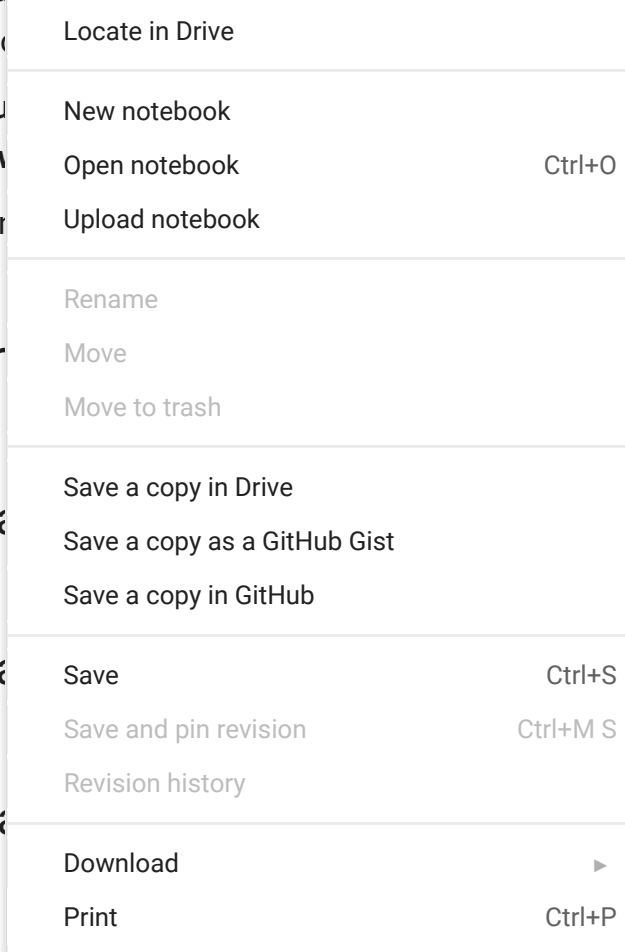This is a companion notebook for the book [Deep Learning with Python, Second Edition](). For readability, it only contains runnable code blocks and section titles, and omits everything else in the book.

If you recommend reading the notebook side by side

side

This

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▾ Intr   orFlow

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Kera   ory

▾ Setting up a deep-learning workspace

Jupyter notebooks: The preferred way to run deep-learning experiments

▾ Using Colaboratory

First steps with Colaboratory

Installing packages with pip

Using the GPU runtime

▾ First steps with TensorFlow

▾ Constant tensors and variables

All-ones or all-zeros tensors

```
import tensorflow as tf
x = tf.ones(shape=(2, 1))
print(x)
```

```
x = tf.zeros(shape=(2, 1))
print(x)
```

Random tensors

```
x = tf.random.normal(shape=(3, 1), mean=0., stddev=1.)
print(x)
```

```
x = tf.random.uniform(shape=(3, 1), minval=0., maxval=1.)
print(x)
```

NumPy arrays are assignable

```
import numpy as np
x = np.ones(shape=(2, 2))
x[0, 0] = 0.
```

Creating a TensorFlow variable

```
v = tf.Variable(initial_value=tf.random.normal(shape=(3, 1)))
print(v)
```

Assigning a value to a TensorFlow variable

```
v.assign(tf.ones((3, 1)))
```

Assigning a value to a subset of a TensorFlow variable

```
v[0, 0].assign(3.)
```

Using `assign_add`

```
v.assign_add(tf.ones((3, 1)))
```

▼ Tensor operations: Doing math in TensorFlow

A few basic math operations

```
a = tf.ones((2, 2))
b = tf.square(a)
c = tf.sqrt(a)
d = b + c
e = tf.matmul(a, b)
e *= d
```

▾ A second look at the GradientTape API

Using the `GradientTape`

```
input_var = tf.Variable(initial_value=3.)
with tf.GradientTape() as tape:
    result = tf.square(input_var)
gradient = tape.gradient(result, input_var)
```

Using `GradientTape` with constant tensor inputs

```
input_const = tf.constant(3.)
with tf.GradientTape() as tape:
    tape.watch(input_const)
    result = tf.square(input_const)
gradient = tape.gradient(result, input_const)
```

Using nested gradient tapes to compute second-order gradients

```
time = tf.Variable(0.)
with tf.GradientTape() as outer_tape:
    with tf.GradientTape() as inner_tape:
        position =  4.9 * time ** 2
    speed = inner_tape.gradient(position, time)
acceleration = outer_tape.gradient(speed, time)
```

▾ An end-to-end example: A linear classifier in pure TensorFlow

Generating two classes of random points in a 2D plane

```
num_samples_per_class = 1000
negative_samples = np.random.multivariate_normal(
    mean=[0, 3],
    cov=[[1, 0.5],[0.5, 1]],
```

```
        size=num_samples_per_class)
positive_samples = np.random.multivariate_normal(
        mean=[3, 0],
        cov=[[1, 0.5],[0.5, 1]],
        size=num_samples_per_class)
```

Stacking the two classes into an array with shape (2000, 2)

```
inputs = np.vstack((negative_samples, positive_samples)).astype(np.float32)
```

