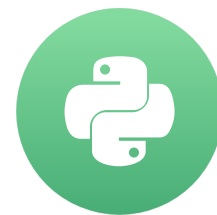


Input data

INTRODUCTION TO TENSORFLOW IN PYTHON



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NUMERIC DATA

price	bedrooms	bathrooms	sqft_living
221900.0	3	1.00	1180
538000.0	3	2.25	2570
180000.0	2	1.00	770
604000.0	4	3.00	1960
510000.0	3	2.00	1680
1225000.0	4	4.50	5420
257500.0	3	2.25	1715
291850.0	3	1.50	1060
229500.0	3	1.00	1780
323000.0	3	2.50	1890
662500.0	3	2.50	3560
468000.0	2	1.00	1160

IMAGE DATA



```
[[164, 161, 159, ..., 79, 87, 131],  
 [161, 162, 164, ..., 98, 117, 146],  
 [147, 151, 151, ..., 155, 165, 167], 93, 137],  
 ..., 123, 152],  
 [178, 172, 176, ..., 178, 175, 123], 172, 174], 91, 135],  
 [ 84, 82, 86, ..., 168, 192, 175], 119, 148],  
 [157, 158, 162, ..., 157, 179, 174]] 180, 128], 165, 167],  
 [ 88, 87, 88, ..., 169, 194, 177],  
 [159, 158, 161, ..., 156, 180, 175]] 176, 122],  
 [ 87, 83, 85, ..., 164, 189, 172],  
 [158, 156, 159, ..., 151, 174, 169]]
```

TEXT DATA

King County is one of three Washington counties that are included in the [Seattle–Tacoma–Bellevue metropolitan statistical area](#). (The others are [Snohomish County](#) to the north, and [Pierce County](#) to the south.) About two-thirds of King County's population lives in Seattle's [suburbs](#).

```
0.0 0.0 0.0 1.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

Importing data for use in TensorFlow

- Data can be imported using `tensorflow`
 - Useful for managing complex pipelines
 - Not necessary for this chapter
- Simpler option used in this chapter
 - Import data using `pandas`
 - Convert data to `numpy` array
 - Use in `tensorflow` without modification

How to import and convert data

```
# Import numpy and pandas
import numpy as np
import pandas as pd

# Load data from csv
housing = pd.read_csv('kc_housing.csv')

# Convert to numpy array
housing = np.array(housing)
```

- We will focus on data stored in csv format in this chapter
- Pandas also has methods for handling data in other formats
 - E.g. `read_json()` , `read_html()` , `read_excel()`

Parameters of read_csv()

Parameter	Description	Default
<code>filepath_or_buffer</code>	Accepts a file path or a URL.	<code>None</code>
<code>sep</code>	Delimiter between columns.	<code>,</code>
<code>delim_whitespace</code>	Boolean for whether to delimit whitespace.	<code>False</code>
<code>encoding</code>	Specifies encoding to be used if any.	<code>None</code>

Using mixed type datasets

date	price	bedrooms
20141013T000000	221900	3
20141209T000000	538000	3
20150225T000000	180000	2
20141209T000000	604000	4
20150218T000000	510000	3
20140627T000000	257500	3
20150115T000000	291850	3
20150415T000000	229500	3

floors	waterfront	view
1	0	0
2	0	0
1	1	0
1	0	0
1	0	2
2	0	0
1	0	4
1	0	0

Setting the data type

```
# Load KC dataset
housing = pd.read_csv('kc_housing.csv')

# Convert price column to float32
price = np.array(housing['price'], np.float32)

# Convert waterfront column to Boolean
waterfront = np.array(housing['waterfront'], np.bool)
```

Setting the data type

```
# Load KC dataset
housing = pd.read_csv('kc_housing.csv')

