KNN

June 22, 2021

1 Künstliche Neuronale Netze

2 mit Tensorflow / Keras

2.1 Beispiel 1: XOR-Verknüpfung

Mit Hilfe eines KNNs soll die XOR-Verknüpfung nachgebildet werden:

X1	X2	y
0	0	0
0	1	1
1	0	1
1	1	0

[1]:
```
import numpy as np
from tensorflow.keras.optimizers import *
from tensorflow.keras.models import *
from tensorflow.keras.layers import *
from tensorflow.keras.losses import *
from tensorflow.keras.utils import *
```

[2]:
```
# Daten
X = [[0,0],[0,1],[1,0],[1,1] ]
y = [[0],  [1],  [1],  [0]]
```

[3]:
```
model = Sequential()
model.add(Dense(8, input_dim=2)) # Input-Layer
model.add(Activation("relu"))

model.add(Dense(10)) # Hidden-Layer
model.add(Activation("tanh"))

model.add(Dense(10)) # Hidden-Layer
model.add(Activation("tanh"))

model.add(Dense(1)) # Output-Layer
model.add(Activation("sigmoid"))
```

```python
sgd = SGD(lr=0.1) # Stochastic Gradient Descent
model.compile(loss="binary_crossentropy", optimizer=sgd, metrics="accuracy")
model.fit(X,y, epochs=100)
```

```
Epoch 1/100
1/1 [==============================] - 0s 975us/step - loss: 0.6604 - accuracy:
0.7500
Epoch 2/100
1/1 [==============================] - 0s 1ms/step - loss: 0.6563 - accuracy:
0.7500
Epoch 3/100
1/1 [==============================] - 0s 999us/step - loss: 0.6522 - accuracy:
0.7500
Epoch 4/100
1/1 [==============================] - 0s 0s/step - loss: 0.6481 - accuracy:
0.7500
Epoch 5/100
1/1 [==============================] - 0s 1ms/step - loss: 0.6439 - accuracy:
0.7500
Epoch 6/100
1/1 [==============================] - 0s 999us/step - loss: 0.6397 - accuracy:
0.7500
Epoch 7/100
1/1 [==============================] - 0s 999us/step - loss: 0.6354 - accuracy:
0.7500
Epoch 8/100
1/1 [==============================] - 0s 1000us/step - loss: 0.6309 - accuracy:
0.7500
Epoch 9/100
1/1 [==============================] - 0s 0s/step - loss: 0.6263 - accuracy:
0.7500
Epoch 10/100
1/1 [==============================] - 0s 999us/step - loss: 0.6216 - accuracy:
0.7500
Epoch 11/100
1/1 [==============================] - 0s 1ms/step - loss: 0.6168 - accuracy:
1.0000
Epoch 12/100
1/1 [==============================] - 0s 999us/step - loss: 0.6118 - accuracy:
1.0000
Epoch 13/100
1/1 [==============================] - 0s 1ms/step - loss: 0.6066 - accuracy:
1.0000
Epoch 14/100
1/1 [==============================] - 0s 1000us/step - loss: 0.6011 - accuracy:
1.0000
```

```
Epoch 15/100
1/1 [==============================] - 0s 1000us/step - loss: 0.5955 - accuracy:
1.0000
Epoch 16/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5896 - accuracy:
1.0000
Epoch 17/100
1/1 [==============================] - 0s 989us/step - loss: 0.5835 - accuracy:
1.0000
Epoch 18/100
1/1 [==============================] - 0s 0s/step - loss: 0.5772 - accuracy:
1.0000
Epoch 19/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5706 - accuracy:
1.0000
Epoch 20/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5647 - accuracy:
1.0000
Epoch 21/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5586 - accuracy:
1.0000
Epoch 22/100
1/1 [==============================] - 0s 0s/step - loss: 0.5519 - accuracy:
1.0000
Epoch 23/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5463 - accuracy:
1.0000
Epoch 24/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5385 - accuracy:
1.0000
Epoch 25/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5328 - accuracy:
1.0000
Epoch 26/100
1/1 [==============================] - 0s 997us/step - loss: 0.5246 - accuracy:
1.0000
Epoch 27/100
