Midterm

October 22, 2023

[1]:
```python
print("""
Riker Wachtler
22 October 2023
Wine Classification Midterm Project
https://github.com/RikerW/midterm
""")
```

```
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22 October 2023
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```

[2]:
```python
import os, shutil

import numpy as np, pandas as pd, matplotlib.pyplot as plt, seaborn as sns

import keras, keras_tuner as kt, tensorflow as tf
from keras import Sequential
from keras.layers import Dense
from keras.initializers import TruncatedNormal
from keras.utils import to_categorical
from keras.optimizers import Adam
from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
from scikitplot.metrics import plot_confusion_matrix

import warnings

warnings.filterwarnings('ignore')
%matplotlib inline
sns.set_style("whitegrid")
```

```
Using TensorFlow backend
```

[3]:
```python
print("""
This is a classification attempt on a very unoriginal dataset (for the midterm,␣
↪I mean), the wine dataset from UCI, used via the sklearn databases.

The data is composed of 13 features; Alcohol, Malic acid, Ash, Alcalinity of␣
↪ash, Magnesium, Total phenols, Flavanoids, Nonflavanoid phenols,␣
↪Proanthocyanins, Color intensity, Hue, OD280/OD315 of diluted wines, and␣
↪Proline. They are not measured on any uniform scale. The samples are in 3␣
↪classes, so this is a classification problem on those features. It has no␣
↪missing values and has been cleaned up already.

I used a very simple ANN with one hidden layer, and used hyperparameter tuning␣
↪to decide the number of nodes in that layer. The input layer was obviously␣
↪based on the input dimension & the output the number of classes, so they␣
↪were not tuned. I used a Hyperband tuner to do this, with the normal epoch/
↪factor of 100/3. After that search, I fit the model on the training data␣
↪(randomly selected as 75% of the dataset) over 300 epochs, validated with␣
↪the remaining 25% test data from the dataset, and then plotted the accuracy/
↪loss & confusion matrix. """)
```

```
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Proanthocyanins, Color intensity, Hue, OD280/OD315 of diluted wines, and
Proline. They are not measured on any uniform scale. The samples are in 3
classes, so this is a classification problem on those features. It has no
missing values and has been cleaned up already.

I used a very simple ANN with one hidden layer, and used hyperparameter tuning
to decide the number of nodes in that layer. The input layer was obviously based
on the input dimension & the output the number of classes, so they were not
tuned. I used a Hyperband tuner to do this, with the normal epoch/factor of
100/3. After that search, I fit the model on the training data (randomly
selected as 75% of the dataset) over 300 epochs, validated with the remaining
25% test data from the dataset, and then plotted the accuracy/loss & confusion
matrix.
```

[4]:
```python
# fetch dataset
wine = pd.read_csv("data/wine.csv")
```

[5]:
```python
# split dataset into train/test, proportioned at 25%
X, y = wine, wine["label"]
X_train, X_test, y_train, y_test = train_test_split(X, y, shuffle = True,␣
↪test_size = 0.25)
```

```
# convert y_train & y_test to categorical data
y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
```

[6]:
```
wine.head()
```

[6]:
```
   alcohol  malic_acid   ash  alcalinity_of_ash  magnesium  total_phenols  \
0    14.23        1.71  2.43               15.6      127.0           2.80
1    13.20        1.78  2.14               11.2      100.0           2.65
2    13.16        2.36  2.67               18.6      101.0           2.80
3    14.37        1.95  2.50               16.8      113.0           3.85
4    13.24        2.59  2.87               21.0      118.0           2.80

   flavanoids  nonflavanoid_phenols  proanthocyanins  color_intensity   hue  \
0        3.06                  0.28             2.29             5.64  1.04
1        2.76                  0.26             1.28             4.38  1.05
2        3.24                  0.30             2.81             5.68  1.03
3        3.49                  0.24             2.18             7.80  0.86
4        2.69                  0.39             1.82             4.32  1.04

   od280/od315_of_diluted_wines  proline  label
0                          3.92   1065.0      0
1                          3.40   1050.0      0
2                          3.17   1185.0      0
3                          3.45   1480.0      0
4                          2.93    735.0      0
```

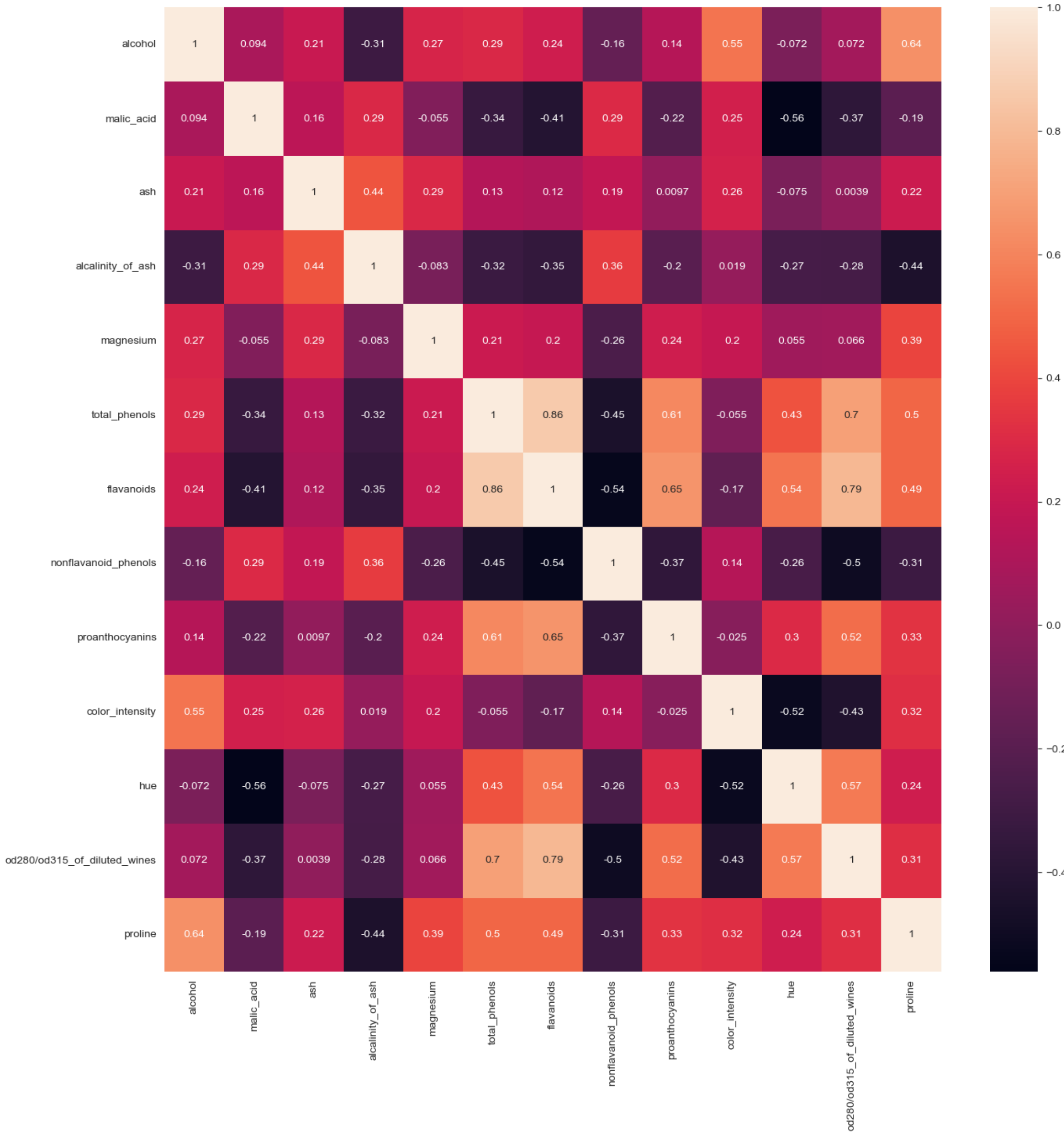
[7]:
```
wine.describe()
```

[7]:
```
          alcohol  malic_acid         ash  alcalinity_of_ash   magnesium  \
count  178.000000  178.000000  178.000000         178.000000  178.000000
mean    13.000618    2.336348    2.366517          19.494944   99.741573
std      0.811827    1.117146    0.274344           3.339564   14.282484
min     11.030000    0.740000    1.360000          10.600000   70.000000
25%     12.362500    1.602500    2.210000          17.200000   88.000000
50%     13.050000    1.865000    2.360000          19.500000   98.000000
75%     13.677500    3.082500    2.557500          21.500000  107.000000
max     14.830000    5.800000    3.230000          30.000000  162.000000

