worksheet_22

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1 Worksheet 22

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1.0.1 Topics

- Neural Networks

1.1 Neural Networks

Nothing to do in this worksheet except follow along in lecture / use this code to better understand Neural Networks.

[4]:
```
import math as m
import numpy as np
import matplotlib.pyplot as plt
import sklearn.datasets as datasets
from tensorflow import keras, math, random, stack
from tensorflow.keras import layers, initializers
from tensorflow.keras.activations import relu

#       x[0] --- h1
#            \ /   \
#             X      output
#            / \   /
#       x[1] --- h2
#
# This is the base model - nothing fancy here

# Set random seed for reproducibility
np.random.seed(1)
random.set_seed(1)

# Data generation - don't modify
centers = [[0, 0]]
t, _ = datasets.make_blobs(n_samples=200, centers=centers, cluster_std=1,
                           random_state=1)

colors = np.array([x for x in 'bgrcmyk'])
```

```
colors = np.hstack([colors] * 20)

# CIRCLE
def generate_circle_data(t):
    # create some space between the classes
    X = np.array(list(filter(lambda x : (x[0] - centers[0][0])**2 + (x[1] -␣
 ↪centers[0][1])**2 < 1 or (x[0] - centers[0][0])**2 + (x[1] -␣
 ↪centers[0][1])**2 > 1.5, t)))
    Y = np.array([1 if (x[0] - centers[0][0])**2 + (x[1] - centers[0][1])**2 >=␣
 ↪1 else 0 for x in X])
    return X, Y

# LINE
def generate_line_data(t):
    # create some space between the classes
    X = np.array(list(filter(lambda x : x[0] - x[1] < -.5 or x[0] - x[1] > .5,␣
 ↪t)))
    Y = np.array([1 if x[0] - x[1] >= 0 else 0 for x in X])
    return X, Y

# CURVE
def generate_curve_data(t):
    # create some space between the classes
    X = np.array(list(filter(lambda x : m.cos(4*x[0]) - x[1] < -.5 or m.
 ↪cos(4*x[0]) - x[1] > .5, t)))
    Y = np.array([1 if m.cos(4*x[0]) - x[1] >= 0 else 0 for x in X])
    return X, Y

# XOR
def generate_xor_data():
    X = np.array([
        [0,0],
        [0,1],
        [1,0],
        [1,1]])
    Y = np.array([x[0]^x[1] for x in X])
    return X, Y

PLOT_HIDDEN_LAYER_2D = False
PLOT_HIDDEN_LAYER_3D = True

# The model - modify this
model = keras.models.Sequential()
model.add(layers.Dense(3, input_dim=2, activation="sigmoid"))
model.add(layers.Dense(1, activation="sigmoid"))
model.compile(loss="binary_crossentropy")
```

```
# X, Y = generate_circle_data(t)
# X, Y = generate_line_data(t)
# X, Y = generate_curve_data(t)
X, Y = generate_xor_data()

# plot the data
plt.scatter(X[:,0],X[:,1],color=colors[Y].tolist(), s=100, alpha=.9)
plt.show()

history = model.fit(X, Y, batch_size=1, epochs=1000)

if PLOT_HIDDEN_LAYER_2D:
    # Show the transformation of the input at the first hidden layer
    layer = model.layers[0]
    print(layer.get_config(), layer.get_weights())
    keras_function = keras.backend.function([model.input], [layer.output])
    layerVals = np.array(keras_function(X))[0]
    plt.scatter(layerVals[:,0], layerVals[:, 1], color=colors[Y].tolist(),␣