1/1 [==============================] - 0s 1000us/step - loss: 0.5184 - accuracy:
1.0000
Epoch 28/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5099 - accuracy:
1.0000
Epoch 29/100
1/1 [==============================] - 0s 1ms/step - loss: 0.5023 - accuracy:
1.0000
Epoch 30/100
1/1 [==============================] - 0s 0s/step - loss: 0.4948 - accuracy:
1.0000
```

```
Epoch 31/100
1/1 [==============================] - 0s 1000us/step - loss: 0.4854 - accuracy:
1.0000
Epoch 32/100
1/1 [==============================] - 0s 1ms/step - loss: 0.4779 - accuracy:
1.0000
Epoch 33/100
1/1 [==============================] - 0s 0s/step - loss: 0.4681 - accuracy:
1.0000
Epoch 34/100
1/1 [==============================] - 0s 1ms/step - loss: 0.4598 - accuracy:
1.0000
Epoch 35/100
1/1 [==============================] - 0s 999us/step - loss: 0.4495 - accuracy:
1.0000
Epoch 36/100
1/1 [==============================] - 0s 0s/step - loss: 0.4416 - accuracy:
1.0000
Epoch 37/100
1/1 [==============================] - 0s 999us/step - loss: 0.4299 - accuracy:
1.0000
Epoch 38/100
1/1 [==============================] - 0s 999us/step - loss: 0.4223 - accuracy:
1.0000
Epoch 39/100
1/1 [==============================] - 0s 0s/step - loss: 0.4105 - accuracy:
1.0000
Epoch 40/100
1/1 [==============================] - 0s 0s/step - loss: 0.4013 - accuracy:
1.0000
Epoch 41/100
1/1 [==============================] - 0s 1ms/step - loss: 0.3897 - accuracy:
1.0000
Epoch 42/100
1/1 [==============================] - 0s 1ms/step - loss: 0.3804 - accuracy:
1.0000
Epoch 43/100
1/1 [==============================] - 0s 1ms/step - loss: 0.3696 - accuracy:
1.0000
Epoch 44/100
1/1 [==============================] - 0s 998us/step - loss: 0.3575 - accuracy:
1.0000
Epoch 45/100
1/1 [==============================] - 0s 997us/step - loss: 0.3506 - accuracy:
1.0000
Epoch 46/100
1/1 [==============================] - 0s 999us/step - loss: 0.3365 - accuracy:
1.0000
```

```
Epoch 47/100
1/1 [==============================] - 0s 1ms/step - loss: 0.3252 - accuracy:
1.0000
Epoch 48/100
1/1 [==============================] - 0s 2ms/step - loss: 0.3178 - accuracy:
1.0000
Epoch 49/100
1/1 [==============================] - 0s 1ms/step - loss: 0.3063 - accuracy:
1.0000
Epoch 50/100
1/1 [==============================] - 0s 1ms/step - loss: 0.2947 - accuracy:
1.0000
Epoch 51/100
1/1 [==============================] - 0s 1ms/step - loss: 0.2863 - accuracy:
1.0000
Epoch 52/100
1/1 [==============================] - 0s 998us/step - loss: 0.2754 - accuracy:
1.0000
Epoch 53/100
1/1 [==============================] - 0s 1000us/step - loss: 0.2666 - accuracy:
1.0000
Epoch 54/100
1/1 [==============================] - 0s 998us/step - loss: 0.2543 - accuracy:
1.0000
Epoch 55/100
1/1 [==============================] - 0s 0s/step - loss: 0.2488 - accuracy:
1.0000
Epoch 56/100
1/1 [==============================] - 0s 1ms/step - loss: 0.2375 - accuracy:
1.0000
Epoch 57/100
1/1 [==============================] - 0s 1ms/step - loss: 0.2287 - accuracy:
1.0000
Epoch 58/100
1/1 [==============================] - 0s 0s/step - loss: 0.2205 - accuracy:
1.0000
Epoch 59/100
1/1 [==============================] - 0s 999us/step - loss: 0.2112 - accuracy:
1.0000
Epoch 60/100
1/1 [==============================] - 0s 0s/step - loss: 0.2050 - accuracy:
1.0000
Epoch 61/100
1/1 [==============================] - 0s 999us/step - loss: 0.1948 - accuracy:
1.0000
Epoch 62/100
1/1 [==============================] - 0s 1000us/step - loss: 0.1891 - accuracy:
1.0000
```

```