       total_phenols  flavanoids  nonflavanoid_phenols  proanthocyanins  \
count     178.000000  178.000000            178.000000       178.000000
mean        2.295112    2.029270              0.361854         1.590899
std         0.625851    0.998859              0.124453         0.572359
min         0.980000    0.340000              0.130000         0.410000
25%         1.742500    1.205000              0.270000         1.250000
50%         2.355000    2.135000              0.340000         1.555000
```

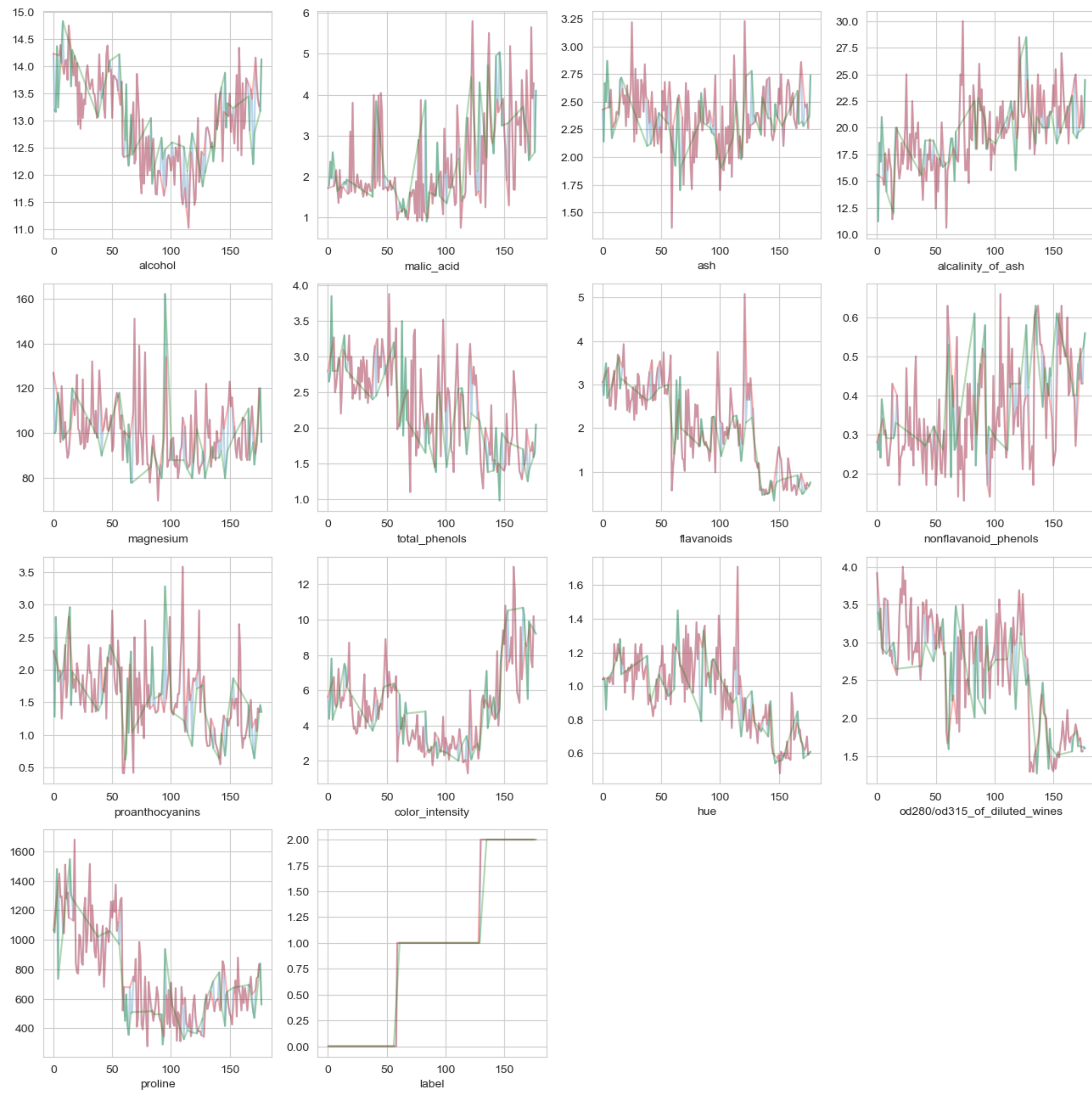
```
75%         2.800000    2.875000                0.437500          1.950000
max         3.880000    5.080000                0.660000          3.580000

       color_intensity         hue  od280/od315_of_diluted_wines      proline  \
count       178.000000  178.000000                    178.000000   178.000000
mean          5.058090    0.957449                      2.611685   746.893258
std           2.318286    0.228572                      0.709990   314.907474
min           1.280000    0.480000                      1.270000   278.000000
25%           3.220000    0.782500                      1.937500   500.500000
50%           4.690000    0.965000                      2.780000   673.500000
75%           6.200000    1.120000                      3.170000   985.000000
max          13.000000    1.710000                      4.000000  1680.000000

            label
count  178.000000
mean     0.938202
std      0.775035
min      0.000000
25%      0.000000
50%      1.000000
75%      2.000000
max      2.000000
```

[8]:

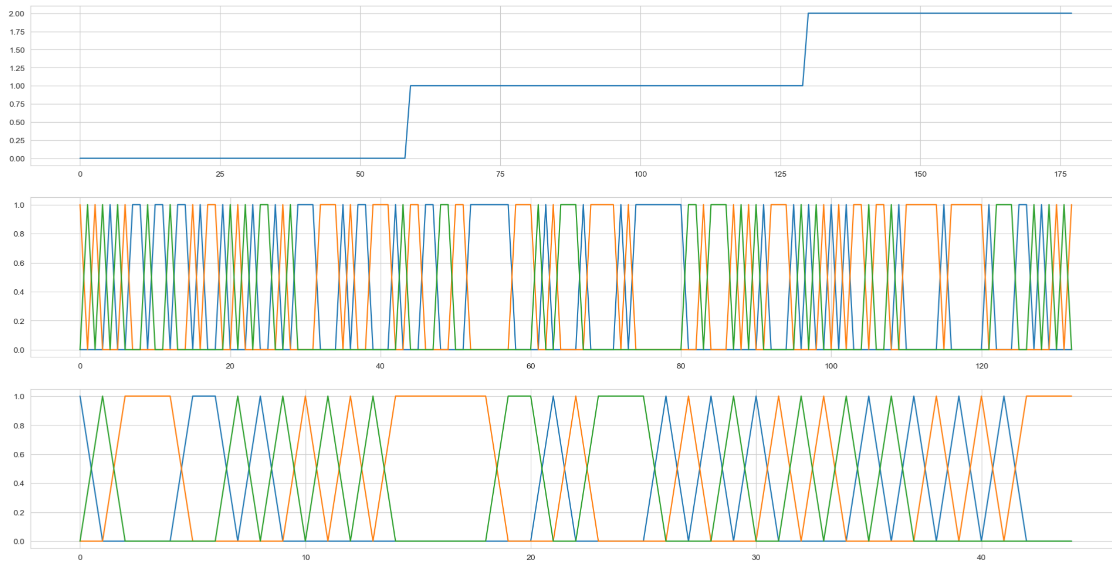
```
plt.figure(figsize = (16,16))
sns.heatmap(wine.iloc[:,:-1].corr(), annot=True)
plt.show()
```



[9]:
```python
fig = plt.figure(figsize=(16, 16))
labels = wine.columns
for label in range(len(labels)):
    ax = fig.add_subplot(4,4,label+1)
    ax.plot(X.iloc[:, label], alpha = 0.3)
    ax.plot(X_train.sort_index().iloc[:, label], color="red", alpha = 0.3)
    ax.plot(X_test.sort_index().iloc[:, label], color="green", alpha = 0.3)
    ax.set_xlabel(labels[label])
```



[10]:
```
fig = plt.figure(figsize=(24,12))
ax1 = fig.add_subplot(3,1,1)
ax1.plot(y)
ax2 = fig.add_subplot(3,1,2)
ax2.plot(y_train)
ax3 = fig.add_subplot(3,1,3)
ax3.plot(y_test)
plt.show()
```



```
[11]: folder_path = "logs/midterm"

# Check if the folder exists before attempting to delete it
if os.path.exists(folder_path):
    # Remove the folder and its contents recursively
    shutil.rmtree(folder_path)
    print(f"The folder '{folder_path}' has been deleted.")
else:
    print(f"The folder '{folder_path}' does not exist.")
```

The folder 'logs/midterm' has been deleted.