# Convert price column to float32
price = tf.cast(housing['price'], tf.float32)

# Convert waterfront column to Boolean
waterfront = tf.cast(housing['waterfront'], tf.bool)
```


Let's practice!

INTRODUCTION TO TENSORFLOW IN PYTHON

Loss functions

INTRODUCTION TO TENSORFLOW IN PYTHON



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Economist

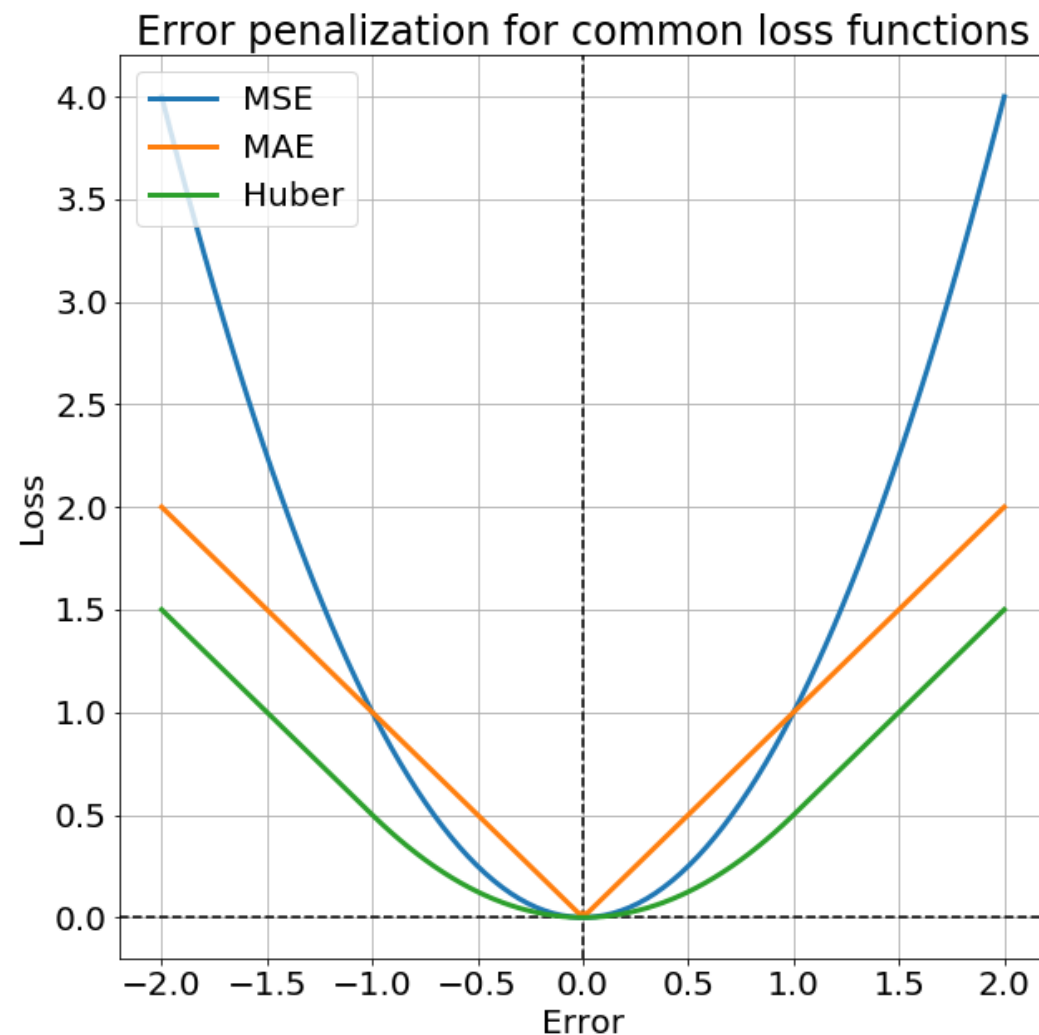
Introduction to loss functions

- Fundamental `tensorflow` operation
 - Used to train a model
 - Measure of model fit
- Higher value -> worse fit
 - Minimize the loss function

Common loss functions in TensorFlow

- TensorFlow has operations for common loss functions
 - Mean squared error (MSE)
 - Mean absolute error (MAE)
 - Huber error
- Loss functions are accessible from `tf.keras.losses()`
 - `tf.keras.losses.mse()`
 - `tf.keras.losses.mae()`
 - `tf.keras.losses.Huber()`

Why do we care about loss functions?



- **MSE**
 - Strongly penalizes outliers
 - High (gradient) sensitivity near minimum
- **MAE**
 - Scales linearly with size of error
 - Low sensitivity near minimum
- **Huber**
 - Similar to MSE near minimum
 - Similar to MAE away from minimum

Defining a loss function

```
# Import TensorFlow under standard alias
import tensorflow as tf

# Compute the MSE loss
loss = tf.keras.losses.mse(targets, predictions)
```

Defining a loss function

```
# Define a linear regression model
```

```
def linear_regression(intercept, slope = slope, features = features):  
    return intercept + features*slope
```

```
# Define a loss function to compute the MSE
```

```
def loss_function(intercept, slope, targets = targets, features = features):  
    # Compute the predictions for a linear model  
    predictions = linear_regression(intercept, slope)  
  