Epoch 63/100
1/1 [==============================] - 0s 998us/step - loss: 0.1820 - accuracy:
1.0000
Epoch 64/100
1/1 [==============================] - 0s 0s/step - loss: 0.1739 - accuracy:
1.0000
Epoch 65/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1683 - accuracy:
1.0000
Epoch 66/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1617 - accuracy:
1.0000
Epoch 67/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1567 - accuracy:
1.0000
Epoch 68/100
1/1 [==============================] - 0s 0s/step - loss: 0.1501 - accuracy:
1.0000
Epoch 69/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1454 - accuracy:
1.0000
Epoch 70/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1396 - accuracy:
1.0000
Epoch 71/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1345 - accuracy:
1.0000
Epoch 72/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1306 - accuracy:
1.0000
Epoch 73/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1267 - accuracy:
1.0000
Epoch 74/100
1/1 [==============================] - 0s 999us/step - loss: 0.1209 - accuracy:
1.0000
Epoch 75/100
1/1 [==============================] - 0s 0s/step - loss: 0.1180 - accuracy:
1.0000
Epoch 76/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1138 - accuracy:
1.0000
Epoch 77/100
1/1 [==============================] - 0s 967us/step - loss: 0.1097 - accuracy:
1.0000
Epoch 78/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1068 - accuracy:
1.0000
```

```
Epoch 79/100
1/1 [==============================] - 0s 1000us/step - loss: 0.1027 - accuracy:
1.0000
Epoch 80/100
1/1 [==============================] - 0s 1ms/step - loss: 0.1000 - accuracy:
1.0000
Epoch 81/100
1/1 [==============================] - 0s 967us/step - loss: 0.0967 - accuracy:
1.0000
Epoch 82/100
1/1 [==============================] - 0s 998us/step - loss: 0.0936 - accuracy:
1.0000
Epoch 83/100
1/1 [==============================] - 0s 0s/step - loss: 0.0909 - accuracy:
1.0000
Epoch 84/100
1/1 [==============================] - 0s 0s/step - loss: 0.0883 - accuracy:
1.0000
Epoch 85/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0861 - accuracy:
1.0000
Epoch 86/100
1/1 [==============================] - 0s 998us/step - loss: 0.0832 - accuracy:
1.0000
Epoch 87/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0807 - accuracy:
1.0000
Epoch 88/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0788 - accuracy:
1.0000
Epoch 89/100
1/1 [==============================] - 0s 999us/step - loss: 0.0769 - accuracy:
1.0000
Epoch 90/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0743 - accuracy:
1.0000
Epoch 91/100
1/1 [==============================] - 0s 0s/step - loss: 0.0728 - accuracy:
1.0000
Epoch 92/100
1/1 [==============================] - 0s 1000us/step - loss: 0.0706 - accuracy:
1.0000
Epoch 93/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0687 - accuracy:
1.0000
Epoch 94/100
1/1 [==============================] - 0s 0s/step - loss: 0.0672 - accuracy:
1.0000
```

```
Epoch 95/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0656 - accuracy:
1.0000
Epoch 96/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0639 - accuracy:
1.0000
Epoch 97/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0623 - accuracy:
1.0000
Epoch 98/100
1/1 [==============================] - 0s 1000us/step - loss: 0.0608 - accuracy:
1.0000
Epoch 99/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0594 - accuracy:
1.0000
Epoch 100/100
1/1 [==============================] - 0s 1ms/step - loss: 0.0581 - accuracy:
1.0000
```