```
[12]: # define model builder for tuning
input_dim = len(X_train.iloc[0, :])
class_num = len(y_train[0, :])



# Only the hidden layer is tuned, and just its nodes
# We use rect. linear unified function for the hidden layer
# and then softmax for output because this is classification and we want that␣
↪probability distribution
def model_builder(hp):
    # create model
    init = TruncatedNormal(stddev=0.01)
    adam = Adam(learning_rate=0.005)
    model = Sequential()
    # hidden layer
    hp_units = hp.Int("units", min_value = 5, max_value = 60, step = 5)
```

```
    model.add(Dense(units = hp_units, input_dim = input_dim, activation =␣
↪"relu", kernel_initializer = init))
    ### add the final layer
    model.add(Dense(class_num, activation = "softmax", kernel_initializer =␣
↪init))
    # Compile model
    model.compile(loss='categorical_crossentropy', optimizer=adam,␣
↪metrics=['accuracy'])
    return model
```

[13]:

```
# create a Hyperband tuner for accuracy, with 100 epochs
tuner = kt.Hyperband(model_builder, objective='val_accuracy', max_epochs=100,␣
↪factor=3,
                     directory="logs/", project_name='midterm')

# set the callback for loss
stop_early = tf.keras.callbacks.EarlyStopping(monitor="val_loss", patience=5)

# set up a search on the training set, 100 epochs, splitting at 20% for␣
↪validation
tuner.search(X_train, y_train, epochs=100, validation_split=0.2,␣
↪callbacks=[stop_early])

# Get the optimal hyperparameters
best_hps=tuner.get_best_hyperparameters(num_trials=5)[0]
print(f"""The hyperparameter search is complete. The optimal number of units in␣
↪the first densely-connected layer is {best_hps.get('units')}.""")
```

```
Trial 12 Complete [00h 00m 01s]
val_accuracy: 0.2222222238779068

Best val_accuracy So Far: 0.6296296119689941
Total elapsed time: 00h 00m 12s
The hyperparameter search is complete. The optimal number of units in the first
densely-connected layer is 55.
```

[14]:

```
# Build the model with the optimal hyperparameters and train it on the data for␣
↪300 epochs
model = tuner.hypermodel.build(best_hps)
history = model.fit(X_train, y_train, epochs=300, validation_data=(X_test,␣
↪y_test), shuffle=False)
val_acc_per_epoch = history.history['val_accuracy']
best_epoch = val_acc_per_epoch.index(max(val_acc_per_epoch)) + 1
print('Best epoch: %d' % (best_epoch,))
```

```
Epoch 1/300
5/5 [==============================] - 1s 40ms/step - loss: 1.1704 - accuracy:
0.3308 - val_loss: 1.1132 - val_accuracy: 0.4222
```

```
Epoch 2/300
5/5 [==============================] - 0s 8ms/step - loss: 1.0984 - accuracy:
0.3985 - val_loss: 1.0794 - val_accuracy: 0.6444
Epoch 3/300
5/5 [==============================] - 0s 8ms/step - loss: 1.0695 - accuracy:
0.5865 - val_loss: 1.0546 - val_accuracy: 0.3556
Epoch 4/300
5/5 [==============================] - 0s 8ms/step - loss: 1.0247 - accuracy:
0.3835 - val_loss: 1.0450 - val_accuracy: 0.2667
Epoch 5/300
5/5 [==============================] - 0s 8ms/step - loss: 0.9810 - accuracy:
0.3534 - val_loss: 1.0014 - val_accuracy: 0.3778
Epoch 6/300
5/5 [==============================] - 0s 8ms/step - loss: 0.9358 - accuracy:
0.5338 - val_loss: 0.9548 - val_accuracy: 0.6444
Epoch 7/300
5/5 [==============================] - 0s 8ms/step - loss: 0.9125 - accuracy:
0.5865 - val_loss: 0.9237 - val_accuracy: 0.5556
Epoch 8/300
5/5 [==============================] - 0s 9ms/step - loss: 0.8549 - accuracy:
0.6090 - val_loss: 0.8752 - val_accuracy: 0.6444
Epoch 9/300
5/5 [==============================] - 0s 8ms/step - loss: 0.8355 - accuracy:
0.6165 - val_loss: 0.8552 - val_accuracy: 0.6444
Epoch 10/300
5/5 [==============================] - 0s 8ms/step - loss: 0.8030 - accuracy:
0.6241 - val_loss: 0.8282 - val_accuracy: 0.6667
Epoch 11/300
5/5 [==============================] - 0s 9ms/step - loss: 0.7845 - accuracy:
0.6165 - val_loss: 0.8153 - val_accuracy: 0.6444
Epoch 12/300
5/5 [==============================] - 0s 9ms/step - loss: 0.7694 - accuracy:
0.6241 - val_loss: 0.7997 - val_accuracy: 0.6667
Epoch 13/300
5/5 [==============================] - 0s 8ms/step - loss: 0.7591 - accuracy:
0.6541 - val_loss: 0.7879 - val_accuracy: 0.6667
Epoch 14/300
5/5 [==============================] - 0s 8ms/step - loss: 0.7486 - accuracy:
0.6767 - val_loss: 0.7725 - val_accuracy: 0.6667
Epoch 15/300
5/5 [==============================] - 0s 8ms/step - loss: 0.7406 - accuracy:
0.6767 - val_loss: 0.7681 - val_accuracy: 0.6667
Epoch 16/300
5/5 [==============================] - 0s 8ms/step - loss: 0.7330 - accuracy:
0.6842 - val_loss: 0.7604 - val_accuracy: 0.6667
Epoch 17/300
5/5 [==============================] - 0s 8ms/step - loss: 0.7238 - accuracy:
0.6842 - val_loss: 0.7571 - val_accuracy: 0.6667
```

```
Epoch 18/300
5/5 [==============================] - 0s 8ms/step - loss: 0.7198 - accuracy:
0.6842 - val_loss: 0.7492 - val_accuracy: 0.6667
Epoch 19/300
5/5 [==============================] - 0s 9ms/step - loss: 0.7095 - accuracy:
0.6917 - val_loss: 0.7387 - val_accuracy: 0.6667
Epoch 20/300
5/5 [==============================] - 0s 9ms/step - loss: 0.7056 - accuracy:
0.6842 - val_loss: 0.7292 - val_accuracy: 0.6667
Epoch 21/300
5/5 [==============================] - 0s 8ms/step - loss: 0.7008 - accuracy:
0.6767 - val_loss: 0.7434 - val_accuracy: 0.6444
Epoch 22/300
5/5 [==============================] - 0s 8ms/step - loss: 0.6923 - accuracy:
0.6917 - val_loss: 0.7240 - val_accuracy: 0.6667
Epoch 23/300
5/5 [==============================] - 0s 8ms/step - loss: 0.6872 - accuracy:
0.6842 - val_loss: 0.7176 - val_accuracy: 0.6667
Epoch 24/300
5/5 [==============================] - 0s 8ms/step - loss: 0.6817 - accuracy:
0.6842 - val_loss: 0.7176 - val_accuracy: 0.6667
Epoch 25/300
5/5 [==============================] - 0s 8ms/step - loss: 0.6719 - accuracy:
0.6917 - val_loss: 0.7111 - val_accuracy: 0.6667
Epoch 26/300
5/5 [==============================] - 0s 8ms/step - loss: 0.6695 - accuracy:
0.6842 - val_loss: 0.7062 - val_accuracy: 0.6667
Epoch 27/300
5/5 [==============================] - 0s 8ms/step - loss: 0.6586 - accuracy:
0.6917 - val_loss: 0.7011 - val_accuracy: 0.6667
Epoch 28/300
5/5 [==============================] - 0s 8ms/step - loss: 0.6572 - accuracy:
0.6842 - val_loss: 0.6984 - val_accuracy: 0.6667
Epoch 29/300
5/5 [==============================] - 0s 8ms/step - loss: 0.6478 - accuracy:
0.6842 - val_loss: 0.6962 - val_accuracy: 0.6667
Epoch 30/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6430 - accuracy:
0.6917 - val_loss: 0.6859 - val_accuracy: 0.6667
Epoch 31/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6379 - accuracy:
0.6992 - val_loss: 0.6841 - val_accuracy: 0.6667
Epoch 32/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6316 - accuracy:
0.6917 - val_loss: 0.6836 - val_accuracy: 0.6444
Epoch 33/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6280 - accuracy:
0.6917 - val_loss: 0.6736 - val_accuracy: 0.6667
```