 ↪s=100, alpha=.9)
    plt.show()

    # create a mesh to plot in
    h = .02  # step size in the mesh
    x_min, x_max = layerVals[:, 0].min() - .5, layerVals[:, 0].max() + 1
    y_min, y_max = layerVals[:, 1].min() - .5, layerVals[:, 1].max() + 1
    xx, yy = np.meshgrid(np.arange(x_min, x_max, h),
                         np.arange(y_min, y_max, h))
    meshData = np.c_[xx.ravel(), yy.ravel()]

    # Plot the decision boundary. For that, we will assign a color to each
    # point in the mesh
    fig, ax = plt.subplots()
    layer = model.layers[-1]

    intermediateModel = keras.models.Sequential()
    intermediateModel.add(layers.Dense(1, input_dim=2, activation="sigmoid"))
    intermediateModel.compile(loss="binary_crossentropy")
    intermediateModel.layers[0].set_weights(layer.get_weights())

    Z = intermediateModel.predict(meshData)
    Z = np.array([0 if x < .5 else 1 for x in Z])
    Z = Z.reshape(xx.shape)
    ax.contourf(xx, yy, Z, alpha=.3, cmap=plt.cm.Paired)

    T = intermediateModel.predict(layerVals)
    T = np.array([0 if x < .5 else 1 for x in T])
    T = T.reshape(layerVals[:, 0].shape)
```

```
    ax.scatter(layerVals[:, 0], layerVals[:, 1], color=colors[T].tolist(),␣
 ↪s=100, alpha=.9)
    ax.set_xlabel("h0")
    ax.set_ylabel("h1")
    plt.show()

if PLOT_HIDDEN_LAYER_3D:
    # Show the transformation of the input at the first hidden layer
    layer = model.layers[0]
    print(layer.get_config(), layer.get_weights())
    keras_function = keras.backend.function([model.input], [layer.output])
    layerVals = np.array(keras_function(X))[0]
    fig = plt.figure()
    ax = fig.add_subplot(111, projection='3d')
    ax.scatter(layerVals[:,0], layerVals[:, 1], layerVals[:, 2],␣
 ↪color=colors[Y].tolist(), s=100, alpha=.9)
    plt.show()

    # create a mesh to plot in
    h = .1  # step size in the mesh
    x_min, x_max = layerVals[:, 0].min() - .5, layerVals[:, 0].max() + 1
    y_min, y_max = layerVals[:, 1].min() - .5, layerVals[:, 1].max() + 1
    xx, yy = np.meshgrid(np.arange(x_min, x_max, h),
                         np.arange(y_min, y_max, h))
    meshData = np.c_[xx.ravel(), yy.ravel(), np.zeros(len(xx.ravel()))]

    # Plot the decision boundary. For that, we will assign a color to each
    # point in the mesh
    fig, ax = plt.subplots()
    layer = model.layers[-1]

    intermediateModel = keras.models.Sequential()
    intermediateModel.add(layers.Dense(1, input_dim=3, activation="sigmoid"))
    intermediateModel.compile(loss="binary_crossentropy")
    intermediateModel.layers[0].set_weights(layer.get_weights())

    Z = intermediateModel.predict(meshData)
    Z = np.array([0 if x < .5 else 1 for x in Z])
    Z = Z.reshape(xx.shape)
    ax.contourf(xx, yy, Z, alpha=.3, cmap=plt.cm.Paired) # plot in 2D
    ax.axis('off')

    T = intermediateModel.predict(layerVals)
    T = np.array([0 if x < .5 else 1 for x in T])
    T = T.reshape(layerVals[:, 0].shape)
    ax.scatter(layerVals[:, 0], layerVals[:, 1], color=colors[T].tolist(),␣
 ↪s=100, alpha=.9) # plot in 2D
```