    # Return the loss  
    return tf.keras.losses.mse(targets, predictions)
```

Defining the loss function

```
# Compute the loss for test data inputs  
loss_function(intercept, slope, test_targets, test_features)
```

```
10.77
```

```
# Compute the loss for default data inputs  
loss_function(intercept, slope)
```

```
5.43
```


Let's practice!

INTRODUCTION TO TENSORFLOW IN PYTHON

Linear regression

INTRODUCTION TO TENSORFLOW IN PYTHON

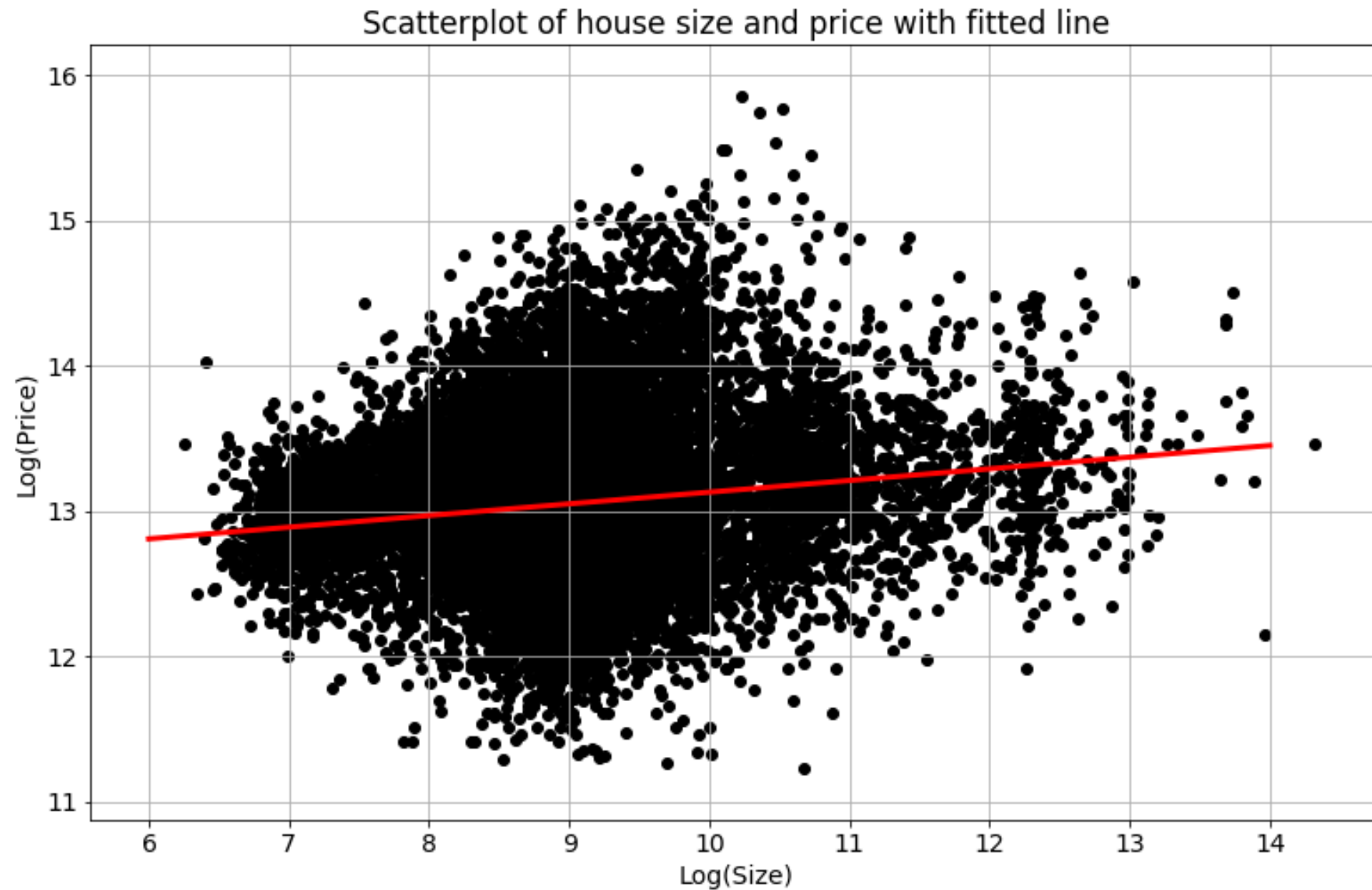


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What is a linear regression?



What is a linear regression?



The linear regression model

- A linear regression model assumes a linear relationship:
 - $price = intercept + size * slope + error$
- This is an example of a univariate regression.
 - There is only one feature, `size`.
- Multiple regression models have more than one feature.
 - E.g. `size` and `location`

Linear regression in TensorFlow