```
Epoch 34/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6206 - accuracy:
0.6917 - val_loss: 0.6722 - val_accuracy: 0.6667
Epoch 35/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6166 - accuracy:
0.6992 - val_loss: 0.6652 - val_accuracy: 0.6667
Epoch 36/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6088 - accuracy:
0.6917 - val_loss: 0.6682 - val_accuracy: 0.6444
Epoch 37/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6067 - accuracy:
0.6917 - val_loss: 0.6555 - val_accuracy: 0.6667
Epoch 38/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6001 - accuracy:
0.6917 - val_loss: 0.6474 - val_accuracy: 0.6667
Epoch 39/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5946 - accuracy:
0.6917 - val_loss: 0.6769 - val_accuracy: 0.6444
Epoch 40/300
5/5 [==============================] - 0s 8ms/step - loss: 0.5961 - accuracy:
0.7068 - val_loss: 0.6372 - val_accuracy: 0.6667
Epoch 41/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5842 - accuracy:
0.6917 - val_loss: 0.6454 - val_accuracy: 0.6667
Epoch 42/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5843 - accuracy:
0.6842 - val_loss: 0.6273 - val_accuracy: 0.6667
Epoch 43/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5705 - accuracy:
0.7068 - val_loss: 0.6190 - val_accuracy: 0.6667
Epoch 44/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5802 - accuracy:
0.6917 - val_loss: 0.6420 - val_accuracy: 0.6444
Epoch 45/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5555 - accuracy:
0.7143 - val_loss: 0.6027 - val_accuracy: 0.6667
Epoch 46/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5401 - accuracy:
0.6917 - val_loss: 0.5787 - val_accuracy: 0.6667
Epoch 47/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5320 - accuracy:
0.7143 - val_loss: 0.5757 - val_accuracy: 0.6667
Epoch 48/300
5/5 [==============================] - 0s 8ms/step - loss: 0.5003 - accuracy:
0.6842 - val_loss: 0.5181 - val_accuracy: 0.6667
Epoch 49/300
5/5 [==============================] - 0s 8ms/step - loss: 0.4634 - accuracy:
0.6992 - val_loss: 0.4974 - val_accuracy: 0.6667
```

```
Epoch 50/300
5/5 [==============================] - 0s 8ms/step - loss: 0.4553 - accuracy:
0.6917 - val_loss: 0.4617 - val_accuracy: 0.6667
Epoch 51/300
5/5 [==============================] - 0s 7ms/step - loss: 0.4274 - accuracy:
0.6992 - val_loss: 0.4485 - val_accuracy: 0.6667
Epoch 52/300
5/5 [==============================] - 0s 7ms/step - loss: 0.4204 - accuracy:
0.7669 - val_loss: 0.4247 - val_accuracy: 0.9778
Epoch 53/300
5/5 [==============================] - 0s 7ms/step - loss: 0.3941 - accuracy:
0.8872 - val_loss: 0.4075 - val_accuracy: 0.9778
Epoch 54/300
5/5 [==============================] - 0s 8ms/step - loss: 0.3752 - accuracy:
0.9098 - val_loss: 0.3762 - val_accuracy: 0.9556
Epoch 55/300
5/5 [==============================] - 0s 8ms/step - loss: 0.3685 - accuracy:
0.9098 - val_loss: 0.3716 - val_accuracy: 0.9778
Epoch 56/300
5/5 [==============================] - 0s 7ms/step - loss: 0.3598 - accuracy:
0.8872 - val_loss: 0.3626 - val_accuracy: 0.9778
Epoch 57/300
5/5 [==============================] - 0s 7ms/step - loss: 0.3408 - accuracy:
0.9098 - val_loss: 0.3478 - val_accuracy: 0.9778
Epoch 58/300
5/5 [==============================] - 0s 7ms/step - loss: 0.3296 - accuracy:
0.9173 - val_loss: 0.3424 - val_accuracy: 0.9778
Epoch 59/300
5/5 [==============================] - 0s 7ms/step - loss: 0.3221 - accuracy:
0.9173 - val_loss: 0.3285 - val_accuracy: 0.9778
Epoch 60/300
5/5 [==============================] - 0s 7ms/step - loss: 0.3085 - accuracy:
0.9248 - val_loss: 0.3229 - val_accuracy: 0.9778
Epoch 61/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2992 - accuracy:
0.9398 - val_loss: 0.3156 - val_accuracy: 0.9778
Epoch 62/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2891 - accuracy:
0.9549 - val_loss: 0.3059 - val_accuracy: 0.9778
Epoch 63/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2789 - accuracy:
0.9624 - val_loss: 0.3001 - val_accuracy: 0.9778
Epoch 64/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2703 - accuracy:
0.9624 - val_loss: 0.2933 - val_accuracy: 0.9778
Epoch 65/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2606 - accuracy:
0.9624 - val_loss: 0.2890 - val_accuracy: 0.9778
```

```
Epoch 66/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2516 - accuracy:
0.9624 - val_loss: 0.2757 - val_accuracy: 0.9778
Epoch 67/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2419 - accuracy:
0.9624 - val_loss: 0.2644 - val_accuracy: 0.9778
Epoch 68/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2448 - accuracy:
0.9699 - val_loss: 0.2726 - val_accuracy: 0.9778
Epoch 69/300
5/5 [==============================] - 0s 8ms/step - loss: 0.2372 - accuracy:
0.9624 - val_loss: 0.2572 - val_accuracy: 0.9556
Epoch 70/300
5/5 [==============================] - 0s 8ms/step - loss: 0.2266 - accuracy:
0.9624 - val_loss: 0.2595 - val_accuracy: 0.9778
Epoch 71/300
5/5 [==============================] - 0s 8ms/step - loss: 0.2157 - accuracy:
0.9699 - val_loss: 0.2392 - val_accuracy: 0.9556
Epoch 72/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2112 - accuracy:
0.9624 - val_loss: 0.2435 - val_accuracy: 0.9778
Epoch 73/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2063 - accuracy:
0.9774 - val_loss: 0.2265 - val_accuracy: 0.9556
Epoch 74/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2039 - accuracy:
0.9624 - val_loss: 0.2435 - val_accuracy: 0.9778
Epoch 75/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1961 - accuracy:
0.9774 - val_loss: 0.2174 - val_accuracy: 0.9556
Epoch 76/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1929 - accuracy:
0.9699 - val_loss: 0.2265 - val_accuracy: 0.9778
Epoch 77/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1850 - accuracy:
0.9774 - val_loss: 0.2057 - val_accuracy: 0.9556
Epoch 78/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1865 - accuracy:
0.9699 - val_loss: 0.2290 - val_accuracy: 0.9778
Epoch 79/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1779 - accuracy:
0.9774 - val_loss: 0.1982 - val_accuracy: 0.9556
Epoch 80/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1813 - accuracy:
0.9699 - val_loss: 0.2288 - val_accuracy: 0.9778
Epoch 81/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1735 - accuracy:
0.9850 - val_loss: 0.1910 - val_accuracy: 0.9556
```

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Epoch 82/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1757 - accuracy:
0.9699 - val_loss: 0.2219 - val_accuracy: 0.9778
Epoch 83/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1662 - accuracy:
0.9850 - val_loss: 0.1829 - val_accuracy: 0.9556
Epoch 84/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1684 - accuracy:
0.9774 - val_loss: 0.2197 - val_accuracy: 0.9778
Epoch 85/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1620 - accuracy:
0.9850 - val_loss: 0.1754 - val_accuracy: 0.9556
Epoch 86/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1625 - accuracy:
0.9774 - val_loss: 0.2283 - val_accuracy: 0.9333
Epoch 87/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1599 - accuracy:
0.9774 - val_loss: 0.1791 - val_accuracy: 0.9333
Epoch 88/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1749 - accuracy:
0.9624 - val_loss: 0.2622 - val_accuracy: 0.9111
Epoch 89/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1744 - accuracy:
0.9699 - val_loss: 0.1975 - val_accuracy: 0.9111
Epoch 90/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1915 - accuracy:
0.9173 - val_loss: 0.2551 - val_accuracy: 0.9333
Epoch 91/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1863 - accuracy:
0.9549 - val_loss: 0.1669 - val_accuracy: 0.9778
Epoch 92/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1771 - accuracy:
0.9624 - val_loss: 0.2753 - val_accuracy: 0.9111
Epoch 93/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1923 - accuracy:
0.9624 - val_loss: 0.1568 - val_accuracy: 0.9778
Epoch 94/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1552 - accuracy:
0.9774 - val_loss: 0.1976 - val_accuracy: 0.9333
Epoch 95/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1473 - accuracy:
0.9925 - val_loss: 0.1727 - val_accuracy: 0.9778
Epoch 96/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1273 - accuracy:
0.9850 - val_loss: 0.1449 - val_accuracy: 0.9778
Epoch 97/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1247 - accuracy:
0.9850 - val_loss: 0.1742 - val_accuracy: 0.9556
```

