 2000]},
                   pre_dispatch='2*n_jobs', random_state=42, refit=True,
                   return_train_score=False, scoring=None, verbose=2)
```

Find the best parameters in the grid

[27]:
```
regr_random.best_params_
```

[27]:
```
{'n_estimators': 600,
 'min_samples_split': 5,
 'min_samples_leaf': 1,
 'max_features': 'auto',
 'max_depth': 80,
 'bootstrap': True}
```

Evaluate the models with the optimal parameters found

[28]:
```
regr = RandomForestRegressor(n_estimators = 600,
 min_samples_split = 5,
 min_samples_leaf = 1,
 max_features = 'auto',
 max_depth = 80,
 bootstrap = True)
regr.fit(features, labels)
```

[28]:
```
RandomForestRegressor(bootstrap=True, criterion='mse', max_depth=80,
                      max_features='auto', max_leaf_nodes=None,
                      min_impurity_decrease=0.0, min_impurity_split=None,
                      min_samples_leaf=1, min_samples_split=5,
                      min_weight_fraction_leaf=0.0, n_estimators=600,
                      n_jobs=None, oob_score=False, random_state=None,
                      verbose=0, warm_start=False)
```

Evaluate the model for the test set

[29]:
```
preds = regr.predict(test_features)
actual = test_labels
```

```
/home/mathieu/anaconda3/lib/python3.7/site-
```

```
packages/sklearn/ensemble/base.py:158: DeprecationWarning: `np.int` is a
deprecated alias for the builtin `int`. To silence this warning, use `int` by
itself. Doing this will not modify any behavior and is safe. When replacing
`np.int`, you may wish to use e.g. `np.int64` or `np.int32` to specify the
precision. If you wish to review your current use, check the release note link
for additional information.
Deprecated in NumPy 1.20; for more details and guidance:
https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations
  dtype=np.int)
```

[30]:
```
tot_sum = 0
for i in range(len(preds)):
    tot_sum += (np.log(preds[i] + 1) - np.log(actual[i] + 1)) ** 2
np.sqrt(tot_sum / len(preds))
```

[30]:
```
0.15025485584369982
```

It turns out that in this case, the RF model did not do better than the neural network

[ ]:
```
```