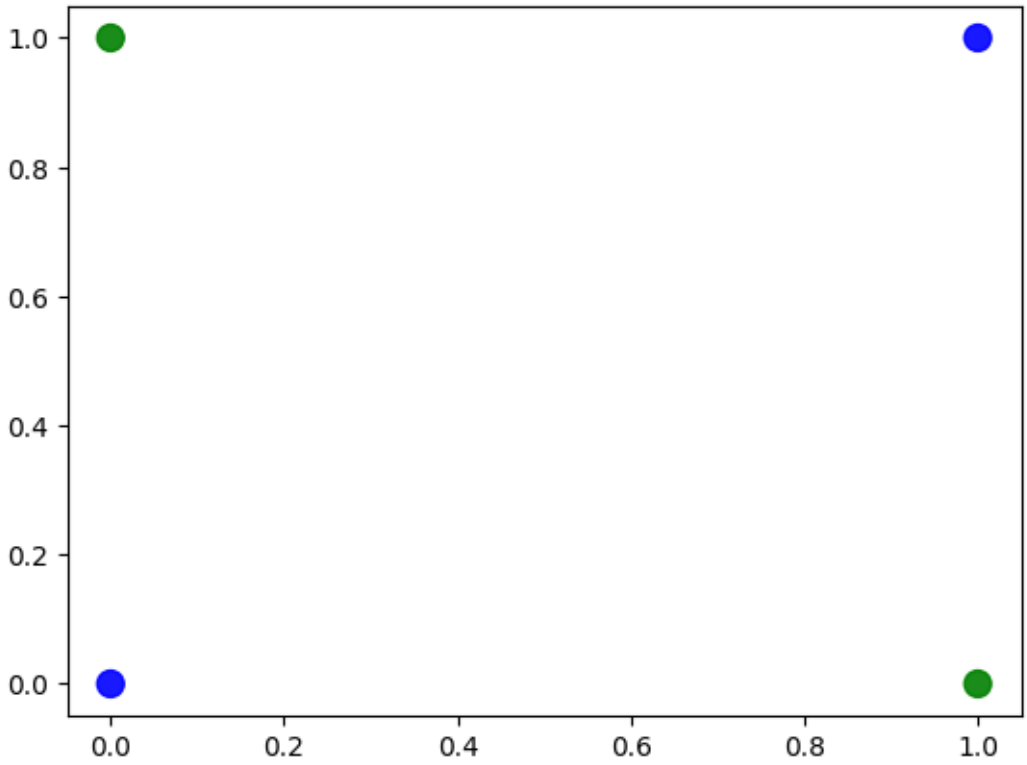
```
    plt.show()

# Plot the decision boundary

# create a mesh to plot in
h = .02  # step size in the mesh
x_min, x_max = X[:, 0].min() - .5, X[:, 0].max() + 1
y_min, y_max = X[:, 1].min() - .5, X[:, 1].max() + 1
xx, yy = np.meshgrid(np.arange(x_min, x_max, h),
                     np.arange(y_min, y_max, h))
meshData = np.c_[xx.ravel(), yy.ravel()]

fig, ax = plt.subplots()
Z = model.predict(meshData)
Z = np.array([0 if x < .5 else 1 for x in Z])
Z = Z.reshape(xx.shape)
ax.contourf(xx, yy, Z, alpha=.3, cmap=plt.cm.Paired)
ax.axis('off')

# Plot also the training points
T = model.predict(X)
T = np.array([0 if x < .5 else 1 for x in T])
T = T.reshape(X[:,0].shape)
ax.scatter(X[:, 0], X[:, 1], color=colors[T].tolist(), s=100, alpha=.9)
plt.title("Decision Boundary")
plt.show()
```