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Epoch 98/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1223 - accuracy:
0.9925 - val_loss: 0.1503 - val_accuracy: 0.9556
Epoch 99/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1194 - accuracy:
0.9850 - val_loss: 0.1504 - val_accuracy: 0.9778
Epoch 100/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1153 - accuracy:
0.9925 - val_loss: 0.1499 - val_accuracy: 0.9778
Epoch 101/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1117 - accuracy:
0.9850 - val_loss: 0.1393 - val_accuracy: 0.9778
Epoch 102/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1110 - accuracy:
0.9850 - val_loss: 0.1514 - val_accuracy: 0.9778
Epoch 103/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1091 - accuracy:
0.9925 - val_loss: 0.1401 - val_accuracy: 0.9778
Epoch 104/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1069 - accuracy:
0.9850 - val_loss: 0.1493 - val_accuracy: 0.9778
Epoch 105/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1056 - accuracy:
0.9925 - val_loss: 0.1352 - val_accuracy: 0.9778
Epoch 106/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1029 - accuracy:
0.9850 - val_loss: 0.1378 - val_accuracy: 0.9778
Epoch 107/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1013 - accuracy:
0.9925 - val_loss: 0.1331 - val_accuracy: 0.9778
Epoch 108/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1002 - accuracy:
0.9925 - val_loss: 0.1396 - val_accuracy: 0.9778
Epoch 109/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0985 - accuracy:
0.9925 - val_loss: 0.1300 - val_accuracy: 0.9778
Epoch 110/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0964 - accuracy:
0.9850 - val_loss: 0.1287 - val_accuracy: 0.9778
Epoch 111/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0954 - accuracy:
0.9925 - val_loss: 0.1302 - val_accuracy: 0.9778
Epoch 112/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0942 - accuracy:
0.9925 - val_loss: 0.1326 - val_accuracy: 0.9778
Epoch 113/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0925 - accuracy:
0.9925 - val_loss: 0.1194 - val_accuracy: 0.9778
```

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Epoch 114/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0920 - accuracy:
0.9850 - val_loss: 0.1298 - val_accuracy: 0.9778
Epoch 115/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0900 - accuracy:
0.9925 - val_loss: 0.1227 - val_accuracy: 1.0000
Epoch 116/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0898 - accuracy:
0.9925 - val_loss: 0.1259 - val_accuracy: 0.9778
Epoch 117/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0872 - accuracy:
0.9925 - val_loss: 0.1186 - val_accuracy: 0.9778
Epoch 118/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0859 - accuracy:
0.9925 - val_loss: 0.1219 - val_accuracy: 0.9778
Epoch 119/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0848 - accuracy:
0.9925 - val_loss: 0.1166 - val_accuracy: 0.9778
Epoch 120/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0831 - accuracy:
0.9925 - val_loss: 0.1152 - val_accuracy: 0.9778
Epoch 121/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0822 - accuracy:
0.9925 - val_loss: 0.1143 - val_accuracy: 1.0000
Epoch 122/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0814 - accuracy:
0.9925 - val_loss: 0.1215 - val_accuracy: 0.9778
Epoch 123/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0807 - accuracy:
0.9925 - val_loss: 0.1091 - val_accuracy: 0.9778
Epoch 124/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0788 - accuracy:
0.9925 - val_loss: 0.1142 - val_accuracy: 1.0000
Epoch 125/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0778 - accuracy:
0.9925 - val_loss: 0.1081 - val_accuracy: 1.0000
Epoch 126/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0767 - accuracy:
0.9925 - val_loss: 0.1146 - val_accuracy: 0.9778
Epoch 127/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0756 - accuracy:
0.9925 - val_loss: 0.1086 - val_accuracy: 1.0000
Epoch 128/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0757 - accuracy:
0.9925 - val_loss: 0.1122 - val_accuracy: 0.9778
Epoch 129/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0737 - accuracy:
0.9925 - val_loss: 0.1022 - val_accuracy: 1.0000
```

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Epoch 130/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0727 - accuracy:
0.9925 - val_loss: 0.1069 - val_accuracy: 0.9778
Epoch 131/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0717 - accuracy:
0.9925 - val_loss: 0.1027 - val_accuracy: 1.0000
Epoch 132/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0707 - accuracy:
0.9925 - val_loss: 0.1034 - val_accuracy: 0.9778
Epoch 133/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0696 - accuracy:
0.9925 - val_loss: 0.1012 - val_accuracy: 1.0000
Epoch 134/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0690 - accuracy:
0.9925 - val_loss: 0.1066 - val_accuracy: 0.9778
Epoch 135/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0681 - accuracy:
0.9925 - val_loss: 0.0985 - val_accuracy: 1.0000
Epoch 136/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0671 - accuracy:
0.9925 - val_loss: 0.1116 - val_accuracy: 0.9778
Epoch 137/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0674 - accuracy:
0.9925 - val_loss: 0.1012 - val_accuracy: 0.9778
Epoch 138/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0652 - accuracy:
0.9925 - val_loss: 0.1023 - val_accuracy: 0.9778
Epoch 139/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0649 - accuracy:
0.9925 - val_loss: 0.0964 - val_accuracy: 0.9778
Epoch 140/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0632 - accuracy:
0.9925 - val_loss: 0.0949 - val_accuracy: 0.9778
Epoch 141/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0630 - accuracy:
0.9925 - val_loss: 0.1014 - val_accuracy: 0.9778
Epoch 142/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0618 - accuracy:
0.9925 - val_loss: 0.0894 - val_accuracy: 1.0000
Epoch 143/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0614 - accuracy:
0.9925 - val_loss: 0.1025 - val_accuracy: 0.9778
Epoch 144/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0609 - accuracy:
0.9925 - val_loss: 0.0998 - val_accuracy: 0.9778
Epoch 145/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0603 - accuracy:
0.9925 - val_loss: 0.0944 - val_accuracy: 0.9778
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Epoch 146/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0585 - accuracy:
0.9925 - val_loss: 0.0914 - val_accuracy: 0.9778
Epoch 147/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0578 - accuracy:
0.9925 - val_loss: 0.0964 - val_accuracy: 0.9778
Epoch 148/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0571 - accuracy:
0.9925 - val_loss: 0.0958 - val_accuracy: 0.9778
Epoch 149/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0571 - accuracy:
0.9925 - val_loss: 0.0940 - val_accuracy: 0.9778
Epoch 150/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0557 - accuracy:
0.9925 - val_loss: 0.0870 - val_accuracy: 0.9778
Epoch 151/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0548 - accuracy:
0.9925 - val_loss: 0.0907 - val_accuracy: 0.9778
Epoch 152/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0543 - accuracy:
0.9925 - val_loss: 0.0987 - val_accuracy: 0.9778
Epoch 153/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0546 - accuracy:
0.9925 - val_loss: 0.0868 - val_accuracy: 0.9778
Epoch 154/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0522 - accuracy:
0.9925 - val_loss: 0.0832 - val_accuracy: 0.9778
Epoch 155/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0522 - accuracy:
0.9925 - val_loss: 0.0942 - val_accuracy: 0.9778
Epoch 156/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0519 - accuracy:
0.9925 - val_loss: 0.0902 - val_accuracy: 0.9778
Epoch 157/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0508 - accuracy:
0.9925 - val_loss: 0.0894 - val_accuracy: 0.9778
Epoch 158/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0500 - accuracy:
0.9925 - val_loss: 0.0794 - val_accuracy: 0.9778
Epoch 159/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0493 - accuracy:
0.9925 - val_loss: 0.0904 - val_accuracy: 0.9778
Epoch 160/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0487 - accuracy:
0.9925 - val_loss: 0.0903 - val_accuracy: 0.9778
Epoch 161/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0491 - accuracy:
0.9925 - val_loss: 0.0830 - val_accuracy: 0.9778
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Epoch 162/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0473 - accuracy:
0.9925 - val_loss: 0.0879 - val_accuracy: 0.9778
Epoch 163/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0473 - accuracy:
0.9925 - val_loss: 0.0846 - val_accuracy: 0.9778
Epoch 164/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0463 - accuracy:
0.9925 - val_loss: 0.0783 - val_accuracy: 0.9778
Epoch 165/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0453 - accuracy:
0.9925 - val_loss: 0.0861 - val_accuracy: 0.9778
Epoch 166/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0453 - accuracy:
0.9925 - val_loss: 0.0875 - val_accuracy: 0.9778
Epoch 167/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0447 - accuracy:
0.9925 - val_loss: 0.0757 - val_accuracy: 0.9778
Epoch 168/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0436 - accuracy:
0.9925 - val_loss: 0.0889 - val_accuracy: 0.9778
Epoch 169/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0435 - accuracy:
0.9925 - val_loss: 0.0834 - val_accuracy: 0.9778
Epoch 170/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0429 - accuracy:
0.9925 - val_loss: 0.0806 - val_accuracy: 0.9778
Epoch 171/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0418 - accuracy:
0.9925 - val_loss: 0.0816 - val_accuracy: 0.9778
Epoch 172/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0418 - accuracy:
0.9925 - val_loss: 0.0812 - val_accuracy: 0.9778
Epoch 173/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0410 - accuracy:
0.9925 - val_loss: 0.0765 - val_accuracy: 0.9778
Epoch 174/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0398 - accuracy:
0.9925 - val_loss: 0.0771 - val_accuracy: 0.9778
Epoch 175/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0399 - accuracy:
0.9925 - val_loss: 0.0840 - val_accuracy: 0.9778
Epoch 176/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0394 - accuracy:
0.9925 - val_loss: 0.0711 - val_accuracy: 0.9778
Epoch 177/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0385 - accuracy:
0.9925 - val_loss: 0.0809 - val_accuracy: 0.9778
```

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Epoch 178/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0382 - accuracy:
0.9925 - val_loss: 0.0743 - val_accuracy: 0.9778
Epoch 179/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0372 - accuracy:
0.9925 - val_loss: 0.0830 - val_accuracy: 0.9778
Epoch 180/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0375 - accuracy:
0.9925 - val_loss: 0.0688 - val_accuracy: 0.9778
Epoch 181/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0365 - accuracy:
0.9925 - val_loss: 0.0817 - val_accuracy: 0.9778
Epoch 182/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0364 - accuracy:
0.9925 - val_loss: 0.0818 - val_accuracy: 0.9778
Epoch 183/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0359 - accuracy:
0.9925 - val_loss: 0.0725 - val_accuracy: 0.9778
Epoch 184/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0348 - accuracy:
0.9925 - val_loss: 0.0744 - val_accuracy: 0.9778
Epoch 185/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0346 - accuracy:
0.9925 - val_loss: 0.0808 - val_accuracy: 0.9778
Epoch 186/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0345 - accuracy:
0.9925 - val_loss: 0.0655 - val_accuracy: 0.9778
Epoch 187/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0341 - accuracy:
1.0000 - val_loss: 0.0847 - val_accuracy: 0.9778
Epoch 188/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0339 - accuracy:
0.9925 - val_loss: 0.0728 - val_accuracy: 0.9778
Epoch 189/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0325 - accuracy:
1.0000 - val_loss: 0.0667 - val_accuracy: 0.9778
Epoch 190/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0326 - accuracy:
1.0000 - val_loss: 0.0830 - val_accuracy: 0.9778
Epoch 191/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0325 - accuracy:
0.9925 - val_loss: 0.0701 - val_accuracy: 0.9778
Epoch 192/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0313 - accuracy:
1.0000 - val_loss: 0.0677 - val_accuracy: 0.9778
Epoch 193/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0312 - accuracy:
1.0000 - val_loss: 0.0760 - val_accuracy: 0.9778
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Epoch 194/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0312 - accuracy:
1.0000 - val_loss: 0.0702 - val_accuracy: 0.9778
Epoch 195/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0303 - accuracy:
1.0000 - val_loss: 0.0748 - val_accuracy: 0.9778
Epoch 196/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0299 - accuracy:
1.0000 - val_loss: 0.0708 - val_accuracy: 0.9778
Epoch 197/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0295 - accuracy:
1.0000 - val_loss: 0.0664 - val_accuracy: 0.9778
Epoch 198/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0291 - accuracy:
1.0000 - val_loss: 0.0715 - val_accuracy: 0.9778
Epoch 199/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0289 - accuracy:
1.0000 - val_loss: 0.0710 - val_accuracy: 0.9778
Epoch 200/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0285 - accuracy:
1.0000 - val_loss: 0.0706 - val_accuracy: 0.9778
Epoch 201/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0280 - accuracy:
1.0000 - val_loss: 0.0702 - val_accuracy: 0.9778
Epoch 202/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0277 - accuracy:
1.0000 - val_loss: 0.0639 - val_accuracy: 0.9778
Epoch 203/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0275 - accuracy:
1.0000 - val_loss: 0.0744 - val_accuracy: 0.9778
Epoch 204/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0275 - accuracy:
1.0000 - val_loss: 0.0639 - val_accuracy: 0.9778
Epoch 205/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0272 - accuracy:
1.0000 - val_loss: 0.0789 - val_accuracy: 0.9778
Epoch 206/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0270 - accuracy:
1.0000 - val_loss: 0.0590 - val_accuracy: 0.9778
Epoch 207/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0264 - accuracy:
1.0000 - val_loss: 0.0798 - val_accuracy: 0.9778
Epoch 208/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0261 - accuracy:
1.0000 - val_loss: 0.0628 - val_accuracy: 0.9778
Epoch 209/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0252 - accuracy:
1.0000 - val_loss: 0.0617 - val_accuracy: 0.9778
```