[3]:
```
<tensorflow.python.keras.callbacks.History at 0x24ac42d40d0>
```

[4]:
```
(model.predict(X)>0.5).astype(int)
```

[4]:
```
array([[0],
       [1],
       [1],
       [0]])
```

[5]:
```
model.summary()
```

```
Model: "sequential"

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense (Dense)                (None, 8)                 24
_________________________________________________________________
activation (Activation)      (None, 8)                 0
_________________________________________________________________
dense_1 (Dense)              (None, 10)                90
_________________________________________________________________
activation_1 (Activation)    (None, 10)                0
_________________________________________________________________
dense_2 (Dense)              (None, 10)                110
_________________________________________________________________
activation_2 (Activation)    (None, 10)                0
_________________________________________________________________
dense_3 (Dense)              (None, 1)                 11
_________________________________________________________________
```

```
activation_3 (Activation)    (None, 1)                 0
=================================================================
Total params: 235
Trainable params: 235
Non-trainable params: 0
_________________________________________________________________
```

2.2 Beispiel 2: Vorhersage Brustkrebs

[6]:
```python
from sklearn.datasets import load_breast_cancer
from sklearn.model_selection import train_test_split

data = load_breast_cancer()
print(data.DESCR)
```

```
.. _breast_cancer_dataset:

Breast cancer wisconsin (diagnostic) dataset
--------------------------------------------

**Data Set Characteristics:**

    :Number of Instances: 569

    :Number of Attributes: 30 numeric, predictive attributes and the class

    :Attribute Information:
        - radius (mean of distances from center to points on the perimeter)
        - texture (standard deviation of gray-scale values)
        - perimeter
        - area
        - smoothness (local variation in radius lengths)
        - compactness (perimeter^2 / area - 1.0)
        - concavity (severity of concave portions of the contour)
        - concave points (number of concave portions of the contour)
        - symmetry
        - fractal dimension ("coastline approximation" - 1)

        The mean, standard error, and "worst" or largest (mean of the three
        worst/largest values) of these features were computed for each image,
        resulting in 30 features.  For instance, field 0 is Mean Radius, field
        10 is Radius SE, field 20 is Worst Radius.

        - class:
                - WDBC-Malignant
                - WDBC-Benign

    :Summary Statistics:
```

```
===================================== ====== ======
                                       Min    Max
===================================== ====== ======
radius (mean):                        6.981  28.11
texture (mean):                       9.71   39.28
perimeter (mean):                     43.79  188.5
area (mean):                          143.5  2501.0
smoothness (mean):                    0.053  0.163
compactness (mean):                   0.019  0.345
concavity (mean):                     0.0    0.427
concave points (mean):                0.0    0.201
symmetry (mean):                      0.106  0.304
fractal dimension (mean):             0.05   0.097
radius (standard error):              0.112  2.873
texture (standard error):             0.36   4.885
perimeter (standard error):           0.757  21.98
area (standard error):                6.802  542.2
smoothness (standard error):          0.002  0.031
compactness (standard error):         0.002  0.135
concavity (standard error):           0.0    0.396
concave points (standard error):      0.0    0.053
symmetry (standard error):            0.008  0.079
fractal dimension (standard error):   0.001  0.03
radius (worst):                       7.93   36.04
texture (worst):                      12.02  49.54
perimeter (worst):                    50.41  251.2
area (worst):                         185.2  4254.0
smoothness (worst):                   0.071  0.223
compactness (worst):                  0.027  1.058
concavity (worst):                    0.0    1.252
concave points (worst):               0.0    0.291
symmetry (worst):                     0.156  0.664
fractal dimension (worst):            0.055  0.208
===================================== ====== ======

:Missing Attribute Values: None

:Class Distribution: 212 - Malignant, 357 - Benign

:Creator:  Dr. William H. Wolberg, W. Nick Street, Olvi L. Mangasarian

:Donor: Nick Street

:Date: November, 1995
```

```
This is a copy of UCI ML Breast Cancer Wisconsin (Diagnostic) datasets.
https://goo.gl/U2Uwz2
```

```
Features are computed from a digitized image of a fine needle
aspirate (FNA) of a breast mass.  They describe
characteristics of the cell nuclei present in the image.

Separating plane described above was obtained using
Multisurface Method-Tree (MSM-T) [K. P. Bennett, "Decision Tree
Construction Via Linear Programming." Proceedings of the 4th
Midwest Artificial Intelligence and Cognitive Science Society,
pp. 97-101, 1992], a classification method which uses linear
programming to construct a decision tree.  Relevant features
were selected using an exhaustive search in the space of 1-4
features and 1-3 separating planes.

The actual linear program used to obtain the separating plane
in the 3-dimensional space is that described in:
[K. P. Bennett and O. L. Mangasarian: "Robust Linear
Programming Discrimination of Two Linearly Inseparable Sets",
Optimization Methods and Software 1, 1992, 23-34].

This database is also available through the UW CS ftp server:

ftp ftp.cs.wisc.edu
cd math-prog/cpo-dataset/machine-learn/WDBC/

.. topic:: References

   - W.N. Street, W.H. Wolberg and O.L. Mangasarian. Nuclear feature extraction
     for breast tumor diagnosis. IS&T/SPIE 1993 International Symposium on
     Electronic Imaging: Science and Technology, volume 1905, pages 861-870,
     San Jose, CA, 1993.
   - O.L. Mangasarian, W.N. Street and W.H. Wolberg. Breast cancer diagnosis and
     prognosis via linear programming. Operations Research, 43(4), pages
570-577,
     July-August 1995.
   - W.H. Wolberg, W.N. Street, and O.L. Mangasarian. Machine learning
techniques
     to diagnose breast cancer from fine-needle aspirates. Cancer Letters 77
(1994)
     163-171.
```