```
# Define the targets and features
price = np.array(housing['price'], np.float32)
size = np.array(housing['sqft_living'], np.float32)

# Define the intercept and slope
intercept = tf.Variable(0.1, np.float32)
slope = tf.Variable(0.1, np.float32)
```

```
# Define a linear regression model
def linear_regression(intercept, slope, features = size):
    return intercept + features*slope
```

```
# Compute the predicted values and loss
def loss_function(intercept, slope, targets = price, features = size):
    predictions = linear_regression(intercept, slope)
    return tf.keras.losses.mse(targets, predictions)
```

Linear regression in TensorFlow

```
# Define an optimization operation
opt = tf.keras.optimizers.Adam()
```

```
# Minimize the loss function and print the loss
for j in range(1000):
    opt.minimize(lambda: loss_function(intercept, slope), \
var_list=[intercept, slope])
    print(loss_function(intercept, slope))
```

```
tf.Tensor(10.909373, shape=(), dtype=float32)
...
tf.Tensor(0.15479447, shape=(), dtype=float32)
```

```
# Print the trained parameters
print(intercept.numpy(), slope.numpy())
```

Let's practice!

INTRODUCTION TO TENSORFLOW IN PYTHON

Batch training

INTRODUCTION TO TENSORFLOW IN PYTHON



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What is batch training?

price	sqft_lot	bedrooms
221900.0	5650	3
538000.0	7242	3
180000.0	10000	2
604000.0	5000	4
510000.0	8080	3
1225000.0	101930	4
257500.0	6819	3
291850.0	9711	3
229500.0	7470	3
323000.0	6560	3
662500.0	9796	3
468000.0	6000	2
310000.0	19901	3
400000.0	9680	3
530000.0	4850	5

price	sqft_lot	bedrooms
221900.0	5650	3
538000.0	7242	3
180000.0	10000	2
604000.0	5000	4
510000.0	8080	3
1225000.0	101930	4
257500.0	6819	3
291850.0	9711	3
229500.0	7470	3
323000.0	6560	3
662500.0	9796	3
468000.0	6000	2
310000.0	19901	3
400000.0	9680	3
530000.0	4850	5

Batch 1

Batch 2

Batch 3

The chunksize parameter

- `pd.read_csv()` allows us to load data in batches
 - Avoid loading entire dataset
 - `chunksize` parameter provides batch size

```
# Import pandas and numpy
import pandas as pd
import numpy as np

# Load data in batches
for batch in pd.read_csv('kc_housing.csv', chunksize=100):
    # Extract price column
    price = np.array(batch['price'], np.float32)

    # Extract size column
    size = np.array(batch['size'], np.float32)
```

Training a linear model in batches

```
# Import tensorflow, pandas, and numpy
import tensorflow as tf
import pandas as pd
import numpy as np
```

```
# Define trainable variables
intercept = tf.Variable(0.1, tf.float32)
slope = tf.Variable(0.1, tf.float32)
```

```
# Define the model
def linear_regression(intercept, slope, features):
    return intercept + features*slope
```

Training a linear model in batches

```
# Compute predicted values and return loss function
def loss_function(intercept, slope, targets, features):
    predictions = linear_regression(intercept, slope, features)
    return tf.keras.losses.mse(targets, predictions)
```

```
# Define optimization operation
opt = tf.keras.optimizers.Adam()
```

Training a linear model in batches

```
# Load the data in batches from pandas
for batch in pd.read_csv('kc_housing.csv', chunksize=100):
    # Extract the target and feature columns
    price_batch = np.array(batch['price'], np.float32)
    size_batch = np.array(batch['lot_size'], np.float32)

    # Minimize the loss function
    opt.minimize(lambda: loss_function(intercept, slope, price_batch, size_batch),
                  var_list=[intercept, slope])

# Print parameter values
print(intercept.numpy(), slope.numpy())
```

Full sample versus batch training

- **Full Sample**
 1. One update per epoch
 2. Accepts dataset without modification
 3. Limited by memory
- **Batch Training**
 1. Multiple updates per epoch
 2. Requires division of dataset
 3. No limit on dataset size

Let's practice!

INTRODUCTION TO TENSORFLOW IN PYTHON