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Epoch 210/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0255 - accuracy:
1.0000 - val_loss: 0.0758 - val_accuracy: 0.9778
Epoch 211/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0254 - accuracy:
1.0000 - val_loss: 0.0582 - val_accuracy: 0.9778
Epoch 212/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0253 - accuracy:
1.0000 - val_loss: 0.0842 - val_accuracy: 0.9778
Epoch 213/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0257 - accuracy:
1.0000 - val_loss: 0.0527 - val_accuracy: 0.9778
Epoch 214/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0255 - accuracy:
1.0000 - val_loss: 0.0952 - val_accuracy: 0.9556
Epoch 215/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0261 - accuracy:
1.0000 - val_loss: 0.0503 - val_accuracy: 0.9778
Epoch 216/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0250 - accuracy:
1.0000 - val_loss: 0.0845 - val_accuracy: 0.9778
Epoch 217/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0242 - accuracy:
1.0000 - val_loss: 0.0573 - val_accuracy: 0.9778
Epoch 218/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0230 - accuracy:
1.0000 - val_loss: 0.0700 - val_accuracy: 0.9778
Epoch 219/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0234 - accuracy:
1.0000 - val_loss: 0.0723 - val_accuracy: 0.9778
Epoch 220/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0227 - accuracy:
1.0000 - val_loss: 0.0529 - val_accuracy: 0.9778
Epoch 221/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0234 - accuracy:
1.0000 - val_loss: 0.0971 - val_accuracy: 0.9556
Epoch 222/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0248 - accuracy:
1.0000 - val_loss: 0.0455 - val_accuracy: 1.0000
Epoch 223/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0252 - accuracy:
1.0000 - val_loss: 0.1078 - val_accuracy: 0.9556
Epoch 224/300
5/5 [==============================] - 0s 10ms/step - loss: 0.0256 - accuracy:
1.0000 - val_loss: 0.0429 - val_accuracy: 1.0000
Epoch 225/300
5/5 [==============================] - 0s 12ms/step - loss: 0.0254 - accuracy:
1.0000 - val_loss: 0.1026 - val_accuracy: 0.9556
```

```
Epoch 226/300
5/5 [==============================] - 0s 10ms/step - loss: 0.0246 - accuracy:
1.0000 - val_loss: 0.0492 - val_accuracy: 0.9778
Epoch 227/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0227 - accuracy:
1.0000 - val_loss: 0.0709 - val_accuracy: 0.9778
Epoch 228/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0225 - accuracy:
1.0000 - val_loss: 0.0878 - val_accuracy: 0.9778
Epoch 229/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0232 - accuracy:
1.0000 - val_loss: 0.0448 - val_accuracy: 1.0000
Epoch 230/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0259 - accuracy:
1.0000 - val_loss: 0.1510 - val_accuracy: 0.9111
Epoch 231/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0423 - accuracy:
0.9850 - val_loss: 0.0408 - val_accuracy: 1.0000
Epoch 232/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0252 - accuracy:
1.0000 - val_loss: 0.1166 - val_accuracy: 0.9333
Epoch 233/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0266 - accuracy:
0.9925 - val_loss: 0.0544 - val_accuracy: 0.9778
Epoch 234/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0277 - accuracy:
1.0000 - val_loss: 0.0635 - val_accuracy: 0.9778
Epoch 235/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0315 - accuracy:
1.0000 - val_loss: 0.1581 - val_accuracy: 0.9111
Epoch 236/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0723 - accuracy:
0.9774 - val_loss: 0.0977 - val_accuracy: 0.9556
Epoch 237/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0368 - accuracy:
0.9925 - val_loss: 0.0515 - val_accuracy: 0.9778
Epoch 238/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0462 - accuracy:
0.9850 - val_loss: 0.1954 - val_accuracy: 0.9333
Epoch 239/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0738 - accuracy:
0.9774 - val_loss: 0.1611 - val_accuracy: 0.9778
Epoch 240/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2791 - accuracy:
0.8872 - val_loss: 0.8927 - val_accuracy: 0.7111
Epoch 241/300
5/5 [==============================] - 0s 7ms/step - loss: 0.4546 - accuracy:
0.8496 - val_loss: 0.2584 - val_accuracy: 0.8889
```