[7]:
```python
# Aufteilen in Trainings- und Testdaten
X = data.data
y = data.target

X_train, X_test, y_train, y_test = train_test_split(X,y,shuffle=True,
 ↪test_size=0.3)
```

[8]:

```python
# KNN erstellen und trainieren
# Wir verwenden hier "ADAM" als Optimizer (Adaptive moment estimation)
model2 = Sequential()
model2.add(Dense(30, input_dim=X_train.shape[1])) # Input-Layer
model2.add(Activation("relu"))

model2.add(Dense(50)) # Hidden-Layer
model2.add(Activation("relu"))

model2.add(Dense(50)) # Hidden-Layer
model2.add(Activation("relu"))

model2.add(Dense(50)) # Hidden-Layer
model2.add(Activation("relu"))


model2.add(Dense(1)) # Output-Layer
model2.add(Activation("sigmoid"))

model2.compile(loss="binary_crossentropy", optimizer=Adam(lr=0.001),␣
 ↪metrics="accuracy")
model2.fit(x=X_train,y=y_train, epochs=100, validation_data=(X_test, y_test))
```

```
Epoch 1/100
13/13 [==============================] - 0s 12ms/step - loss: 5.6527 - accuracy:
0.4523 - val_loss: 1.3917 - val_accuracy: 0.6374
Epoch 2/100
13/13 [==============================] - 0s 2ms/step - loss: 0.7728 - accuracy:
0.7161 - val_loss: 0.5259 - val_accuracy: 0.7778
Epoch 3/100
13/13 [==============================] - 0s 2ms/step - loss: 0.4275 - accuracy:
0.8367 - val_loss: 0.2381 - val_accuracy: 0.9064
Epoch 4/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3459 - accuracy:
0.8769 - val_loss: 0.3617 - val_accuracy: 0.8889
Epoch 5/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3062 - accuracy:
0.8920 - val_loss: 0.2201 - val_accuracy: 0.9181
Epoch 6/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2514 - accuracy:
0.8995 - val_loss: 0.5024 - val_accuracy: 0.8129
Epoch 7/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3116 - accuracy:
0.8794 - val_loss: 0.4182 - val_accuracy: 0.8304
Epoch 8/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2445 - accuracy:
0.9045 - val_loss: 0.2200 - val_accuracy: 0.9006
Epoch 9/100
```

```
13/13 [==============================] - 0s 2ms/step - loss: 0.2404 - accuracy:
0.9121 - val_loss: 0.2749 - val_accuracy: 0.9123
Epoch 10/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2038 - accuracy:
0.9221 - val_loss: 0.2086 - val_accuracy: 0.9123
Epoch 11/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1980 - accuracy:
0.9221 - val_loss: 0.4479 - val_accuracy: 0.8655
Epoch 12/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2520 - accuracy:
0.9095 - val_loss: 0.3020 - val_accuracy: 0.8713
Epoch 13/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2498 - accuracy:
0.9095 - val_loss: 0.3032 - val_accuracy: 0.8889
Epoch 14/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2914 - accuracy:
0.9121 - val_loss: 0.2743 - val_accuracy: 0.8713
Epoch 15/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2374 - accuracy:
0.9171 - val_loss: 0.2055 - val_accuracy: 0.9298
Epoch 16/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2135 - accuracy:
0.9196 - val_loss: 0.2838 - val_accuracy: 0.8713
Epoch 17/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1877 - accuracy:
0.9347 - val_loss: 0.3048 - val_accuracy: 0.8713
Epoch 18/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2027 - accuracy:
0.9121 - val_loss: 0.1919 - val_accuracy: 0.9357
Epoch 19/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2405 - accuracy:
0.9095 - val_loss: 0.3296 - val_accuracy: 0.8655
Epoch 20/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2414 - accuracy:
0.9095 - val_loss: 0.2209 - val_accuracy: 0.9181
Epoch 21/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2591 - accuracy:
0.8995 - val_loss: 0.2571 - val_accuracy: 0.8889
Epoch 22/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1935 - accuracy:
0.9271 - val_loss: 0.2378 - val_accuracy: 0.9006
Epoch 23/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1916 - accuracy:
0.9196 - val_loss: 0.1851 - val_accuracy: 0.9240
Epoch 24/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1851 - accuracy:
0.9347 - val_loss: 0.2058 - val_accuracy: 0.9181
Epoch 25/100
```

```
13/13 [==============================] - 0s 2ms/step - loss: 0.1783 - accuracy:
0.9372 - val_loss: 0.1910 - val_accuracy: 0.9064
Epoch 26/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1721 - accuracy:
0.9322 - val_loss: 0.2325 - val_accuracy: 0.9006
Epoch 27/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2700 - accuracy:
0.9095 - val_loss: 0.3626 - val_accuracy: 0.8596
Epoch 28/100
13/13 [==============================] - 0s 2ms/step - loss: 0.4266 - accuracy:
0.8518 - val_loss: 0.6961 - val_accuracy: 0.8246
Epoch 29/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3011 - accuracy:
0.9020 - val_loss: 0.1973 - val_accuracy: 0.9064
Epoch 30/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3217 - accuracy:
0.8819 - val_loss: 0.3667 - val_accuracy: 0.8713
Epoch 31/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2921 - accuracy:
0.8693 - val_loss: 0.3353 - val_accuracy: 0.8947
Epoch 32/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2143 - accuracy:
0.9196 - val_loss: 0.1905 - val_accuracy: 0.9415
Epoch 33/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1922 - accuracy:
0.9271 - val_loss: 0.2273 - val_accuracy: 0.9123
Epoch 34/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1782 - accuracy:
0.9347 - val_loss: 0.1809 - val_accuracy: 0.9357
Epoch 35/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1851 - accuracy:
0.9397 - val_loss: 0.2520 - val_accuracy: 0.9006
Epoch 36/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2216 - accuracy:
0.9146 - val_loss: 0.1892 - val_accuracy: 0.9298
Epoch 37/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2075 - accuracy:
0.9121 - val_loss: 0.3544 - val_accuracy: 0.8596
Epoch 38/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2951 - accuracy:
0.8920 - val_loss: 0.1711 - val_accuracy: 0.9415
Epoch 39/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2266 - accuracy:
0.9221 - val_loss: 0.1811 - val_accuracy: 0.9181
Epoch 40/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1978 - accuracy:
0.9196 - val_loss: 0.3103 - val_accuracy: 0.8889
Epoch 41/100
```

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13/13 [==============================] - 0s 2ms/step - loss: 0.2048 - accuracy:
0.9146 - val_loss: 0.2454 - val_accuracy: 0.9181
Epoch 42/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3079 - accuracy:
0.8869 - val_loss: 0.1891 - val_accuracy: 0.9298
Epoch 43/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3344 - accuracy:
0.8668 - val_loss: 0.2748 - val_accuracy: 0.8947
Epoch 44/100
13/13 [==============================] - 0s 2ms/step - loss: 0.4250 - accuracy:
0.8844 - val_loss: 0.3118 - val_accuracy: 0.9064
Epoch 45/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2661 - accuracy:
0.9121 - val_loss: 0.3464 - val_accuracy: 0.8713
Epoch 46/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2806 - accuracy:
0.8945 - val_loss: 0.2578 - val_accuracy: 0.9181
Epoch 47/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2199 - accuracy:
0.9246 - val_loss: 0.2413 - val_accuracy: 0.9006
Epoch 48/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1852 - accuracy:
0.9271 - val_loss: 0.1727 - val_accuracy: 0.9357
Epoch 49/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1787 - accuracy:
0.9372 - val_loss: 0.1708 - val_accuracy: 0.9357
Epoch 50/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1729 - accuracy:
0.9322 - val_loss: 0.1725 - val_accuracy: 0.9181
Epoch 51/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3009 - accuracy:
0.9095 - val_loss: 0.2127 - val_accuracy: 0.9181
Epoch 52/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1702 - accuracy:
0.9397 - val_loss: 0.1708 - val_accuracy: 0.9298
Epoch 53/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1632 - accuracy:
0.9347 - val_loss: 0.1711 - val_accuracy: 0.9240
Epoch 54/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1750 - accuracy:
0.9296 - val_loss: 0.1934 - val_accuracy: 0.9240
Epoch 55/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1723 - accuracy:
0.9397 - val_loss: 0.1668 - val_accuracy: 0.9357
Epoch 56/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1884 - accuracy:
0.9246 - val_loss: 0.1793 - val_accuracy: 0.9298
Epoch 57/100
```

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13/13 [==============================] - 0s 2ms/step - loss: 0.1718 - accuracy:
0.9447 - val_loss: 0.1673 - val_accuracy: 0.9298
Epoch 58/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1816 - accuracy:
0.9347 - val_loss: 0.2204 - val_accuracy: 0.9123
Epoch 59/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2393 - accuracy:
0.9070 - val_loss: 0.1658 - val_accuracy: 0.9415
Epoch 60/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1673 - accuracy:
0.9271 - val_loss: 0.2113 - val_accuracy: 0.9181
Epoch 61/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1783 - accuracy:
0.9296 - val_loss: 0.1735 - val_accuracy: 0.9298
Epoch 62/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1720 - accuracy:
0.9347 - val_loss: 0.1726 - val_accuracy: 0.9240
Epoch 63/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1609 - accuracy:
0.9422 - val_loss: 0.2131 - val_accuracy: 0.9181
Epoch 64/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1937 - accuracy:
0.9271 - val_loss: 0.1744 - val_accuracy: 0.9298
Epoch 65/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1661 - accuracy:
0.9372 - val_loss: 0.1636 - val_accuracy: 0.9298
Epoch 66/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2035 - accuracy:
0.9322 - val_loss: 0.1904 - val_accuracy: 0.9357
Epoch 67/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2501 - accuracy:
0.9095 - val_loss: 0.2546 - val_accuracy: 0.9006
Epoch 68/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3092 - accuracy:
0.8794 - val_loss: 0.7587 - val_accuracy: 0.7485
Epoch 69/100
13/13 [==============================] - 0s 2ms/step - loss: 0.4166 - accuracy:
0.8668 - val_loss: 0.5992 - val_accuracy: 0.8363
Epoch 70/100
13/13 [==============================] - 0s 2ms/step - loss: 0.3506 - accuracy:
0.8819 - val_loss: 0.1651 - val_accuracy: 0.9415
Epoch 71/100
13/13 [==============================] - ETA: 0s - loss: 0.1983 - accuracy: 0.93
- 0s 2ms/step - loss: 0.2080 - accuracy: 0.9171 - val_loss: 0.1633 -
val_accuracy: 0.9415
Epoch 72/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2340 - accuracy:
0.9221 - val_loss: 0.2850 - val_accuracy: 0.9006
```