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Epoch 1/1000
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Epoch 11/1000
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Epoch 732/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6954
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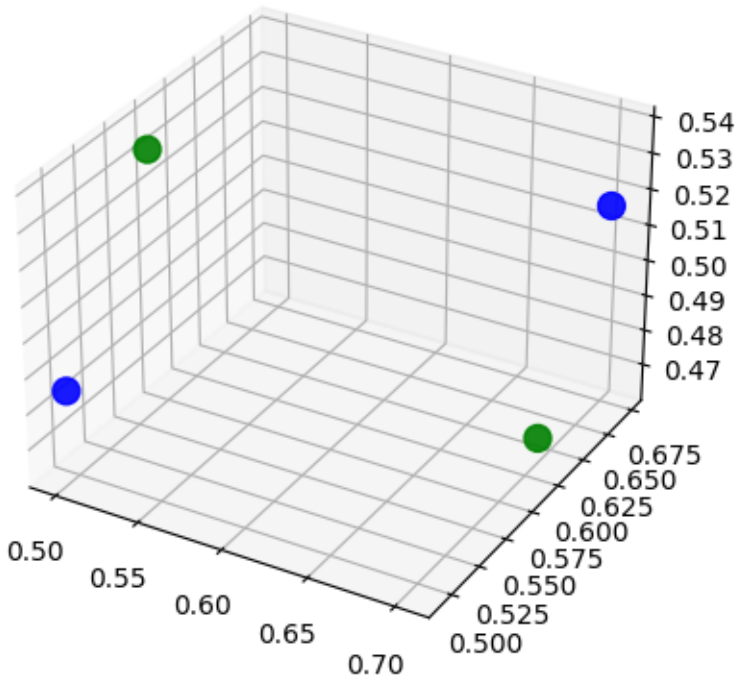
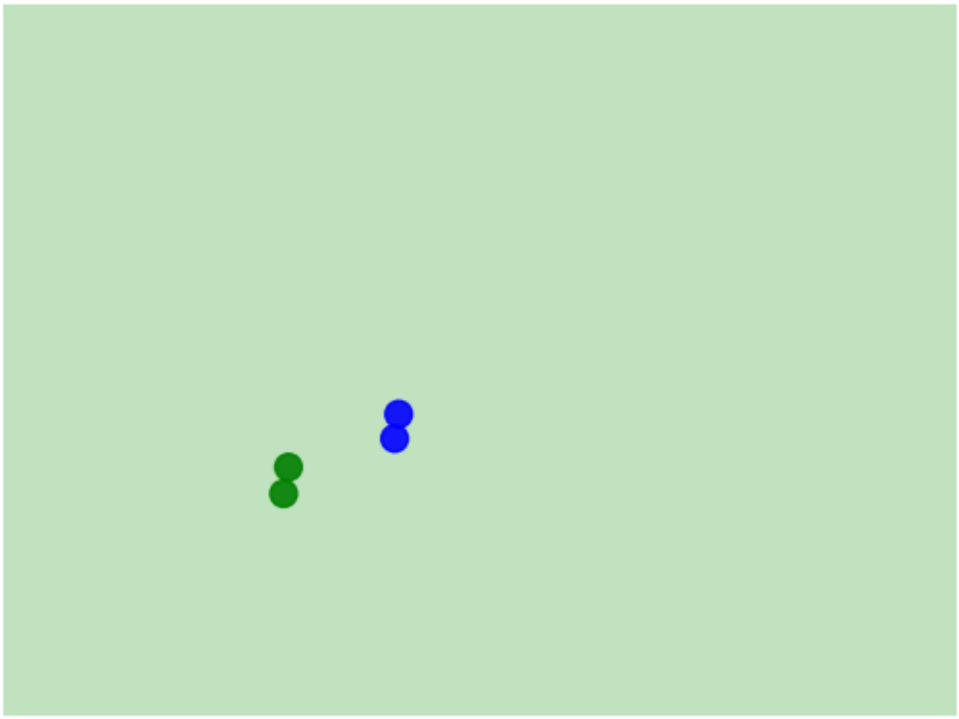
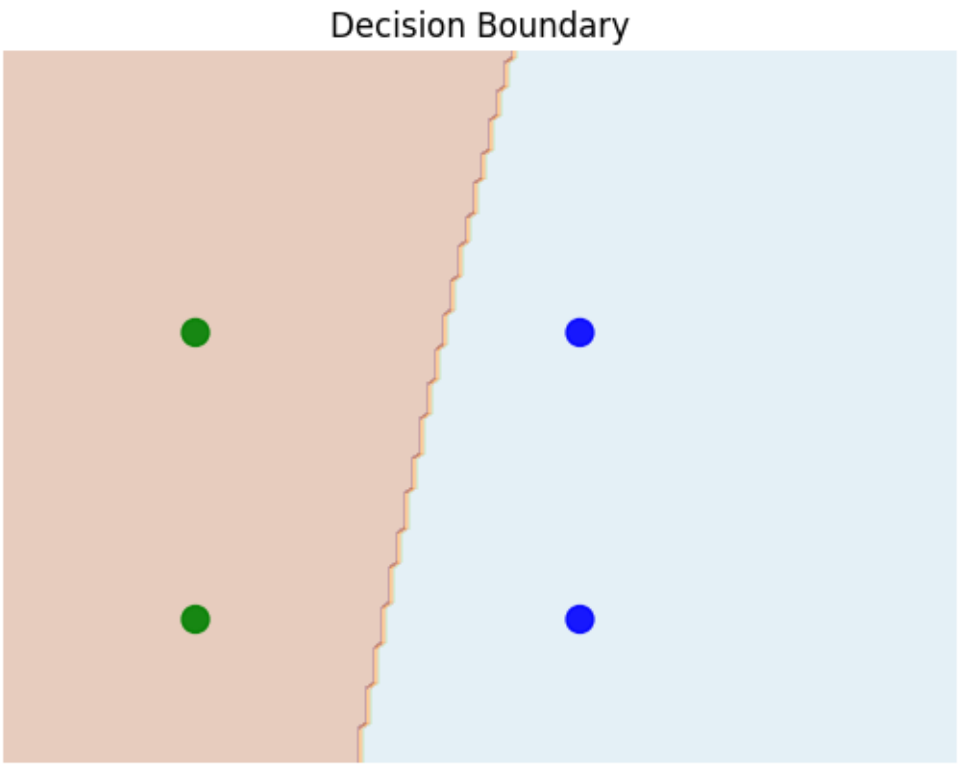
Epoch 1000/1000
4/4 [==============================] - 0s 3ms/step - loss: 0.6950
{'name': 'dense_3', 'trainable': True, 'dtype': 'float32', 'batch_input_shape':
(None, 2), 'units': 3, 'activation': 'sigmoid', 'use_bias': True,
'kernel_initializer': {'module': 'keras.initializers', 'class_name':
'GlorotUniform', 'config': {'seed': None}, 'registered_name': None},
'bias_initializer': {'module': 'keras.initializers', 'class_name': 'Zeros',
'config': {}, 'registered_name': None}, 'kernel_regularizer': None,
'bias_regularizer': None, 'activity_regularizer': None, 'kernel_constraint':
None, 'bias_constraint': None} [array([[ 0.8367641 ,  0.5053533 , -0.08252378],
       [ 0.03439252,  0.23976038,  0.20824854]], dtype=float32),
array([-0.00356962, -0.02803187, -0.05872077], dtype=float32)]
```