```
Epoch 242/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1742 - accuracy:
0.9098 - val_loss: 0.3131 - val_accuracy: 0.9111
Epoch 243/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1711 - accuracy:
0.9323 - val_loss: 0.1316 - val_accuracy: 0.9778
Epoch 244/300
5/5 [==============================] - 0s 7ms/step - loss: 0.3061 - accuracy:
0.8647 - val_loss: 0.3509 - val_accuracy: 0.9111
Epoch 245/300
5/5 [==============================] - 0s 8ms/step - loss: 0.4427 - accuracy:
0.8421 - val_loss: 0.1142 - val_accuracy: 0.9556
Epoch 246/300
5/5 [==============================] - 0s 7ms/step - loss: 0.2394 - accuracy:
0.9023 - val_loss: 0.2512 - val_accuracy: 0.9111
Epoch 247/300
5/5 [==============================] - 0s 7ms/step - loss: 0.1829 - accuracy:
0.9173 - val_loss: 0.2016 - val_accuracy: 0.9333
Epoch 248/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0804 - accuracy:
0.9774 - val_loss: 0.0702 - val_accuracy: 0.9556
Epoch 249/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0435 - accuracy:
0.9850 - val_loss: 0.0838 - val_accuracy: 0.9778
Epoch 250/300
5/5 [==============================] - 0s 11ms/step - loss: 0.0652 - accuracy:
0.9699 - val_loss: 0.3470 - val_accuracy: 0.8889
Epoch 251/300
5/5 [==============================] - 0s 9ms/step - loss: 0.2436 - accuracy:
0.9098 - val_loss: 0.1314 - val_accuracy: 0.9778
Epoch 252/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0990 - accuracy:
0.9699 - val_loss: 0.0479 - val_accuracy: 1.0000
Epoch 253/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0326 - accuracy:
0.9850 - val_loss: 0.0699 - val_accuracy: 0.9778
Epoch 254/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0481 - accuracy:
0.9925 - val_loss: 0.1671 - val_accuracy: 0.9333
Epoch 255/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0654 - accuracy:
0.9925 - val_loss: 0.0721 - val_accuracy: 0.9778
Epoch 256/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0776 - accuracy:
0.9699 - val_loss: 0.0737 - val_accuracy: 0.9778
Epoch 257/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0742 - accuracy:
0.9774 - val_loss: 0.1401 - val_accuracy: 0.9778
```

```
Epoch 258/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1396 - accuracy:
0.9624 - val_loss: 0.3882 - val_accuracy: 0.8889
Epoch 259/300
5/5 [==============================] - 0s 8ms/step - loss: 0.3641 - accuracy:
0.9248 - val_loss: 0.8502 - val_accuracy: 0.8000
Epoch 260/300
5/5 [==============================] - 0s 7ms/step - loss: 0.6919 - accuracy:
0.8496 - val_loss: 0.1691 - val_accuracy: 0.9111
Epoch 261/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0945 - accuracy:
0.9850 - val_loss: 0.2105 - val_accuracy: 0.9778
Epoch 262/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1558 - accuracy:
0.9474 - val_loss: 0.3919 - val_accuracy: 0.8889
Epoch 263/300
5/5 [==============================] - 0s 8ms/step - loss: 0.4159 - accuracy:
0.9098 - val_loss: 0.2118 - val_accuracy: 0.9778
Epoch 264/300
5/5 [==============================] - 0s 8ms/step - loss: 0.4318 - accuracy:
0.8947 - val_loss: 0.3176 - val_accuracy: 0.9111
Epoch 265/300
5/5 [==============================] - 0s 7ms/step - loss: 0.5518 - accuracy:
0.8722 - val_loss: 0.1188 - val_accuracy: 0.9333
Epoch 266/300
5/5 [==============================] - 0s 8ms/step - loss: 0.1597 - accuracy:
0.9474 - val_loss: 0.0819 - val_accuracy: 0.9778
Epoch 267/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0438 - accuracy:
0.9774 - val_loss: 0.0899 - val_accuracy: 0.9556
Epoch 268/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0716 - accuracy:
0.9774 - val_loss: 0.0558 - val_accuracy: 0.9778
Epoch 269/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0496 - accuracy:
0.9850 - val_loss: 0.0635 - val_accuracy: 0.9778
Epoch 270/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0379 - accuracy:
0.9925 - val_loss: 0.0718 - val_accuracy: 0.9778
Epoch 271/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0446 - accuracy:
0.9850 - val_loss: 0.0506 - val_accuracy: 1.0000
Epoch 272/300
5/5 [==============================] - 0s 10ms/step - loss: 0.0355 - accuracy:
0.9925 - val_loss: 0.0490 - val_accuracy: 1.0000
Epoch 273/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0328 - accuracy:
0.9925 - val_loss: 0.0586 - val_accuracy: 0.9778
```