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Epoch 73/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1608 - accuracy:
0.9372 - val_loss: 0.1708 - val_accuracy: 0.9357
Epoch 74/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1718 - accuracy:
0.9372 - val_loss: 0.1818 - val_accuracy: 0.9123
Epoch 75/100
13/13 [==============================] - ETA: 0s - loss: 0.0226 - accuracy: 1.00
- 0s 2ms/step - loss: 0.1764 - accuracy: 0.9246 - val_loss: 0.1654 -
val_accuracy: 0.9298
Epoch 76/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1887 - accuracy:
0.9221 - val_loss: 0.2615 - val_accuracy: 0.9064
Epoch 77/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1641 - accuracy:
0.9347 - val_loss: 0.1873 - val_accuracy: 0.9123
Epoch 78/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1501 - accuracy:
0.9347 - val_loss: 0.1660 - val_accuracy: 0.9240
Epoch 79/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1600 - accuracy:
0.9347 - val_loss: 0.1686 - val_accuracy: 0.9298
Epoch 80/100
13/13 [==============================] - ETA: 0s - loss: 0.1251 - accuracy: 0.93
- 0s 2ms/step - loss: 0.1466 - accuracy: 0.9422 - val_loss: 0.1689 -
val_accuracy: 0.9240
Epoch 81/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1439 - accuracy:
0.9472 - val_loss: 0.1966 - val_accuracy: 0.9240
Epoch 82/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1456 - accuracy:
0.9472 - val_loss: 0.1742 - val_accuracy: 0.9298
Epoch 83/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1442 - accuracy:
0.9347 - val_loss: 0.2047 - val_accuracy: 0.9240
Epoch 84/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1764 - accuracy:
0.9347 - val_loss: 0.1663 - val_accuracy: 0.9357
Epoch 85/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1447 - accuracy:
0.9372 - val_loss: 0.1704 - val_accuracy: 0.9357
Epoch 86/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1519 - accuracy:
0.9397 - val_loss: 0.1886 - val_accuracy: 0.9357
Epoch 87/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1433 - accuracy:
0.9397 - val_loss: 0.1665 - val_accuracy: 0.9357
Epoch 88/100
```

```
13/13 [==============================] - 0s 2ms/step - loss: 0.1508 - accuracy:
0.9397 - val_loss: 0.1956 - val_accuracy: 0.9240
Epoch 89/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1367 - accuracy:
0.9497 - val_loss: 0.1831 - val_accuracy: 0.9357
Epoch 90/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1327 - accuracy:
0.9422 - val_loss: 0.1609 - val_accuracy: 0.9357
Epoch 91/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1364 - accuracy:
0.9447 - val_loss: 0.1609 - val_accuracy: 0.9415
Epoch 92/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1546 - accuracy:
0.9497 - val_loss: 0.1598 - val_accuracy: 0.9298
Epoch 93/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1356 - accuracy:
0.9372 - val_loss: 0.1617 - val_accuracy: 0.9357
Epoch 94/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1673 - accuracy:
0.9221 - val_loss: 0.2267 - val_accuracy: 0.8947
Epoch 95/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1313 - accuracy:
0.9523 - val_loss: 0.2254 - val_accuracy: 0.9123
Epoch 96/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1489 - accuracy:
0.9523 - val_loss: 0.2502 - val_accuracy: 0.9064
Epoch 97/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1448 - accuracy:
0.9296 - val_loss: 0.1645 - val_accuracy: 0.9298
Epoch 98/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1247 - accuracy:
0.9447 - val_loss: 0.1751 - val_accuracy: 0.9357
Epoch 99/100
13/13 [==============================] - 0s 2ms/step - loss: 0.1473 - accuracy:
0.9296 - val_loss: 0.3674 - val_accuracy: 0.8538
Epoch 100/100
13/13 [==============================] - 0s 2ms/step - loss: 0.2268 - accuracy:
0.9121 - val_loss: 0.3149 - val_accuracy: 0.8947
```

[8]:

```
<tensorflow.python.keras.callbacks.History at 0x24ac683b8e0>
```

[9]:

```
from sklearn.metrics import confusion_matrix, accuracy_score
pred = (model2.predict(X_test)>0.5).astype(int)
print(confusion_matrix(pred, y_test))
print(accuracy_score(pred, y_test))
```

```
[[ 52   1]
 [ 17 101]]
```

```
0.8947368421052632
```