Generating the corresponding targets (0 and 1)

```
targets = np.vstack((np.zeros((num_samples_per_class, 1), dtype="float32"),
                     np.ones((num_samples_per_class, 1), dtype="float32")))
```

Plotting the two point classes

```
import matplotlib.pyplot as plt
plt.scatter(inputs[:, 0], inputs[:, 1], c=targets[:, 0])
plt.show()
```

Creating the linear classifier variables

```
input_dim = 2
output_dim = 1
W = tf.Variable(initial_value=tf.random.uniform(shape=(input_dim, output_dim)))
b = tf.Variable(initial_value=tf.zeros(shape=(output_dim,)))
```

The forward pass function

```
def model(inputs):
    return tf.matmul(inputs, W) + b
```

The mean squared error loss function

```
def square_loss(targets, predictions):
    per_sample_losses = tf.square(targets - predictions)
    return tf.reduce_mean(per_sample_losses)
```

The training step function

```
learning_rate = 0.1

def training_step(inputs, targets):
```

```
    with tf.GradientTape() as tape:
        predictions = model(inputs)
        loss = square_loss(predictions, targets)
    grad_loss_wrt_W, grad_loss_wrt_b = tape.gradient(loss, [W, b])
    W.assign_sub(grad_loss_wrt_W * learning_rate)
    b.assign_sub(grad_loss_wrt_b * learning_rate)
    return loss
```

The batch training loop

```
for step in range(40):
    loss = training_step(inputs, targets)
    print(f"Loss at step {step}: {loss:.4f}")
```

```
predictions = model(inputs)
plt.scatter(inputs[:, 0], inputs[:, 1], c=predictions[:, 0] > 0.5)
plt.show()
```

```
x = np.linspace(-1, 4, 100)
y = - W[0] /  W[1] * x + (0.5 - b) / W[1]
plt.plot(x, y, "-r")
plt.scatter(inputs[:, 0], inputs[:, 1], c=predictions[:, 0] > 0.5)
```

▾ Anatomy of a neural network: Understanding core Keras APIs

▾ Layers: The building blocks of deep learning

▾ The base Layer class in Keras

A `Dense` layer implemented as a `Layer` subclass

```
from tensorflow import keras

class SimpleDense(keras.layers.Layer):

    def __init__(self, units, activation=None):
        super().__init__()
        self.units = units
        self.activation = activation

    def build(self, input_shape):
        input_dim = input_shape[-1]
        self.W = self.add_weight(shape=(input_dim, self.units),
                                 initializer="random_normal")
        self.b = self.add_weight(shape=(self.units,),
                                 initializer="zeros")
```

```
    def call(self, inputs):
        y = tf.matmul(inputs, self.W) + self.b
        if self.activation is not None:
            y = self.activation(y)
        return y
```

```
my_dense = SimpleDense(units=32, activation=tf.nn.relu)
input_tensor = tf.ones(shape=(2, 784))
output_tensor = my_dense(input_tensor)
print(output_tensor.shape)
```

▾ Automatic shape inference: Building layers on the fly

```
from tensorflow.keras import layers
layer = layers.Dense(32, activation="relu")
```

```
from tensorflow.keras import models
from tensorflow.keras import layers
model = models.Sequential([
    layers.Dense(32, activation="relu"),
    layers.Dense(32)
])
```

```
model = keras.Sequential([
    SimpleDense(32, activation="relu"),
    SimpleDense(64, activation="relu"),
    SimpleDense(32, activation="relu"),
    SimpleDense(10, activation="softmax")
])
```

From layers to models

▾ The "compile" step: Configuring the learning process

```
model = keras.Sequential([keras.layers.Dense(1)])
model.compile(optimizer="rmsprop",
              loss="mean_squared_error",
              metrics=["accuracy"])
```

```
model.compile(optimizer=keras.optimizers.RMSprop(),
              loss=keras.losses.MeanSquaredError(),
              metrics=[keras.metrics.BinaryAccuracy()])
```

Picking a loss function

▾ Understanding the fit() method

Calling `fit()` with NumPy data

```
history = model.fit(
    inputs,
    targets,
    epochs=5,
    batch_size=128
)
```

```
history.history
```

▾ Monitoring loss and metrics on validation data

Using the `validation_data` argument

```
model = keras.Sequential([keras.layers.Dense(1)])
model.compile(optimizer=keras.optimizers.RMSprop(learning_rate=0.1),
              loss=keras.losses.MeanSquaredError(),
              metrics=[keras.metrics.BinaryAccuracy()])

indices_permutation = np.random.permutation(len(inputs))
shuffled_inputs = inputs[indices_permutation]
shuffled_targets = targets[indices_permutation]

num_validation_samples = int(0.3 * len(inputs))
val_inputs = shuffled_inputs[:num_validation_samples]
val_targets = shuffled_targets[:num_validation_samples]
training_inputs = shuffled_inputs[num_validation_samples:]
training_targets = shuffled_targets[num_validation_samples:]
model.fit(
    training_inputs,
    training_targets,
    epochs=5,
    batch_size=16,
    validation_data=(val_inputs, val_targets)
)
```

▾ Inference: Using a model after training

```
predictions = model.predict(val_inputs, batch_size=128)
print(predictions[:10])
```

Summary

Summary