```
10/10 [==============================] - 0s 2ms/step
1/1 [==============================] - 0s 22ms/step
```



```
489/489 [==============================] - 1s 1ms/step
1/1 [==============================] - 0s 60ms/step
```



[1]:
```
pip install numpy matplotlib scikit-learn tensorflow
```

```
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages
(1.25.2)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.10/dist-
packages (3.7.1)
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.10/dist-
packages (1.2.2)
Requirement already satisfied: tensorflow in /usr/local/lib/python3.10/dist-
packages (2.15.0)
Requirement already satisfied: contourpy>=1.0.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (1.2.1)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.10/dist-
packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (4.51.0)
Requirement already satisfied: kiwisolver>=1.0.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (1.4.5)
Requirement already satisfied: packaging>=20.0 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (24.0)
Requirement already satisfied: pillow>=6.2.0 in /usr/local/lib/python3.10/dist-
packages (from matplotlib) (9.4.0)
```

```
Requirement already satisfied: pyparsing>=2.3.1 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (3.1.2)
Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/lib/python3.10/dist-packages (from matplotlib) (2.8.2)
Requirement already satisfied: scipy>=1.3.2 in /usr/local/lib/python3.10/dist-
packages (from scikit-learn) (1.11.4)
Requirement already satisfied: joblib>=1.1.1 in /usr/local/lib/python3.10/dist-
packages (from scikit-learn) (1.4.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in
/usr/local/lib/python3.10/dist-packages (from scikit-learn) (3.4.0)
Requirement already satisfied: absl-py>=1.0.0 in /usr/local/lib/python3.10/dist-
packages (from tensorflow) (1.4.0)
Requirement already satisfied: astunparse>=1.6.0 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (24.3.25)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (0.5.4)
Requirement already satisfied: google-pasta>=0.1.1 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (0.2.0)
Requirement already satisfied: h5py>=2.9.0 in /usr/local/lib/python3.10/dist-
packages (from tensorflow) (3.9.0)
Requirement already satisfied: libclang>=13.0.0 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (18.1.1)
Requirement already satisfied: ml-dtypes~=0.2.0 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (0.2.0)
Requirement already satisfied: opt-einsum>=2.3.2 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (3.3.0)
Requirement already satisfied:
protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3
in /usr/local/lib/python3.10/dist-packages (from tensorflow) (3.20.3)
Requirement already satisfied: setuptools in /usr/local/lib/python3.10/dist-
packages (from tensorflow) (67.7.2)
Requirement already satisfied: six>=1.12.0 in /usr/local/lib/python3.10/dist-
packages (from tensorflow) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (2.4.0)
Requirement already satisfied: typing-extensions>=3.6.6 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (4.11.0)
Requirement already satisfied: wrapt<1.15,>=1.11.0 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (1.14.1)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (0.36.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (1.62.2)
Requirement already satisfied: tensorboard<2.16,>=2.15 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (2.15.2)
Requirement already satisfied: tensorflow-estimator<2.16,>=2.15.0 in
```

```
/usr/local/lib/python3.10/dist-packages (from tensorflow) (2.15.0)
Requirement already satisfied: keras<2.16,>=2.15.0 in
/usr/local/lib/python3.10/dist-packages (from tensorflow) (2.15.0)
Requirement already satisfied: wheel<1.0,>=0.23.0 in
/usr/local/lib/python3.10/dist-packages (from astunparse>=1.6.0->tensorflow)
(0.43.0)
Requirement already satisfied: google-auth<3,>=1.6.3 in
/usr/local/lib/python3.10/dist-packages (from
tensorboard<2.16,>=2.15->tensorflow) (2.27.0)
Requirement already satisfied: google-auth-oauthlib<2,>=0.5 in
/usr/local/lib/python3.10/dist-packages (from
tensorboard<2.16,>=2.15->tensorflow) (1.2.0)
Requirement already satisfied: markdown>=2.6.8 in
/usr/local/lib/python3.10/dist-packages (from
tensorboard<2.16,>=2.15->tensorflow) (3.6)
Requirement already satisfied: requests<3,>=2.21.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorboard<2.16,>=2.15->tensorflow) (2.31.0)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in
/usr/local/lib/python3.10/dist-packages (from
tensorboard<2.16,>=2.15->tensorflow) (0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in
/usr/local/lib/python3.10/dist-packages (from
tensorboard<2.16,>=2.15->tensorflow) (3.0.2)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in
/usr/local/lib/python3.10/dist-packages (from google-
auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow) (5.3.3)
Requirement already satisfied: pyasn1-modules>=0.2.1 in
/usr/local/lib/python3.10/dist-packages (from google-
auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow) (0.4.0)
Requirement already satisfied: rsa<5,>=3.1.4 in /usr/local/lib/python3.10/dist-
packages (from google-auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow) (4.9)
Requirement already satisfied: requests-oauthlib>=0.7.0 in
/usr/local/lib/python3.10/dist-packages (from google-auth-
oauthlib<2,>=0.5->tensorboard<2.16,>=2.15->tensorflow) (1.3.1)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from
requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-
packages (from requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.10/dist-packages (from
requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from
requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow) (2024.2.2)
Requirement already satisfied: MarkupSafe>=2.1.1 in
/usr/local/lib/python3.10/dist-packages (from
```

```
werkzeug>=1.0.1->tensorboard<2.16,>=2.15->tensorflow) (2.1.5)
Requirement already satisfied: pyasn1<0.7.0,>=0.4.6 in
/usr/local/lib/python3.10/dist-packages (from pyasn1-modules>=0.2.1->google-
auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow) (0.6.0)
Requirement already satisfied: oauthlib>=3.0.0 in
/usr/local/lib/python3.10/dist-packages (from requests-oauthlib>=0.7.0->google-
auth-oauthlib<2,>=0.5->tensorboard<2.16,>=2.15->tensorflow) (3.2.2)
```