```
Epoch 274/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0308 - accuracy:
1.0000 - val_loss: 0.0582 - val_accuracy: 0.9778
Epoch 275/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0283 - accuracy:
0.9925 - val_loss: 0.0517 - val_accuracy: 1.0000
Epoch 276/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0290 - accuracy:
0.9925 - val_loss: 0.0526 - val_accuracy: 1.0000
Epoch 277/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0277 - accuracy:
1.0000 - val_loss: 0.0541 - val_accuracy: 0.9778
Epoch 278/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0266 - accuracy:
1.0000 - val_loss: 0.0534 - val_accuracy: 1.0000
Epoch 279/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0268 - accuracy:
0.9925 - val_loss: 0.0537 - val_accuracy: 0.9778
Epoch 280/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0259 - accuracy:
1.0000 - val_loss: 0.0539 - val_accuracy: 0.9778
Epoch 281/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0254 - accuracy:
1.0000 - val_loss: 0.0526 - val_accuracy: 0.9778
Epoch 282/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0251 - accuracy:
1.0000 - val_loss: 0.0524 - val_accuracy: 0.9778
Epoch 283/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0247 - accuracy:
1.0000 - val_loss: 0.0537 - val_accuracy: 0.9778
Epoch 284/300
5/5 [==============================] - 0s 10ms/step - loss: 0.0243 - accuracy:
1.0000 - val_loss: 0.0547 - val_accuracy: 0.9778
Epoch 285/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0240 - accuracy:
1.0000 - val_loss: 0.0548 - val_accuracy: 0.9778
Epoch 286/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0236 - accuracy:
1.0000 - val_loss: 0.0543 - val_accuracy: 0.9778
Epoch 287/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0233 - accuracy:
1.0000 - val_loss: 0.0539 - val_accuracy: 0.9778
Epoch 288/300
5/5 [==============================] - 0s 10ms/step - loss: 0.0230 - accuracy:
1.0000 - val_loss: 0.0541 - val_accuracy: 0.9778
Epoch 289/300
5/5 [==============================] - 0s 11ms/step - loss: 0.0226 - accuracy:
1.0000 - val_loss: 0.0546 - val_accuracy: 0.9778
```

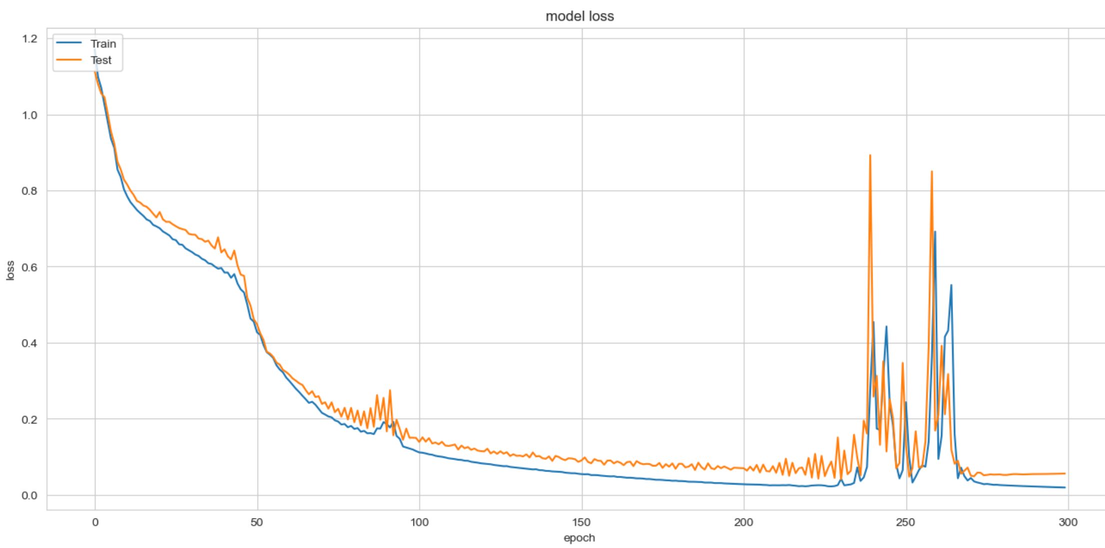
```
Epoch 290/300
5/5 [==============================] - 0s 11ms/step - loss: 0.0223 - accuracy:
1.0000 - val_loss: 0.0548 - val_accuracy: 0.9778
Epoch 291/300
5/5 [==============================] - 0s 10ms/step - loss: 0.0220 - accuracy:
1.0000 - val_loss: 0.0548 - val_accuracy: 0.9778
Epoch 292/300
5/5 [==============================] - 0s 9ms/step - loss: 0.0217 - accuracy:
1.0000 - val_loss: 0.0548 - val_accuracy: 0.9778
Epoch 293/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0214 - accuracy:
1.0000 - val_loss: 0.0549 - val_accuracy: 0.9778
Epoch 294/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0211 - accuracy:
1.0000 - val_loss: 0.0551 - val_accuracy: 0.9778
Epoch 295/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0209 - accuracy:
1.0000 - val_loss: 0.0553 - val_accuracy: 0.9778
Epoch 296/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0206 - accuracy:
1.0000 - val_loss: 0.0555 - val_accuracy: 0.9778
Epoch 297/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0203 - accuracy:
1.0000 - val_loss: 0.0556 - val_accuracy: 0.9778
Epoch 298/300
5/5 [==============================] - 0s 7ms/step - loss: 0.0201 - accuracy:
1.0000 - val_loss: 0.0558 - val_accuracy: 0.9778
Epoch 299/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0198 - accuracy:
1.0000 - val_loss: 0.0560 - val_accuracy: 0.9778
Epoch 300/300
5/5 [==============================] - 0s 8ms/step - loss: 0.0196 - accuracy:
1.0000 - val_loss: 0.0562 - val_accuracy: 0.9778
Best epoch: 115
```

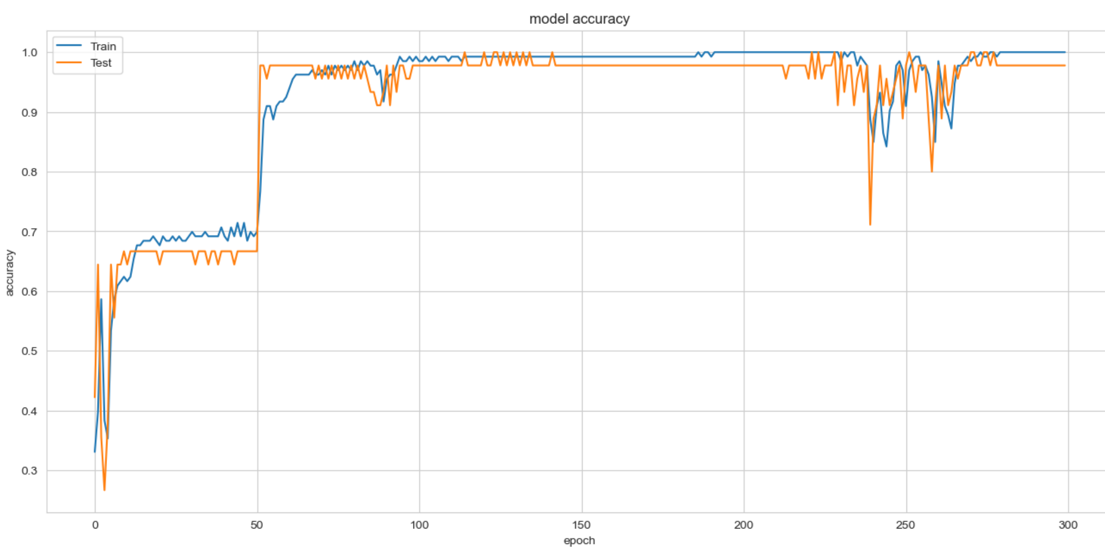
[15]:
```
fig = plt.figure(figsize=(16, 16))

ax1 = fig.add_subplot(2,1,1)
ax1.plot(history.history['loss'])
ax1.plot(history.history['val_loss'])
ax1.set_title('model loss')
ax1.set_ylabel('loss')
ax1.set_xlabel('epoch')
ax1.legend(['Train', 'Test'], loc='upper left')

ax2 = fig.add_subplot(2,1,2)
ax2.plot(history.history['accuracy'])
```

```
ax2.plot(history.history['val_accuracy'])
ax2.set_title('model accuracy')
ax2.set_ylabel('accuracy')
ax2.set_xlabel('epoch')
ax2.legend(['Train', 'Test'], loc='upper left')
fig.show()
```





[16]:
```
y_pred = model.predict(X_test)
y_pred = np.argmax(y_pred, axis=1)
y_test_am = np.argmax(y_test, axis=1)

print(confusion_matrix(y_test_am, y_pred))
```

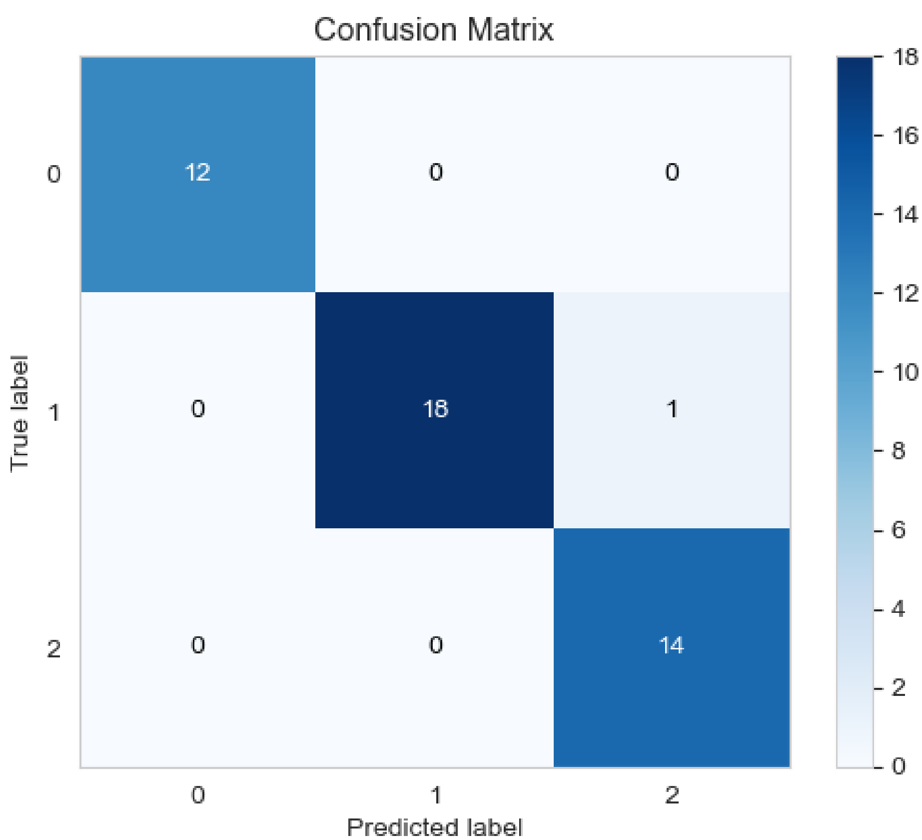
```
print(classification_report(y_test_am, y_pred, labels=[0,1,2]))

plot_confusion_matrix(y_test_am, y_pred)
plt.show()
```

```
2/2 [==============================] - 0s 3ms/step
[[12  0  0]
 [ 0 18  1]
 [ 0  0 14]]
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        12
           1       1.00      0.95      0.97        19
           2       0.93      1.00      0.97        14

    accuracy                           0.98        45
   macro avg       0.98      0.98      0.98        45
weighted avg       0.98      0.98      0.98        45
```



[18]:
```
print("""The precision of the model seems to be pretty great, the recall is␣
↪pretty solid, and the f1-score is quite solid overall. The accuracy is good␣
↪as well. Overall, very few issues in the predictions on the test set, so␣
↪this model is probably not overfit. The accuracy vs. val accuracy was around␣
↪100% vs. 98%, so that's better obviously but really not a huge difference.␣
↪All in all, I think the model is well fit.""")
```

```
The precision of the model seems to be pretty great, the recall is pretty solid,
and the f1-score is quite solid overall. The accuracy is good as well. Overall,
very few issues in the predictions on the test set, so this model is probably
not overfit. The accuracy vs. val accuracy was around 100% vs. 98%, so that's
better obviously but really not a huge difference. All in all, I think the model
is well fit.
```

[ ]: