

DAT405 Assignment 5 – Group 38

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May 17, 2023

```
[4]: # imports
from __future__ import print_function
import keras
from keras import utils as np_utils
import tensorflow
from keras.datasets import mnist
from keras.models import Sequential
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from keras import backend as K
import tensorflow as tf
from matplotlib import pyplot as plt
from tensorflow.python.keras import regularizers
import numpy
```

```
2023-05-15 10:39:57.395321: I tensorflow/core/platform/cpu_feature_guard.cc:182]
This TensorFlow binary is optimized to use available CPU instructions in
performance-critical operations.
To enable the following instructions: AVX2 FMA, in other operations, rebuild
TensorFlow with the appropriate compiler flags.
```

```
[5]: # Hyper-parameters data-loading and formatting

batch_size = 128
num_classes = 10
epochs = 10

img_rows, img_cols = 28, 28

(x_train, lbl_train), (x_test, lbl_test) = mnist.load_data()
print(type(lbl_train))
if K.image_data_format() == 'channels_first':
    x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
    x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
    input_shape = (1, img_rows, img_cols)
else:
    x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
```

```
x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
input_shape = (img_rows, img_cols, 1)
```

Downloading data from <https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz>

11490434/11490434 [=====] - 0s 0us/step

<class 'numpy.ndarray'>

Preprocessing

```
[6]: x_train = x_train.astype('float32')
      x_test = x_test.astype('float32')

      x_train /= 255
      x_test /= 255

      y_train = keras.utils.np_utils.to_categorical(lbl_train, num_classes)
      y_test = keras.utils.np_utils.to_categorical(lbl_test, num_classes)
```

1. Preprocessing

Task 1 In preprocessing we make a copy of the array and cast it to a float32 type. We divide training and test values by 255. Each pixel has a value from 0 to 255, and we need to normalise it between 0 and 1. Then we convert a label which is an integer k into a numpy array of length 10, which has zeros and 1 on k th place.

```
[7]: ## Define model ##
      model = Sequential()

      model.add(Flatten())
      model.add(Dense(64, activation = 'relu'))
      model.add(Dense(64, activation = 'relu'))
      model.add(Dense(num_classes, activation='softmax'))

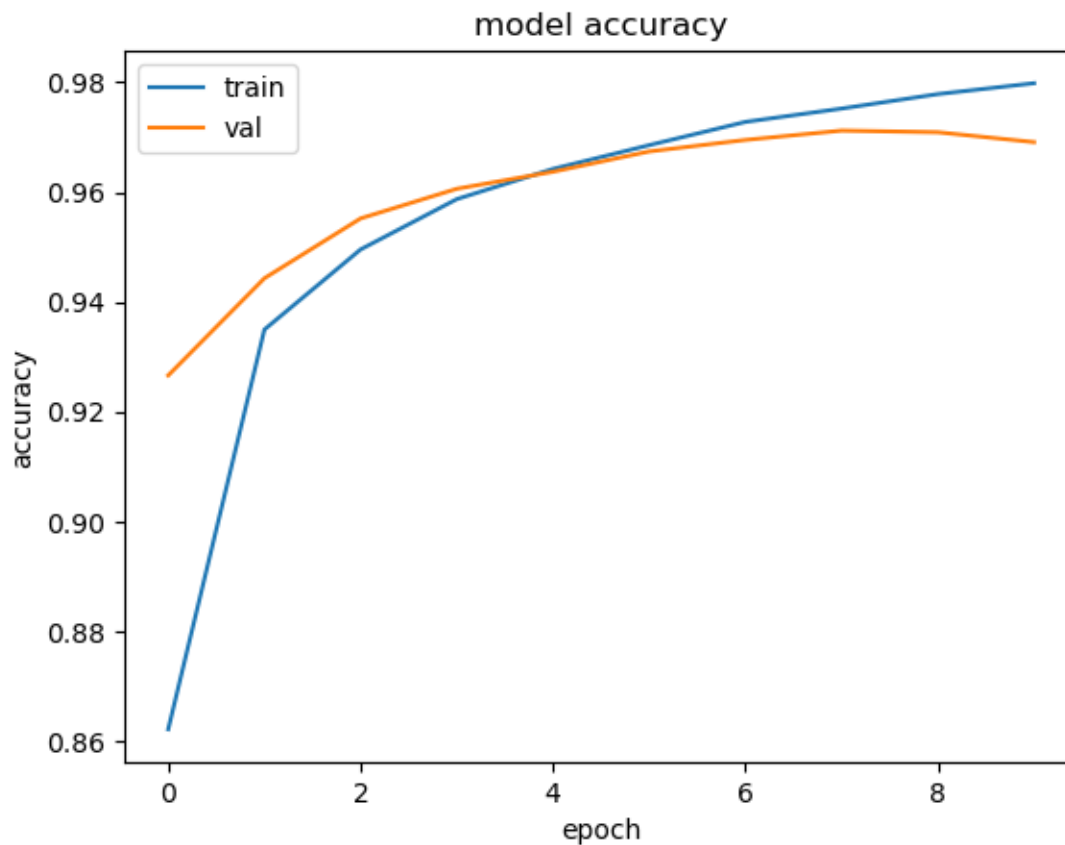
      model.compile(loss=keras.losses.categorical_crossentropy,
                    optimizer=tensorflow.keras.optimizers.SGD(learning_rate = 0.1),
                    metrics=['accuracy'],)

      history = model.fit(x_train, y_train,
                          batch_size=batch_size,
                          epochs=epochs,
                          verbose=1,
                          validation_data=(x_test, y_test))
      plt.plot(history.history['accuracy'])
      plt.plot(history.history['val_accuracy'])
      plt.title('model accuracy')
      plt.ylabel('accuracy')
```

```
plt.xlabel('epoch')
plt.legend(['train', 'val'], loc='upper left')
plt.show()

score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss: {}, Test accuracy {}'.format(score[0], score[1]))
```

```
Epoch 1/10
469/469 [=====] - 1s 2ms/step - loss: 0.4839 -
accuracy: 0.8621 - val_loss: 0.2551 - val_accuracy: 0.9266
Epoch 2/10
469/469 [=====] - 1s 1ms/step - loss: 0.2242 -
accuracy: 0.9349 - val_loss: 0.1889 - val_accuracy: 0.9443
Epoch 3/10
469/469 [=====] - 1s 1ms/step - loss: 0.1734 -
accuracy: 0.9495 - val_loss: 0.1570 - val_accuracy: 0.9552
Epoch 4/10
469/469 [=====] - 1s 1ms/step - loss: 0.1432 -
accuracy: 0.9587 - val_loss: 0.1324 - val_accuracy: 0.9606
Epoch 5/10
469/469 [=====] - 1s 1ms/step - loss: 0.1212 -
accuracy: 0.9642 - val_loss: 0.1234 - val_accuracy: 0.9637
Epoch 6/10
469/469 [=====] - 1s 1ms/step - loss: 0.1062 -
accuracy: 0.9686 - val_loss: 0.1099 - val_accuracy: 0.9674
Epoch 7/10
469/469 [=====] - 1s 1ms/step - loss: 0.0938 -
accuracy: 0.9728 - val_loss: 0.1037 - val_accuracy: 0.9695
Epoch 8/10
469/469 [=====] - 1s 1ms/step - loss: 0.0844 -
accuracy: 0.9752 - val_loss: 0.0987 - val_accuracy: 0.9712
Epoch 9/10
469/469 [=====] - 1s 1ms/step - loss: 0.0763 -
accuracy: 0.9779 - val_loss: 0.1008 - val_accuracy: 0.9709
Epoch 10/10
469/469 [=====] - 1s 1ms/step - loss: 0.0694 -
accuracy: 0.9798 - val_loss: 0.1024 - val_accuracy: 0.9691
```



Test loss: 0.10235051810741425, Test accuracy 0.9690999984741211

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

Model: "sequential"

Layer (type)	Output Shape	Param #
flatten (Flatten)	(None, 784)	0
dense (Dense)	(None, 64)	50240
dense_1 (Dense)	(None, 64)	4160
dense_2 (Dense)	(None, 10)	650

Total params: 55,050

Trainable params: 55,050

Non-trainable params: 0

2. Network model, training, and changing hyper-parameters

Task 2.1 There are 4 layers in the network. First has $28 \times 28 = 784$ neurons. Second and third layer has 64 neurons, they are activated with ReLU function, which is the most common activation function. The third one has 10 neurons, it is activated with softmax function. Softmax function is used here because it's at the end of a neural network, it converts the output of previous layer into a probability distribution. There are 55,050 parameters in the model. Input has length 784 because each picture has shape 28×28 pixels and each has a value. Output length is 10 because it has a 'probability' value for each class (0-9).

Task 2.2 CategoricalCrossentropy function has been used. The smaller the cross-entropy, the more similar the two probability distributions are. It is appropriate for the problem at hand because a probability distribution is what we get from the network.

$$\mathbb{L}(y, s) = - \sum_{i=1}^C y_i \cdot \log(s_i)$$

It takes as input two discrete probability distributions. C denotes the number of different classes. y is a given label and s is a vector of the probabilities generated by the softmax layer.

Task 2.3

```
[9]: epochs = 40
model = Sequential()

model.add(Flatten())
model.add(Dense(500, activation = 'relu'))
model.add(Dense(300, activation = 'relu'))
model.add(Dense(num_classes, activation='softmax'))

model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=tensorflow.keras.optimizers.SGD(learning_rate = 0.1),
              metrics=['accuracy'],)

history = model.fit(x_train, y_train,
                  batch_size=batch_size,
                  epochs=epochs,
                  verbose=1,
                  validation_data=(x_test, y_test))
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'val'], loc='upper left')
plt.show()
```

```
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss: {}, Test accuracy {}'.format(score[0], score[1]))
```

Epoch 1/40

469/469 [=====] - 2s 3ms/step - loss: 0.4034 - accuracy: 0.8887 - val_loss: 0.2106 - val_accuracy: 0.9407

Epoch 2/40

469/469 [=====] - 1s 2ms/step - loss: 0.1870 - accuracy: 0.9460 - val_loss: 0.1593 - val_accuracy: 0.9531

Epoch 3/40

469/469 [=====] - 1s 2ms/step - loss: 0.1355 - accuracy: 0.9611 - val_loss: 0.1208 - val_accuracy: 0.9637

Epoch 4/40

469/469 [=====] - 1s 2ms/step - loss: 0.1070 - accuracy: 0.9694 - val_loss: 0.1117 - val_accuracy: 0.9662

Epoch 5/40

469/469 [=====] - 1s 3ms/step - loss: 0.0867 - accuracy: 0.9750 - val_loss: 0.0911 - val_accuracy: 0.9705

Epoch 6/40

469/469 [=====] - 1s 3ms/step - loss: 0.0725 - accuracy: 0.9793 - val_loss: 0.0829 - val_accuracy: 0.9749

Epoch 7/40

469/469 [=====] - 1s 3ms/step - loss: 0.0620 - accuracy: 0.9821 - val_loss: 0.0785 - val_accuracy: 0.9756

Epoch 8/40

469/469 [=====] - 1s 2ms/step - loss: 0.0527 - accuracy: 0.9854 - val_loss: 0.0732 - val_accuracy: 0.9774

Epoch 9/40

469/469 [=====] - 1s 3ms/step - loss: 0.0459 - accuracy: 0.9869 - val_loss: 0.0745 - val_accuracy: 0.9753

Epoch 10/40

469/469 [=====] - 1s 3ms/step - loss: 0.0398 - accuracy: 0.9887 - val_loss: 0.0678 - val_accuracy: 0.9782

Epoch 11/40

469/469 [=====] - 1s 3ms/step - loss: 0.0346 - accuracy: 0.9910 - val_loss: 0.0669 - val_accuracy: 0.9796

Epoch 12/40

469/469 [=====] - 1s 2ms/step - loss: 0.0301 - accuracy: 0.9921 - val_loss: 0.0669 - val_accuracy: 0.9791

Epoch 13/40

469/469 [=====] - 1s 3ms/step - loss: 0.0261 - accuracy: 0.9936 - val_loss: 0.0664 - val_accuracy: 0.9788

Epoch 14/40

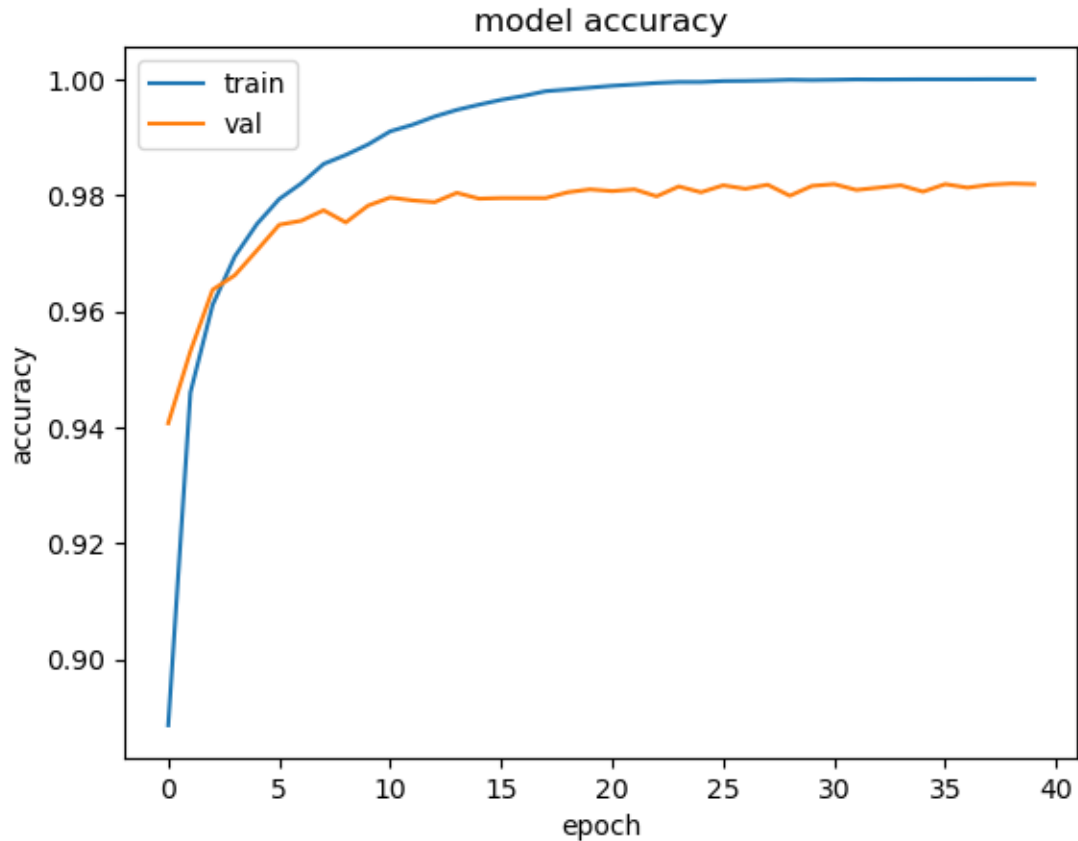
469/469 [=====] - 1s 3ms/step - loss: 0.0226 - accuracy: 0.9947 - val_loss: 0.0655 - val_accuracy: 0.9804

Epoch 15/40

469/469 [=====] - 1s 3ms/step - loss: 0.0200 - accuracy: 0.9956 - val_loss: 0.0658 - val_accuracy: 0.9794

Epoch 16/40
469/469 [=====] - 1s 3ms/step - loss: 0.0173 -
accuracy: 0.9964 - val_loss: 0.0646 - val_accuracy: 0.9795
Epoch 17/40
469/469 [=====] - 1s 2ms/step - loss: 0.0152 -
accuracy: 0.9971 - val_loss: 0.0651 - val_accuracy: 0.9795
Epoch 18/40
469/469 [=====] - 1s 2ms/step - loss: 0.0131 -
accuracy: 0.9979 - val_loss: 0.0638 - val_accuracy: 0.9795
Epoch 19/40
469/469 [=====] - 1s 2ms/step - loss: 0.0118 -
accuracy: 0.9982 - val_loss: 0.0606 - val_accuracy: 0.9805
Epoch 20/40
469/469 [=====] - 1s 2ms/step - loss: 0.0104 -
accuracy: 0.9985 - val_loss: 0.0632 - val_accuracy: 0.9810
Epoch 21/40
469/469 [=====] - 1s 2ms/step - loss: 0.0091 -
accuracy: 0.9988 - val_loss: 0.0620 - val_accuracy: 0.9807
Epoch 22/40
469/469 [=====] - 1s 3ms/step - loss: 0.0082 -
accuracy: 0.9991 - val_loss: 0.0633 - val_accuracy: 0.9810
Epoch 23/40
469/469 [=====] - 1s 2ms/step - loss: 0.0072 -
accuracy: 0.9993 - val_loss: 0.0658 - val_accuracy: 0.9798
Epoch 24/40
469/469 [=====] - 1s 2ms/step - loss: 0.0064 -
accuracy: 0.9995 - val_loss: 0.0625 - val_accuracy: 0.9815
Epoch 25/40
469/469 [=====] - 1s 2ms/step - loss: 0.0059 -
accuracy: 0.9995 - val_loss: 0.0652 - val_accuracy: 0.9805
Epoch 26/40
469/469 [=====] - 1s 2ms/step - loss: 0.0052 -
accuracy: 0.9997 - val_loss: 0.0633 - val_accuracy: 0.9817
Epoch 27/40
469/469 [=====] - 1s 2ms/step - loss: 0.0048 -
accuracy: 0.9997 - val_loss: 0.0648 - val_accuracy: 0.9811
Epoch 28/40
469/469 [=====] - 1s 2ms/step - loss: 0.0043 -
accuracy: 0.9998 - val_loss: 0.0640 - val_accuracy: 0.9818
Epoch 29/40
469/469 [=====] - 1s 2ms/step - loss: 0.0038 -
accuracy: 0.9999 - val_loss: 0.0680 - val_accuracy: 0.9799
Epoch 30/40
469/469 [=====] - 1s 2ms/step - loss: 0.0037 -
accuracy: 0.9998 - val_loss: 0.0649 - val_accuracy: 0.9816
Epoch 31/40
469/469 [=====] - 1s 2ms/step - loss: 0.0033 -
accuracy: 0.9999 - val_loss: 0.0657 - val_accuracy: 0.9819

Epoch 32/40
469/469 [=====] - 1s 2ms/step - loss: 0.0030 -
accuracy: 0.9999 - val_loss: 0.0681 - val_accuracy: 0.9809
Epoch 33/40
469/469 [=====] - 1s 2ms/step - loss: 0.0028 -
accuracy: 0.9999 - val_loss: 0.0659 - val_accuracy: 0.9813
Epoch 34/40
469/469 [=====] - 1s 2ms/step - loss: 0.0026 -
accuracy: 0.9999 - val_loss: 0.0664 - val_accuracy: 0.9817
Epoch 35/40
469/469 [=====] - 1s 2ms/step - loss: 0.0025 -
accuracy: 1.0000 - val_loss: 0.0668 - val_accuracy: 0.9806
Epoch 36/40
469/469 [=====] - 1s 2ms/step - loss: 0.0023 -
accuracy: 1.0000 - val_loss: 0.0660 - val_accuracy: 0.9819
Epoch 37/40
469/469 [=====] - 1s 2ms/step - loss: 0.0022 -
accuracy: 1.0000 - val_loss: 0.0680 - val_accuracy: 0.9813
Epoch 38/40
469/469 [=====] - 1s 2ms/step - loss: 0.0021 -
accuracy: 1.0000 - val_loss: 0.0677 - val_accuracy: 0.9818
Epoch 39/40
469/469 [=====] - 1s 2ms/step - loss: 0.0020 -
accuracy: 1.0000 - val_loss: 0.0678 - val_accuracy: 0.9820
Epoch 40/40
469/469 [=====] - 1s 2ms/step - loss: 0.0019 -
accuracy: 1.0000 - val_loss: 0.0674 - val_accuracy: 0.9819



Test loss: 0.06744514405727386, Test accuracy 0.9818999767303467

The best validation accuracy we can achieve is 0.9820.

```
[104]: epochs = 40
val = [[0 for x in range(5)] for y in range(3)]
param = [0.000001, 0.00001, 0.0001, 0.0005, 0.001]

for i in range(5):
    for j in range(3):

        model = Sequential()

        model.add(Flatten())
        model.add(Dense(500, activation = 'relu',
↪kernel_regularizer=regularizers.L2(param[i])))
        model.add(Dense(300, activation = 'relu',
↪kernel_regularizer=regularizers.L2(param[i])))
        model.add(Dense(num_classes, activation='softmax'))
```

```

model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=tensorflow.keras.optimizers.SGD(learning_rate = 0.1),
              metrics=['accuracy'],)

history = model.fit(x_train, y_train,
                    batch_size=batch_size,
                    epochs=epochs,
                    verbose=1,
                    validation_data=(x_test, y_test))

val[j][i] = history.history['val_accuracy'][epochs-1]
score = model.evaluate(x_test, y_test, verbose=0)

val = numpy.asarray(val)
std_dev = [0 for i in range(5)]
mean = [0 for i in range(5)]
for i in range(5):
    std_dev[i] = numpy.std(val[:,i])
    mean[i] = numpy.mean(val[:,i])

print('Test loss: {}, Test accuracy {}'.format(score[0], score[1]))
plt.plot(param, mean)
plt.errorbar(param, mean,
             yerr = std_dev,
             fmt = 'o')
plt.title('parameter comparison')
plt.ylabel('validation accuracy')
plt.xlabel('regularization factor')
plt.legend(['val acc', 'std dev'], loc='upper left')
plt.show()

```

```

Epoch 1/40
469/469 [=====] - 4s 8ms/step - loss: 0.4059 -
accuracy: 0.8881 - val_loss: 0.2120 - val_accuracy: 0.9399
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.1909 -
accuracy: 0.9458 - val_loss: 0.1626 - val_accuracy: 0.9534
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.1394 -
accuracy: 0.9601 - val_loss: 0.1232 - val_accuracy: 0.9645
Epoch 4/40
469/469 [=====] - 4s 8ms/step - loss: 0.1092 -
accuracy: 0.9690 - val_loss: 0.1075 - val_accuracy: 0.9681
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.0886 -
accuracy: 0.9751 - val_loss: 0.0956 - val_accuracy: 0.9709
Epoch 6/40

```

469/469 [=====] - 3s 7ms/step - loss: 0.0749 -
accuracy: 0.9790 - val_loss: 0.0873 - val_accuracy: 0.9742
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.0635 -
accuracy: 0.9823 - val_loss: 0.0789 - val_accuracy: 0.9761
Epoch 8/40
469/469 [=====] - 4s 8ms/step - loss: 0.0541 -
accuracy: 0.9855 - val_loss: 0.0749 - val_accuracy: 0.9769
Epoch 9/40
469/469 [=====] - 4s 8ms/step - loss: 0.0472 -
accuracy: 0.9872 - val_loss: 0.0710 - val_accuracy: 0.9791
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.0414 -
accuracy: 0.9892 - val_loss: 0.0719 - val_accuracy: 0.9787
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.0359 -
accuracy: 0.9910 - val_loss: 0.0672 - val_accuracy: 0.9791
Epoch 12/40
469/469 [=====] - 4s 8ms/step - loss: 0.0317 -
accuracy: 0.9921 - val_loss: 0.0712 - val_accuracy: 0.9775
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.0275 -
accuracy: 0.9935 - val_loss: 0.0700 - val_accuracy: 0.9789
Epoch 14/40
469/469 [=====] - 3s 7ms/step - loss: 0.0242 -
accuracy: 0.9946 - val_loss: 0.0665 - val_accuracy: 0.9788
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.0213 -
accuracy: 0.9959 - val_loss: 0.0653 - val_accuracy: 0.9794
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.0189 -
accuracy: 0.9964 - val_loss: 0.0680 - val_accuracy: 0.9804
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.0167 -
accuracy: 0.9971 - val_loss: 0.0631 - val_accuracy: 0.9811
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.0143 -
accuracy: 0.9980 - val_loss: 0.0668 - val_accuracy: 0.9799
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.0131 -
accuracy: 0.9983 - val_loss: 0.0636 - val_accuracy: 0.9817
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.0116 -
accuracy: 0.9986 - val_loss: 0.0661 - val_accuracy: 0.9808
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.0105 -
accuracy: 0.9991 - val_loss: 0.0634 - val_accuracy: 0.9809
Epoch 22/40

469/469 [=====] - 3s 7ms/step - loss: 0.0094 -
accuracy: 0.9991 - val_loss: 0.0655 - val_accuracy: 0.9805
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.0084 -
accuracy: 0.9993 - val_loss: 0.0645 - val_accuracy: 0.9804
Epoch 24/40
469/469 [=====] - 4s 8ms/step - loss: 0.0076 -
accuracy: 0.9995 - val_loss: 0.0653 - val_accuracy: 0.9817
Epoch 25/40
469/469 [=====] - 4s 8ms/step - loss: 0.0070 -
accuracy: 0.9996 - val_loss: 0.0639 - val_accuracy: 0.9819
Epoch 26/40
469/469 [=====] - 4s 8ms/step - loss: 0.0064 -
accuracy: 0.9996 - val_loss: 0.0639 - val_accuracy: 0.9820
Epoch 27/40
469/469 [=====] - 4s 8ms/step - loss: 0.0058 -
accuracy: 0.9997 - val_loss: 0.0642 - val_accuracy: 0.9813
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.0055 -
accuracy: 0.9997 - val_loss: 0.0665 - val_accuracy: 0.9810
Epoch 29/40
469/469 [=====] - 4s 8ms/step - loss: 0.0051 -
accuracy: 0.9999 - val_loss: 0.0673 - val_accuracy: 0.9806
Epoch 30/40
469/469 [=====] - 4s 7ms/step - loss: 0.0047 -
accuracy: 0.9999 - val_loss: 0.0659 - val_accuracy: 0.9819
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0045 -
accuracy: 0.9999 - val_loss: 0.0656 - val_accuracy: 0.9821
Epoch 32/40
469/469 [=====] - 4s 8ms/step - loss: 0.0041 -
accuracy: 0.9999 - val_loss: 0.0649 - val_accuracy: 0.9818
Epoch 33/40
469/469 [=====] - 3s 7ms/step - loss: 0.0040 -
accuracy: 0.9999 - val_loss: 0.0662 - val_accuracy: 0.9817
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0038 -
accuracy: 1.0000 - val_loss: 0.0665 - val_accuracy: 0.9816
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0036 -
accuracy: 1.0000 - val_loss: 0.0664 - val_accuracy: 0.9823
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0035 -
accuracy: 1.0000 - val_loss: 0.0680 - val_accuracy: 0.9815
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0034 -
accuracy: 1.0000 - val_loss: 0.0669 - val_accuracy: 0.9823
Epoch 38/40

469/469 [=====] - 3s 7ms/step - loss: 0.0033 -
accuracy: 1.0000 - val_loss: 0.0675 - val_accuracy: 0.9826
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0031 -
accuracy: 1.0000 - val_loss: 0.0677 - val_accuracy: 0.9824
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0030 -
accuracy: 1.0000 - val_loss: 0.0678 - val_accuracy: 0.9826
Epoch 1/40
469/469 [=====] - 4s 7ms/step - loss: 0.4012 -
accuracy: 0.8891 - val_loss: 0.2286 - val_accuracy: 0.9347
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.1899 -
accuracy: 0.9454 - val_loss: 0.1604 - val_accuracy: 0.9528
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.1376 -
accuracy: 0.9610 - val_loss: 0.1250 - val_accuracy: 0.9628
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.1090 -
accuracy: 0.9691 - val_loss: 0.1054 - val_accuracy: 0.9690
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.0898 -
accuracy: 0.9747 - val_loss: 0.0967 - val_accuracy: 0.9709
Epoch 6/40
469/469 [=====] - 3s 7ms/step - loss: 0.0750 -
accuracy: 0.9787 - val_loss: 0.0819 - val_accuracy: 0.9746
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.0641 -
accuracy: 0.9816 - val_loss: 0.0749 - val_accuracy: 0.9769
Epoch 8/40
469/469 [=====] - 3s 6ms/step - loss: 0.0551 -
accuracy: 0.9845 - val_loss: 0.0736 - val_accuracy: 0.9785
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.0475 -
accuracy: 0.9870 - val_loss: 0.0709 - val_accuracy: 0.9777
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.0409 -
accuracy: 0.9890 - val_loss: 0.0736 - val_accuracy: 0.9772
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.0360 -
accuracy: 0.9907 - val_loss: 0.0690 - val_accuracy: 0.9780
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.0317 -
accuracy: 0.9922 - val_loss: 0.0654 - val_accuracy: 0.9805
Epoch 13/40
469/469 [=====] - 3s 6ms/step - loss: 0.0278 -
accuracy: 0.9934 - val_loss: 0.0655 - val_accuracy: 0.9801
Epoch 14/40

469/469 [=====] - 3s 6ms/step - loss: 0.0241 -
accuracy: 0.9948 - val_loss: 0.0621 - val_accuracy: 0.9813
Epoch 15/40
469/469 [=====] - 3s 6ms/step - loss: 0.0213 -
accuracy: 0.9955 - val_loss: 0.0657 - val_accuracy: 0.9812
Epoch 16/40
469/469 [=====] - 3s 6ms/step - loss: 0.0187 -
accuracy: 0.9965 - val_loss: 0.0673 - val_accuracy: 0.9802
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.0165 -
accuracy: 0.9971 - val_loss: 0.0649 - val_accuracy: 0.9809
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.0146 -
accuracy: 0.9979 - val_loss: 0.0626 - val_accuracy: 0.9819
Epoch 19/40
469/469 [=====] - 3s 6ms/step - loss: 0.0131 -
accuracy: 0.9983 - val_loss: 0.0626 - val_accuracy: 0.9818
Epoch 20/40
469/469 [=====] - 3s 6ms/step - loss: 0.0117 -
accuracy: 0.9986 - val_loss: 0.0619 - val_accuracy: 0.9820
Epoch 21/40
469/469 [=====] - 3s 6ms/step - loss: 0.0105 -
accuracy: 0.9987 - val_loss: 0.0635 - val_accuracy: 0.9815
Epoch 22/40
469/469 [=====] - 3s 6ms/step - loss: 0.0093 -
accuracy: 0.9992 - val_loss: 0.0622 - val_accuracy: 0.9814
Epoch 23/40
469/469 [=====] - 3s 6ms/step - loss: 0.0084 -
accuracy: 0.9993 - val_loss: 0.0622 - val_accuracy: 0.9825
Epoch 24/40
469/469 [=====] - 3s 6ms/step - loss: 0.0077 -
accuracy: 0.9995 - val_loss: 0.0636 - val_accuracy: 0.9815
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.0069 -
accuracy: 0.9997 - val_loss: 0.0622 - val_accuracy: 0.9826
Epoch 26/40
469/469 [=====] - 3s 6ms/step - loss: 0.0065 -
accuracy: 0.9997 - val_loss: 0.0642 - val_accuracy: 0.9820
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.0059 -
accuracy: 0.9998 - val_loss: 0.0692 - val_accuracy: 0.9804
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.0056 -
accuracy: 0.9998 - val_loss: 0.0636 - val_accuracy: 0.9824
Epoch 29/40
469/469 [=====] - 4s 8ms/step - loss: 0.0051 -
accuracy: 0.9999 - val_loss: 0.0658 - val_accuracy: 0.9817
Epoch 30/40

469/469 [=====] - 3s 7ms/step - loss: 0.0048 -
accuracy: 0.9999 - val_loss: 0.0651 - val_accuracy: 0.9826
Epoch 31/40
469/469 [=====] - 4s 8ms/step - loss: 0.0045 -
accuracy: 0.9999 - val_loss: 0.0657 - val_accuracy: 0.9823
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0043 -
accuracy: 0.9999 - val_loss: 0.0650 - val_accuracy: 0.9830
Epoch 33/40
469/469 [=====] - 3s 7ms/step - loss: 0.0040 -
accuracy: 0.9999 - val_loss: 0.0646 - val_accuracy: 0.9833
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0038 -
accuracy: 0.9999 - val_loss: 0.0654 - val_accuracy: 0.9834
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0037 -
accuracy: 1.0000 - val_loss: 0.0658 - val_accuracy: 0.9823
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0035 -
accuracy: 1.0000 - val_loss: 0.0675 - val_accuracy: 0.9826
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0034 -
accuracy: 1.0000 - val_loss: 0.0665 - val_accuracy: 0.9824
Epoch 38/40
469/469 [=====] - 3s 7ms/step - loss: 0.0032 -
accuracy: 1.0000 - val_loss: 0.0671 - val_accuracy: 0.9824
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0031 -
accuracy: 1.0000 - val_loss: 0.0674 - val_accuracy: 0.9826
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0031 -
accuracy: 1.0000 - val_loss: 0.0677 - val_accuracy: 0.9825
Epoch 1/40
469/469 [=====] - 4s 7ms/step - loss: 0.4015 -
accuracy: 0.8894 - val_loss: 0.2265 - val_accuracy: 0.9349
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.1885 -
accuracy: 0.9452 - val_loss: 0.1573 - val_accuracy: 0.9546
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.1386 -
accuracy: 0.9599 - val_loss: 0.1335 - val_accuracy: 0.9600
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.1088 -
accuracy: 0.9700 - val_loss: 0.1127 - val_accuracy: 0.9671
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.0889 -
accuracy: 0.9744 - val_loss: 0.1018 - val_accuracy: 0.9701
Epoch 6/40

469/469 [=====] - 3s 7ms/step - loss: 0.0746 -
accuracy: 0.9792 - val_loss: 0.0856 - val_accuracy: 0.9739
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.0636 -
accuracy: 0.9819 - val_loss: 0.0801 - val_accuracy: 0.9751
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.0550 -
accuracy: 0.9844 - val_loss: 0.0843 - val_accuracy: 0.9745
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.0477 -
accuracy: 0.9870 - val_loss: 0.0847 - val_accuracy: 0.9734
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.0413 -
accuracy: 0.9888 - val_loss: 0.0752 - val_accuracy: 0.9770
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.0364 -
accuracy: 0.9908 - val_loss: 0.0716 - val_accuracy: 0.9794
Epoch 12/40
469/469 [=====] - 3s 6ms/step - loss: 0.0320 -
accuracy: 0.9922 - val_loss: 0.0681 - val_accuracy: 0.9807
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.0278 -
accuracy: 0.9935 - val_loss: 0.0648 - val_accuracy: 0.9812
Epoch 14/40
469/469 [=====] - 3s 7ms/step - loss: 0.0243 -
accuracy: 0.9948 - val_loss: 0.0662 - val_accuracy: 0.9805
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.0220 -
accuracy: 0.9953 - val_loss: 0.0647 - val_accuracy: 0.9799
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.0195 -
accuracy: 0.9961 - val_loss: 0.0642 - val_accuracy: 0.9814
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.0169 -
accuracy: 0.9970 - val_loss: 0.0657 - val_accuracy: 0.9804
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.0151 -
accuracy: 0.9977 - val_loss: 0.0615 - val_accuracy: 0.9815
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.0134 -
accuracy: 0.9981 - val_loss: 0.0621 - val_accuracy: 0.9819
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.0121 -
accuracy: 0.9983 - val_loss: 0.0662 - val_accuracy: 0.9817
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.0110 -
accuracy: 0.9987 - val_loss: 0.0637 - val_accuracy: 0.9820
Epoch 22/40

469/469 [=====] - 3s 7ms/step - loss: 0.0097 -
accuracy: 0.9991 - val_loss: 0.0634 - val_accuracy: 0.9817
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.0088 -
accuracy: 0.9993 - val_loss: 0.0616 - val_accuracy: 0.9815
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.0080 -
accuracy: 0.9994 - val_loss: 0.0624 - val_accuracy: 0.9818
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.0073 -
accuracy: 0.9995 - val_loss: 0.0682 - val_accuracy: 0.9798
Epoch 26/40
469/469 [=====] - 3s 6ms/step - loss: 0.0066 -
accuracy: 0.9997 - val_loss: 0.0656 - val_accuracy: 0.9813
Epoch 27/40
469/469 [=====] - 3s 6ms/step - loss: 0.0061 -
accuracy: 0.9998 - val_loss: 0.0638 - val_accuracy: 0.9815
Epoch 28/40
469/469 [=====] - 3s 6ms/step - loss: 0.0058 -
accuracy: 0.9997 - val_loss: 0.0645 - val_accuracy: 0.9817
Epoch 29/40
469/469 [=====] - 3s 7ms/step - loss: 0.0053 -
accuracy: 0.9999 - val_loss: 0.0659 - val_accuracy: 0.9820
Epoch 30/40
469/469 [=====] - 3s 7ms/step - loss: 0.0050 -
accuracy: 0.9999 - val_loss: 0.0653 - val_accuracy: 0.9822
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0047 -
accuracy: 0.9999 - val_loss: 0.0660 - val_accuracy: 0.9819
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0043 -
accuracy: 0.9999 - val_loss: 0.0662 - val_accuracy: 0.9820
Epoch 33/40
469/469 [=====] - 3s 6ms/step - loss: 0.0041 -
accuracy: 0.9999 - val_loss: 0.0665 - val_accuracy: 0.9819
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0039 -
accuracy: 0.9999 - val_loss: 0.0677 - val_accuracy: 0.9816
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0037 -
accuracy: 1.0000 - val_loss: 0.0683 - val_accuracy: 0.9822
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0036 -
accuracy: 1.0000 - val_loss: 0.0677 - val_accuracy: 0.9817
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0035 -
accuracy: 1.0000 - val_loss: 0.0690 - val_accuracy: 0.9818
Epoch 38/40

469/469 [=====] - 3s 7ms/step - loss: 0.0033 -
accuracy: 1.0000 - val_loss: 0.0686 - val_accuracy: 0.9818
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0032 -
accuracy: 1.0000 - val_loss: 0.0680 - val_accuracy: 0.9819
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0031 -
accuracy: 1.0000 - val_loss: 0.0688 - val_accuracy: 0.9818
Epoch 1/40
469/469 [=====] - 4s 7ms/step - loss: 0.4127 -
accuracy: 0.8872 - val_loss: 0.2426 - val_accuracy: 0.9347
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.2000 -
accuracy: 0.9455 - val_loss: 0.1793 - val_accuracy: 0.9499
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.1500 -
accuracy: 0.9603 - val_loss: 0.1342 - val_accuracy: 0.9636
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.1206 -
accuracy: 0.9679 - val_loss: 0.1182 - val_accuracy: 0.9659
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.1009 -
accuracy: 0.9739 - val_loss: 0.1132 - val_accuracy: 0.9665
Epoch 6/40
469/469 [=====] - 3s 7ms/step - loss: 0.0864 -
accuracy: 0.9786 - val_loss: 0.0967 - val_accuracy: 0.9737
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.0755 -
accuracy: 0.9813 - val_loss: 0.0900 - val_accuracy: 0.9739
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.0663 -
accuracy: 0.9848 - val_loss: 0.0876 - val_accuracy: 0.9758
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.0589 -
accuracy: 0.9866 - val_loss: 0.0863 - val_accuracy: 0.9766
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.0525 -
accuracy: 0.9887 - val_loss: 0.0787 - val_accuracy: 0.9779
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.0468 -
accuracy: 0.9904 - val_loss: 0.0829 - val_accuracy: 0.9768
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.0430 -
accuracy: 0.9919 - val_loss: 0.0741 - val_accuracy: 0.9799
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.0389 -
accuracy: 0.9932 - val_loss: 0.0795 - val_accuracy: 0.9786
Epoch 14/40

469/469 [=====] - 3s 7ms/step - loss: 0.0354 -
accuracy: 0.9940 - val_loss: 0.0761 - val_accuracy: 0.9793
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.0322 -
accuracy: 0.9952 - val_loss: 0.0717 - val_accuracy: 0.9811
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.0295 -
accuracy: 0.9962 - val_loss: 0.0789 - val_accuracy: 0.9774
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.0273 -
accuracy: 0.9970 - val_loss: 0.0733 - val_accuracy: 0.9806
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.0252 -
accuracy: 0.9975 - val_loss: 0.0798 - val_accuracy: 0.9782
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.0236 -
accuracy: 0.9982 - val_loss: 0.0740 - val_accuracy: 0.9802
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.0221 -
accuracy: 0.9985 - val_loss: 0.0702 - val_accuracy: 0.9811
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.0211 -
accuracy: 0.9988 - val_loss: 0.0725 - val_accuracy: 0.9810
Epoch 22/40
469/469 [=====] - 3s 7ms/step - loss: 0.0199 -
accuracy: 0.9991 - val_loss: 0.0693 - val_accuracy: 0.9814
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.0193 -
accuracy: 0.9991 - val_loss: 0.0709 - val_accuracy: 0.9811
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.0183 -
accuracy: 0.9993 - val_loss: 0.0693 - val_accuracy: 0.9821
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.0175 -
accuracy: 0.9995 - val_loss: 0.0740 - val_accuracy: 0.9808
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.0170 -
accuracy: 0.9995 - val_loss: 0.0724 - val_accuracy: 0.9816
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.0164 -
accuracy: 0.9997 - val_loss: 0.0699 - val_accuracy: 0.9817
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.0159 -
accuracy: 0.9998 - val_loss: 0.0703 - val_accuracy: 0.9817
Epoch 29/40
469/469 [=====] - 3s 7ms/step - loss: 0.0156 -
accuracy: 0.9998 - val_loss: 0.0698 - val_accuracy: 0.9818
Epoch 30/40

469/469 [=====] - 4s 8ms/step - loss: 0.0152 -
accuracy: 0.9998 - val_loss: 0.0700 - val_accuracy: 0.9822
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0149 -
accuracy: 0.9999 - val_loss: 0.0709 - val_accuracy: 0.9821
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0147 -
accuracy: 0.9999 - val_loss: 0.0714 - val_accuracy: 0.9816
Epoch 33/40
469/469 [=====] - 4s 8ms/step - loss: 0.0144 -
accuracy: 0.9999 - val_loss: 0.0706 - val_accuracy: 0.9817
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0142 -
accuracy: 0.9999 - val_loss: 0.0714 - val_accuracy: 0.9823
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0140 -
accuracy: 1.0000 - val_loss: 0.0720 - val_accuracy: 0.9827
Epoch 36/40
469/469 [=====] - 4s 8ms/step - loss: 0.0138 -
accuracy: 1.0000 - val_loss: 0.0720 - val_accuracy: 0.9822
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0137 -
accuracy: 1.0000 - val_loss: 0.0718 - val_accuracy: 0.9823
Epoch 38/40
469/469 [=====] - 3s 7ms/step - loss: 0.0136 -
accuracy: 1.0000 - val_loss: 0.0718 - val_accuracy: 0.9821
Epoch 39/40
469/469 [=====] - 4s 8ms/step - loss: 0.0134 -
accuracy: 1.0000 - val_loss: 0.0717 - val_accuracy: 0.9825
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0133 -
accuracy: 1.0000 - val_loss: 0.0725 - val_accuracy: 0.9823
Epoch 1/40
469/469 [=====] - 4s 7ms/step - loss: 0.4076 -
accuracy: 0.8907 - val_loss: 0.2309 - val_accuracy: 0.9357
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.2013 -
accuracy: 0.9447 - val_loss: 0.1679 - val_accuracy: 0.9538
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.1500 -
accuracy: 0.9600 - val_loss: 0.1347 - val_accuracy: 0.9628
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.1208 -
accuracy: 0.9682 - val_loss: 0.1228 - val_accuracy: 0.9648
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.1001 -
accuracy: 0.9739 - val_loss: 0.1042 - val_accuracy: 0.9709
Epoch 6/40

469/469 [=====] - 3s 7ms/step - loss: 0.0860 -
accuracy: 0.9787 - val_loss: 0.1022 - val_accuracy: 0.9718
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.0742 -
accuracy: 0.9821 - val_loss: 0.0973 - val_accuracy: 0.9723
Epoch 8/40
469/469 [=====] - 4s 8ms/step - loss: 0.0653 -
accuracy: 0.9847 - val_loss: 0.0901 - val_accuracy: 0.9750
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.0579 -
accuracy: 0.9868 - val_loss: 0.0843 - val_accuracy: 0.9771
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.0520 -
accuracy: 0.9887 - val_loss: 0.0793 - val_accuracy: 0.9789
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.0471 -
accuracy: 0.9905 - val_loss: 0.0794 - val_accuracy: 0.9768
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.0421 -
accuracy: 0.9919 - val_loss: 0.0808 - val_accuracy: 0.9781
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.0382 -
accuracy: 0.9932 - val_loss: 0.0751 - val_accuracy: 0.9791
Epoch 14/40
469/469 [=====] - 3s 7ms/step - loss: 0.0347 -
accuracy: 0.9944 - val_loss: 0.0735 - val_accuracy: 0.9804
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.0315 -
accuracy: 0.9953 - val_loss: 0.0754 - val_accuracy: 0.9800
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.0295 -
accuracy: 0.9964 - val_loss: 0.0752 - val_accuracy: 0.9809
Epoch 17/40
469/469 [=====] - 3s 6ms/step - loss: 0.0269 -
accuracy: 0.9969 - val_loss: 0.0728 - val_accuracy: 0.9813
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.0251 -
accuracy: 0.9977 - val_loss: 0.0736 - val_accuracy: 0.9805
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.0233 -
accuracy: 0.9982 - val_loss: 0.0762 - val_accuracy: 0.9804
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.0220 -
accuracy: 0.9983 - val_loss: 0.0758 - val_accuracy: 0.9801
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.0207 -
accuracy: 0.9988 - val_loss: 0.0721 - val_accuracy: 0.9816
Epoch 22/40

469/469 [=====] - 3s 7ms/step - loss: 0.0196 -
accuracy: 0.9991 - val_loss: 0.0745 - val_accuracy: 0.9802
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.0187 -
accuracy: 0.9994 - val_loss: 0.0735 - val_accuracy: 0.9810
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.0181 -
accuracy: 0.9993 - val_loss: 0.0737 - val_accuracy: 0.9815
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.0173 -
accuracy: 0.9996 - val_loss: 0.0753 - val_accuracy: 0.9816
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.0168 -
accuracy: 0.9997 - val_loss: 0.0736 - val_accuracy: 0.9814
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.0162 -
accuracy: 0.9997 - val_loss: 0.0770 - val_accuracy: 0.9807
Epoch 28/40
469/469 [=====] - 4s 7ms/step - loss: 0.0157 -
accuracy: 0.9999 - val_loss: 0.0756 - val_accuracy: 0.9809
Epoch 29/40
469/469 [=====] - 3s 7ms/step - loss: 0.0154 -
accuracy: 0.9998 - val_loss: 0.0752 - val_accuracy: 0.9813
Epoch 30/40
469/469 [=====] - 3s 7ms/step - loss: 0.0151 -
accuracy: 0.9999 - val_loss: 0.0757 - val_accuracy: 0.9818
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0148 -
accuracy: 0.9999 - val_loss: 0.0766 - val_accuracy: 0.9810
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0145 -
accuracy: 0.9999 - val_loss: 0.0773 - val_accuracy: 0.9813
Epoch 33/40
469/469 [=====] - 4s 7ms/step - loss: 0.0143 -
accuracy: 0.9999 - val_loss: 0.0769 - val_accuracy: 0.9817
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0141 -
accuracy: 1.0000 - val_loss: 0.0773 - val_accuracy: 0.9815
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0139 -
accuracy: 1.0000 - val_loss: 0.0767 - val_accuracy: 0.9818
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0138 -
accuracy: 1.0000 - val_loss: 0.0788 - val_accuracy: 0.9818
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0136 -
accuracy: 1.0000 - val_loss: 0.0787 - val_accuracy: 0.9816
Epoch 38/40

469/469 [=====] - 3s 7ms/step - loss: 0.0135 -
accuracy: 1.0000 - val_loss: 0.0776 - val_accuracy: 0.9818
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0134 -
accuracy: 0.9999 - val_loss: 0.0774 - val_accuracy: 0.9817
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0133 -
accuracy: 1.0000 - val_loss: 0.0785 - val_accuracy: 0.9816
Epoch 1/40
469/469 [=====] - 4s 8ms/step - loss: 0.4055 -
accuracy: 0.8903 - val_loss: 0.2274 - val_accuracy: 0.9365
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.1963 -
accuracy: 0.9460 - val_loss: 0.1720 - val_accuracy: 0.9516
Epoch 3/40
469/469 [=====] - 4s 8ms/step - loss: 0.1474 -
accuracy: 0.9603 - val_loss: 0.1312 - val_accuracy: 0.9639
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.1188 -
accuracy: 0.9687 - val_loss: 0.1110 - val_accuracy: 0.9682
Epoch 5/40
469/469 [=====] - 4s 8ms/step - loss: 0.0986 -
accuracy: 0.9746 - val_loss: 0.1054 - val_accuracy: 0.9708
Epoch 6/40
469/469 [=====] - 3s 7ms/step - loss: 0.0844 -
accuracy: 0.9789 - val_loss: 0.1017 - val_accuracy: 0.9714
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.0729 -
accuracy: 0.9822 - val_loss: 0.0897 - val_accuracy: 0.9761
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.0643 -
accuracy: 0.9851 - val_loss: 0.0926 - val_accuracy: 0.9743
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.0568 -
accuracy: 0.9869 - val_loss: 0.0840 - val_accuracy: 0.9782
Epoch 10/40
469/469 [=====] - 4s 7ms/step - loss: 0.0506 -
accuracy: 0.9891 - val_loss: 0.0817 - val_accuracy: 0.9779
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.0459 -
accuracy: 0.9905 - val_loss: 0.0793 - val_accuracy: 0.9778
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.0410 -
accuracy: 0.9923 - val_loss: 0.0765 - val_accuracy: 0.9796
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.0373 -
accuracy: 0.9934 - val_loss: 0.0748 - val_accuracy: 0.9796
Epoch 14/40

469/469 [=====] - 3s 7ms/step - loss: 0.0338 -
accuracy: 0.9947 - val_loss: 0.0727 - val_accuracy: 0.9807
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.0307 -
accuracy: 0.9961 - val_loss: 0.0698 - val_accuracy: 0.9819
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.0282 -
accuracy: 0.9967 - val_loss: 0.0735 - val_accuracy: 0.9802
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.0261 -
accuracy: 0.9973 - val_loss: 0.0731 - val_accuracy: 0.9818
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.0245 -
accuracy: 0.9980 - val_loss: 0.0760 - val_accuracy: 0.9800
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.0229 -
accuracy: 0.9983 - val_loss: 0.0835 - val_accuracy: 0.9781
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.0215 -
accuracy: 0.9985 - val_loss: 0.0728 - val_accuracy: 0.9816
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.0202 -
accuracy: 0.9989 - val_loss: 0.0718 - val_accuracy: 0.9809
Epoch 22/40
469/469 [=====] - 3s 7ms/step - loss: 0.0194 -
accuracy: 0.9991 - val_loss: 0.0720 - val_accuracy: 0.9816
Epoch 23/40
469/469 [=====] - 4s 8ms/step - loss: 0.0184 -
accuracy: 0.9995 - val_loss: 0.0725 - val_accuracy: 0.9816
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.0177 -
accuracy: 0.9995 - val_loss: 0.0728 - val_accuracy: 0.9823
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.0171 -
accuracy: 0.9997 - val_loss: 0.0712 - val_accuracy: 0.9819
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.0165 -
accuracy: 0.9998 - val_loss: 0.0744 - val_accuracy: 0.9812
Epoch 27/40
469/469 [=====] - 4s 9ms/step - loss: 0.0160 -
accuracy: 0.9997 - val_loss: 0.0730 - val_accuracy: 0.9822
Epoch 28/40
469/469 [=====] - 4s 9ms/step - loss: 0.0157 -
accuracy: 0.9998 - val_loss: 0.0731 - val_accuracy: 0.9819
Epoch 29/40
469/469 [=====] - 4s 8ms/step - loss: 0.0152 -
accuracy: 0.9999 - val_loss: 0.0733 - val_accuracy: 0.9819
Epoch 30/40

469/469 [=====] - 4s 8ms/step - loss: 0.0149 -
accuracy: 0.9999 - val_loss: 0.0730 - val_accuracy: 0.9823
Epoch 31/40
469/469 [=====] - 4s 9ms/step - loss: 0.0147 -
accuracy: 0.9999 - val_loss: 0.0741 - val_accuracy: 0.9819
Epoch 32/40
469/469 [=====] - 4s 8ms/step - loss: 0.0144 -
accuracy: 0.9999 - val_loss: 0.0737 - val_accuracy: 0.9823
Epoch 33/40
469/469 [=====] - 4s 9ms/step - loss: 0.0142 -
accuracy: 0.9999 - val_loss: 0.0746 - val_accuracy: 0.9825
Epoch 34/40
469/469 [=====] - 4s 9ms/step - loss: 0.0140 -
accuracy: 0.9999 - val_loss: 0.0740 - val_accuracy: 0.9819
Epoch 35/40
469/469 [=====] - 4s 8ms/step - loss: 0.0139 -
accuracy: 0.9999 - val_loss: 0.0746 - val_accuracy: 0.9823
Epoch 36/40
469/469 [=====] - 4s 9ms/step - loss: 0.0137 -
accuracy: 1.0000 - val_loss: 0.0761 - val_accuracy: 0.9820
Epoch 37/40
469/469 [=====] - 4s 9ms/step - loss: 0.0135 -
accuracy: 1.0000 - val_loss: 0.0750 - val_accuracy: 0.9828
Epoch 38/40
469/469 [=====] - 4s 9ms/step - loss: 0.0134 -
accuracy: 1.0000 - val_loss: 0.0755 - val_accuracy: 0.9824
Epoch 39/40
469/469 [=====] - 4s 9ms/step - loss: 0.0133 -
accuracy: 1.0000 - val_loss: 0.0763 - val_accuracy: 0.9822
Epoch 40/40
469/469 [=====] - 4s 9ms/step - loss: 0.0132 -
accuracy: 1.0000 - val_loss: 0.0758 - val_accuracy: 0.9822
Epoch 1/40
469/469 [=====] - 5s 9ms/step - loss: 0.4981 -
accuracy: 0.8899 - val_loss: 0.3160 - val_accuracy: 0.9384
Epoch 2/40
469/469 [=====] - 4s 9ms/step - loss: 0.2883 -
accuracy: 0.9456 - val_loss: 0.2487 - val_accuracy: 0.9545
Epoch 3/40
469/469 [=====] - 4s 8ms/step - loss: 0.2380 -
accuracy: 0.9599 - val_loss: 0.2320 - val_accuracy: 0.9586
Epoch 4/40
469/469 [=====] - 4s 8ms/step - loss: 0.2082 -
accuracy: 0.9685 - val_loss: 0.2131 - val_accuracy: 0.9644
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.1878 -
accuracy: 0.9744 - val_loss: 0.1923 - val_accuracy: 0.9715
Epoch 6/40

469/469 [=====] - 3s 7ms/step - loss: 0.1727 -
accuracy: 0.9786 - val_loss: 0.1844 - val_accuracy: 0.9731
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.1615 -
accuracy: 0.9814 - val_loss: 0.1700 - val_accuracy: 0.9779
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.1507 -
accuracy: 0.9844 - val_loss: 0.1696 - val_accuracy: 0.9775
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.1430 -
accuracy: 0.9861 - val_loss: 0.1650 - val_accuracy: 0.9785
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.1358 -
accuracy: 0.9886 - val_loss: 0.1599 - val_accuracy: 0.9792
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.1298 -
accuracy: 0.9900 - val_loss: 0.1583 - val_accuracy: 0.9782
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.1243 -
accuracy: 0.9917 - val_loss: 0.1575 - val_accuracy: 0.9786
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.1200 -
accuracy: 0.9924 - val_loss: 0.1541 - val_accuracy: 0.9794
Epoch 14/40
469/469 [=====] - 3s 7ms/step - loss: 0.1151 -
accuracy: 0.9936 - val_loss: 0.1499 - val_accuracy: 0.9809
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.1115 -
accuracy: 0.9946 - val_loss: 0.1484 - val_accuracy: 0.9808
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.1078 -
accuracy: 0.9958 - val_loss: 0.1474 - val_accuracy: 0.9804
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.1046 -
accuracy: 0.9963 - val_loss: 0.1463 - val_accuracy: 0.9800
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.1017 -
accuracy: 0.9970 - val_loss: 0.1468 - val_accuracy: 0.9801
Epoch 19/40
469/469 [=====] - 4s 8ms/step - loss: 0.0993 -
accuracy: 0.9973 - val_loss: 0.1491 - val_accuracy: 0.9785
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.0965 -
accuracy: 0.9979 - val_loss: 0.1436 - val_accuracy: 0.9802
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.0941 -
accuracy: 0.9984 - val_loss: 0.1398 - val_accuracy: 0.9812
Epoch 22/40

469/469 [=====] - 4s 8ms/step - loss: 0.0924 -
accuracy: 0.9985 - val_loss: 0.1359 - val_accuracy: 0.9818
Epoch 23/40
469/469 [=====] - 4s 8ms/step - loss: 0.0900 -
accuracy: 0.9989 - val_loss: 0.1363 - val_accuracy: 0.9815
Epoch 24/40
469/469 [=====] - 4s 8ms/step - loss: 0.0882 -
accuracy: 0.9992 - val_loss: 0.1392 - val_accuracy: 0.9816
Epoch 25/40
469/469 [=====] - 4s 8ms/step - loss: 0.0864 -
accuracy: 0.9992 - val_loss: 0.1395 - val_accuracy: 0.9802
Epoch 26/40
469/469 [=====] - 4s 8ms/step - loss: 0.0848 -
accuracy: 0.9993 - val_loss: 0.1336 - val_accuracy: 0.9816
Epoch 27/40
469/469 [=====] - 4s 8ms/step - loss: 0.0831 -
accuracy: 0.9995 - val_loss: 0.1313 - val_accuracy: 0.9823
Epoch 28/40
469/469 [=====] - 4s 8ms/step - loss: 0.0818 -
accuracy: 0.9994 - val_loss: 0.1316 - val_accuracy: 0.9818
Epoch 29/40
469/469 [=====] - 4s 8ms/step - loss: 0.0802 -
accuracy: 0.9996 - val_loss: 0.1294 - val_accuracy: 0.9821
Epoch 30/40
469/469 [=====] - 4s 8ms/step - loss: 0.0787 -
accuracy: 0.9997 - val_loss: 0.1275 - val_accuracy: 0.9820
Epoch 31/40
469/469 [=====] - 4s 8ms/step - loss: 0.0775 -
accuracy: 0.9996 - val_loss: 0.1277 - val_accuracy: 0.9820
Epoch 32/40
469/469 [=====] - 4s 9ms/step - loss: 0.0761 -
accuracy: 0.9998 - val_loss: 0.1256 - val_accuracy: 0.9820
Epoch 33/40
469/469 [=====] - 4s 9ms/step - loss: 0.0751 -
accuracy: 0.9998 - val_loss: 0.1254 - val_accuracy: 0.9822
Epoch 34/40
469/469 [=====] - 4s 9ms/step - loss: 0.0738 -
accuracy: 0.9998 - val_loss: 0.1251 - val_accuracy: 0.9823
Epoch 35/40
469/469 [=====] - 4s 9ms/step - loss: 0.0725 -
accuracy: 0.9998 - val_loss: 0.1233 - val_accuracy: 0.9816
Epoch 36/40
469/469 [=====] - 4s 8ms/step - loss: 0.0715 -
accuracy: 0.9999 - val_loss: 0.1221 - val_accuracy: 0.9820
Epoch 37/40
469/469 [=====] - 4s 9ms/step - loss: 0.0703 -
accuracy: 0.9999 - val_loss: 0.1219 - val_accuracy: 0.9823
Epoch 38/40

469/469 [=====] - 4s 8ms/step - loss: 0.0693 -
accuracy: 0.9999 - val_loss: 0.1218 - val_accuracy: 0.9823
Epoch 39/40
469/469 [=====] - 4s 9ms/step - loss: 0.0682 -
accuracy: 0.9999 - val_loss: 0.1194 - val_accuracy: 0.9823
Epoch 40/40
469/469 [=====] - 4s 8ms/step - loss: 0.0672 -
accuracy: 0.9999 - val_loss: 0.1189 - val_accuracy: 0.9822
Epoch 1/40
469/469 [=====] - 5s 9ms/step - loss: 0.4992 -
accuracy: 0.8892 - val_loss: 0.3142 - val_accuracy: 0.9394
Epoch 2/40
469/469 [=====] - 4s 9ms/step - loss: 0.2908 -
accuracy: 0.9442 - val_loss: 0.2545 - val_accuracy: 0.9536
Epoch 3/40
469/469 [=====] - 4s 8ms/step - loss: 0.2389 -
accuracy: 0.9593 - val_loss: 0.2197 - val_accuracy: 0.9648
Epoch 4/40
469/469 [=====] - 4s 8ms/step - loss: 0.2082 -
accuracy: 0.9683 - val_loss: 0.2036 - val_accuracy: 0.9676
Epoch 5/40
469/469 [=====] - 4s 8ms/step - loss: 0.1876 -
accuracy: 0.9739 - val_loss: 0.1903 - val_accuracy: 0.9716
Epoch 6/40
469/469 [=====] - 4s 8ms/step - loss: 0.1722 -
accuracy: 0.9788 - val_loss: 0.1778 - val_accuracy: 0.9754
Epoch 7/40
469/469 [=====] - 4s 8ms/step - loss: 0.1608 -
accuracy: 0.9815 - val_loss: 0.1790 - val_accuracy: 0.9728
Epoch 8/40
469/469 [=====] - 4s 8ms/step - loss: 0.1510 -
accuracy: 0.9841 - val_loss: 0.1752 - val_accuracy: 0.9745
Epoch 9/40
469/469 [=====] - 4s 8ms/step - loss: 0.1431 -
accuracy: 0.9862 - val_loss: 0.1666 - val_accuracy: 0.9770
Epoch 10/40
469/469 [=====] - 4s 8ms/step - loss: 0.1362 -
accuracy: 0.9879 - val_loss: 0.1591 - val_accuracy: 0.9789
Epoch 11/40
469/469 [=====] - 4s 8ms/step - loss: 0.1300 -
accuracy: 0.9897 - val_loss: 0.1549 - val_accuracy: 0.9791
Epoch 12/40
469/469 [=====] - 4s 9ms/step - loss: 0.1239 -
accuracy: 0.9921 - val_loss: 0.1528 - val_accuracy: 0.9806
Epoch 13/40
469/469 [=====] - 4s 9ms/step - loss: 0.1196 -
accuracy: 0.9925 - val_loss: 0.1552 - val_accuracy: 0.9773
Epoch 14/40

469/469 [=====] - 4s 8ms/step - loss: 0.1147 -
accuracy: 0.9943 - val_loss: 0.1484 - val_accuracy: 0.9799
Epoch 15/40
469/469 [=====] - 4s 9ms/step - loss: 0.1115 -
accuracy: 0.9945 - val_loss: 0.1500 - val_accuracy: 0.9796
Epoch 16/40
469/469 [=====] - 4s 8ms/step - loss: 0.1074 -
accuracy: 0.9959 - val_loss: 0.1470 - val_accuracy: 0.9797
Epoch 17/40
469/469 [=====] - 4s 8ms/step - loss: 0.1048 -
accuracy: 0.9963 - val_loss: 0.1449 - val_accuracy: 0.9815
Epoch 18/40
469/469 [=====] - 4s 8ms/step - loss: 0.1016 -
accuracy: 0.9967 - val_loss: 0.1435 - val_accuracy: 0.9804
Epoch 19/40
469/469 [=====] - 4s 9ms/step - loss: 0.0991 -
accuracy: 0.9975 - val_loss: 0.1407 - val_accuracy: 0.9813
Epoch 20/40
469/469 [=====] - 4s 8ms/step - loss: 0.0965 -
accuracy: 0.9979 - val_loss: 0.1386 - val_accuracy: 0.9824
Epoch 21/40
469/469 [=====] - 4s 8ms/step - loss: 0.0940 -
accuracy: 0.9985 - val_loss: 0.1378 - val_accuracy: 0.9822
Epoch 22/40
469/469 [=====] - 4s 8ms/step - loss: 0.0920 -
accuracy: 0.9984 - val_loss: 0.1378 - val_accuracy: 0.9828
Epoch 23/40
469/469 [=====] - 4s 8ms/step - loss: 0.0900 -
accuracy: 0.9987 - val_loss: 0.1370 - val_accuracy: 0.9804
Epoch 24/40
469/469 [=====] - 4s 8ms/step - loss: 0.0882 -
accuracy: 0.9989 - val_loss: 0.1355 - val_accuracy: 0.9803
Epoch 25/40
469/469 [=====] - 4s 8ms/step - loss: 0.0863 -
accuracy: 0.9992 - val_loss: 0.1361 - val_accuracy: 0.9807
Epoch 26/40
469/469 [=====] - 4s 8ms/step - loss: 0.0847 -
accuracy: 0.9994 - val_loss: 0.1325 - val_accuracy: 0.9823
Epoch 27/40
469/469 [=====] - 4s 9ms/step - loss: 0.0829 -
accuracy: 0.9995 - val_loss: 0.1302 - val_accuracy: 0.9824
Epoch 28/40
469/469 [=====] - 4s 8ms/step - loss: 0.0814 -
accuracy: 0.9995 - val_loss: 0.1307 - val_accuracy: 0.9811
Epoch 29/40
469/469 [=====] - 4s 8ms/step - loss: 0.0799 -
accuracy: 0.9996 - val_loss: 0.1298 - val_accuracy: 0.9816
Epoch 30/40

469/469 [=====] - 4s 8ms/step - loss: 0.0786 -
accuracy: 0.9997 - val_loss: 0.1279 - val_accuracy: 0.9821
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0774 -
accuracy: 0.9997 - val_loss: 0.1282 - val_accuracy: 0.9822
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0759 -
accuracy: 0.9998 - val_loss: 0.1261 - val_accuracy: 0.9816
Epoch 33/40
469/469 [=====] - 4s 8ms/step - loss: 0.0748 -
accuracy: 0.9997 - val_loss: 0.1270 - val_accuracy: 0.9817
Epoch 34/40
469/469 [=====] - 4s 8ms/step - loss: 0.0736 -
accuracy: 0.9998 - val_loss: 0.1225 - val_accuracy: 0.9825
Epoch 35/40
469/469 [=====] - 4s 8ms/step - loss: 0.0724 -
accuracy: 0.9999 - val_loss: 0.1229 - val_accuracy: 0.9825
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0713 -
accuracy: 0.9999 - val_loss: 0.1226 - val_accuracy: 0.9820
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0702 -
accuracy: 0.9999 - val_loss: 0.1213 - val_accuracy: 0.9816
Epoch 38/40
469/469 [=====] - 3s 7ms/step - loss: 0.0691 -
accuracy: 0.9999 - val_loss: 0.1194 - val_accuracy: 0.9822
Epoch 39/40
469/469 [=====] - 4s 7ms/step - loss: 0.0680 -
accuracy: 0.9999 - val_loss: 0.1195 - val_accuracy: 0.9814
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0670 -
accuracy: 0.9999 - val_loss: 0.1177 - val_accuracy: 0.9819
Epoch 1/40
469/469 [=====] - 4s 8ms/step - loss: 0.5026 -
accuracy: 0.8891 - val_loss: 0.3186 - val_accuracy: 0.9361
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.2918 -
accuracy: 0.9448 - val_loss: 0.2581 - val_accuracy: 0.9517
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.2392 -
accuracy: 0.9596 - val_loss: 0.2243 - val_accuracy: 0.9636
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.2090 -
accuracy: 0.9678 - val_loss: 0.2088 - val_accuracy: 0.9663
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.1880 -
accuracy: 0.9737 - val_loss: 0.1939 - val_accuracy: 0.9687
Epoch 6/40

469/469 [=====] - 3s 7ms/step - loss: 0.1723 -
accuracy: 0.9786 - val_loss: 0.1879 - val_accuracy: 0.9703
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.1605 -
accuracy: 0.9817 - val_loss: 0.1762 - val_accuracy: 0.9751
Epoch 8/40
469/469 [=====] - 4s 8ms/step - loss: 0.1510 -
accuracy: 0.9843 - val_loss: 0.1677 - val_accuracy: 0.9768
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.1426 -
accuracy: 0.9865 - val_loss: 0.1825 - val_accuracy: 0.9723
Epoch 10/40
469/469 [=====] - 4s 8ms/step - loss: 0.1360 -
accuracy: 0.9879 - val_loss: 0.1721 - val_accuracy: 0.9749
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.1298 -
accuracy: 0.9901 - val_loss: 0.1599 - val_accuracy: 0.9792
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.1242 -
accuracy: 0.9915 - val_loss: 0.1556 - val_accuracy: 0.9781
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.1192 -
accuracy: 0.9928 - val_loss: 0.1547 - val_accuracy: 0.9791
Epoch 14/40
469/469 [=====] - 3s 7ms/step - loss: 0.1155 -
accuracy: 0.9938 - val_loss: 0.1535 - val_accuracy: 0.9790
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.1114 -
accuracy: 0.9949 - val_loss: 0.1497 - val_accuracy: 0.9789
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.1077 -
accuracy: 0.9955 - val_loss: 0.1512 - val_accuracy: 0.9783
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.1045 -
accuracy: 0.9965 - val_loss: 0.1485 - val_accuracy: 0.9809
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.1014 -
accuracy: 0.9971 - val_loss: 0.1496 - val_accuracy: 0.9791
Epoch 19/40
469/469 [=====] - 4s 7ms/step - loss: 0.0989 -
accuracy: 0.9975 - val_loss: 0.1449 - val_accuracy: 0.9808
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.0966 -
accuracy: 0.9979 - val_loss: 0.1432 - val_accuracy: 0.9797
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.0941 -
accuracy: 0.9983 - val_loss: 0.1409 - val_accuracy: 0.9808
Epoch 22/40

469/469 [=====] - 3s 7ms/step - loss: 0.0921 -
accuracy: 0.9986 - val_loss: 0.1413 - val_accuracy: 0.9801
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.0901 -
accuracy: 0.9989 - val_loss: 0.1402 - val_accuracy: 0.9811
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.0880 -
accuracy: 0.9992 - val_loss: 0.1378 - val_accuracy: 0.9805
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.0863 -
accuracy: 0.9992 - val_loss: 0.1367 - val_accuracy: 0.9808
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.0846 -
accuracy: 0.9995 - val_loss: 0.1398 - val_accuracy: 0.9803
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.0832 -
accuracy: 0.9994 - val_loss: 0.1347 - val_accuracy: 0.9809
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.0815 -
accuracy: 0.9997 - val_loss: 0.1337 - val_accuracy: 0.9809
Epoch 29/40
469/469 [=====] - 3s 7ms/step - loss: 0.0801 -
accuracy: 0.9996 - val_loss: 0.1356 - val_accuracy: 0.9811
Epoch 30/40
469/469 [=====] - 3s 7ms/step - loss: 0.0787 -
accuracy: 0.9997 - val_loss: 0.1317 - val_accuracy: 0.9813
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0774 -
accuracy: 0.9998 - val_loss: 0.1314 - val_accuracy: 0.9809
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0761 -
accuracy: 0.9998 - val_loss: 0.1303 - val_accuracy: 0.9810
Epoch 33/40
469/469 [=====] - 3s 7ms/step - loss: 0.0748 -
accuracy: 0.9998 - val_loss: 0.1295 - val_accuracy: 0.9811
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0736 -
accuracy: 0.9999 - val_loss: 0.1269 - val_accuracy: 0.9818
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0725 -
accuracy: 0.9998 - val_loss: 0.1291 - val_accuracy: 0.9810
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0713 -
accuracy: 0.9999 - val_loss: 0.1256 - val_accuracy: 0.9815
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0703 -
accuracy: 0.9999 - val_loss: 0.1241 - val_accuracy: 0.9821
Epoch 38/40

469/469 [=====] - 3s 7ms/step - loss: 0.0691 -
accuracy: 0.9999 - val_loss: 0.1233 - val_accuracy: 0.9818
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0681 -
accuracy: 0.9999 - val_loss: 0.1245 - val_accuracy: 0.9812
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0671 -
accuracy: 0.9999 - val_loss: 0.1222 - val_accuracy: 0.9813
Epoch 1/40
469/469 [=====] - 4s 8ms/step - loss: 0.8817 -
accuracy: 0.8888 - val_loss: 0.6869 - val_accuracy: 0.9362
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.6385 -
accuracy: 0.9452 - val_loss: 0.5870 - val_accuracy: 0.9542
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.5566 -
accuracy: 0.9596 - val_loss: 0.5252 - val_accuracy: 0.9618
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.4972 -
accuracy: 0.9680 - val_loss: 0.4801 - val_accuracy: 0.9668
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.4506 -
accuracy: 0.9728 - val_loss: 0.4464 - val_accuracy: 0.9686
Epoch 6/40
469/469 [=====] - 3s 7ms/step - loss: 0.4108 -
accuracy: 0.9766 - val_loss: 0.4075 - val_accuracy: 0.9734
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.3767 -
accuracy: 0.9797 - val_loss: 0.3785 - val_accuracy: 0.9747
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.3460 -
accuracy: 0.9827 - val_loss: 0.3480 - val_accuracy: 0.9763
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.3197 -
accuracy: 0.9847 - val_loss: 0.3348 - val_accuracy: 0.9749
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.2955 -
accuracy: 0.9862 - val_loss: 0.3181 - val_accuracy: 0.9739
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.2748 -
accuracy: 0.9872 - val_loss: 0.2896 - val_accuracy: 0.9776
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.2554 -
accuracy: 0.9885 - val_loss: 0.2737 - val_accuracy: 0.9777
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.2375 -
accuracy: 0.9900 - val_loss: 0.2598 - val_accuracy: 0.9784
Epoch 14/40

469/469 [=====] - 3s 7ms/step - loss: 0.2217 -
accuracy: 0.9908 - val_loss: 0.2441 - val_accuracy: 0.9788
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.2076 -
accuracy: 0.9913 - val_loss: 0.2316 - val_accuracy: 0.9790
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.1947 -
accuracy: 0.9925 - val_loss: 0.2267 - val_accuracy: 0.9781
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.1826 -
accuracy: 0.9932 - val_loss: 0.2097 - val_accuracy: 0.9807
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.1717 -
accuracy: 0.9936 - val_loss: 0.2011 - val_accuracy: 0.9805
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.1622 -
accuracy: 0.9941 - val_loss: 0.1936 - val_accuracy: 0.9805
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.1527 -
accuracy: 0.9948 - val_loss: 0.1833 - val_accuracy: 0.9803
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.1448 -
accuracy: 0.9948 - val_loss: 0.1755 - val_accuracy: 0.9808
Epoch 22/40
469/469 [=====] - 3s 7ms/step - loss: 0.1373 -
accuracy: 0.9951 - val_loss: 0.1708 - val_accuracy: 0.9800
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.1302 -
accuracy: 0.9957 - val_loss: 0.1627 - val_accuracy: 0.9816
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.1243 -
accuracy: 0.9958 - val_loss: 0.1599 - val_accuracy: 0.9802
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.1187 -
accuracy: 0.9960 - val_loss: 0.1536 - val_accuracy: 0.9809
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.1132 -
accuracy: 0.9962 - val_loss: 0.1449 - val_accuracy: 0.9824
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.1086 -
accuracy: 0.9962 - val_loss: 0.1438 - val_accuracy: 0.9806
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.1035 -
accuracy: 0.9970 - val_loss: 0.1412 - val_accuracy: 0.9803
Epoch 29/40
469/469 [=====] - 3s 7ms/step - loss: 0.1000 -
accuracy: 0.9966 - val_loss: 0.1321 - val_accuracy: 0.9818
Epoch 30/40

469/469 [=====] - 4s 8ms/step - loss: 0.0959 -
accuracy: 0.9969 - val_loss: 0.1309 - val_accuracy: 0.9818
Epoch 31/40
469/469 [=====] - 4s 9ms/step - loss: 0.0927 -
accuracy: 0.9972 - val_loss: 0.1313 - val_accuracy: 0.9812
Epoch 32/40
469/469 [=====] - 4s 8ms/step - loss: 0.0895 -
accuracy: 0.9973 - val_loss: 0.1235 - val_accuracy: 0.9818
Epoch 33/40
469/469 [=====] - 3s 7ms/step - loss: 0.0865 -
accuracy: 0.9974 - val_loss: 0.1210 - val_accuracy: 0.9831
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0836 -
accuracy: 0.9975 - val_loss: 0.1193 - val_accuracy: 0.9820
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0808 -
accuracy: 0.9978 - val_loss: 0.1178 - val_accuracy: 0.9818
Epoch 36/40
469/469 [=====] - 4s 8ms/step - loss: 0.0790 -
accuracy: 0.9978 - val_loss: 0.1191 - val_accuracy: 0.9816
Epoch 37/40
469/469 [=====] - 4s 8ms/step - loss: 0.0765 -
accuracy: 0.9977 - val_loss: 0.1190 - val_accuracy: 0.9808
Epoch 38/40
469/469 [=====] - 4s 8ms/step - loss: 0.0755 -
accuracy: 0.9974 - val_loss: 0.1147 - val_accuracy: 0.9811
Epoch 39/40
469/469 [=====] - 4s 8ms/step - loss: 0.0733 -
accuracy: 0.9978 - val_loss: 0.1136 - val_accuracy: 0.9809
Epoch 40/40
469/469 [=====] - 4s 9ms/step - loss: 0.0712 -
accuracy: 0.9981 - val_loss: 0.1261 - val_accuracy: 0.9774
Epoch 1/40
469/469 [=====] - 4s 8ms/step - loss: 0.8844 -
accuracy: 0.8903 - val_loss: 0.6756 - val_accuracy: 0.9406
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.6420 -
accuracy: 0.9434 - val_loss: 0.5964 - val_accuracy: 0.9481
Epoch 3/40
469/469 [=====] - 4s 8ms/step - loss: 0.5582 -
accuracy: 0.9581 - val_loss: 0.5349 - val_accuracy: 0.9591
Epoch 4/40
469/469 [=====] - 4s 8ms/step - loss: 0.4992 -
accuracy: 0.9666 - val_loss: 0.4839 - val_accuracy: 0.9661
Epoch 5/40
469/469 [=====] - 4s 8ms/step - loss: 0.4512 -
accuracy: 0.9725 - val_loss: 0.4476 - val_accuracy: 0.9694
Epoch 6/40

469/469 [=====] - 4s 9ms/step - loss: 0.4117 -
accuracy: 0.9769 - val_loss: 0.4085 - val_accuracy: 0.9728
Epoch 7/40
469/469 [=====] - 4s 8ms/step - loss: 0.3770 -
accuracy: 0.9795 - val_loss: 0.3802 - val_accuracy: 0.9743
Epoch 8/40
469/469 [=====] - 4s 9ms/step - loss: 0.3467 -
accuracy: 0.9822 - val_loss: 0.3498 - val_accuracy: 0.9767
Epoch 9/40
469/469 [=====] - 4s 8ms/step - loss: 0.3201 -
accuracy: 0.9846 - val_loss: 0.3346 - val_accuracy: 0.9753
Epoch 10/40
469/469 [=====] - 4s 8ms/step - loss: 0.2964 -
accuracy: 0.9861 - val_loss: 0.3179 - val_accuracy: 0.9751
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.2755 -
accuracy: 0.9872 - val_loss: 0.2889 - val_accuracy: 0.9789
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.2564 -
accuracy: 0.9885 - val_loss: 0.2837 - val_accuracy: 0.9759
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.2381 -
accuracy: 0.9901 - val_loss: 0.2725 - val_accuracy: 0.9744
Epoch 14/40
469/469 [=====] - 4s 7ms/step - loss: 0.2223 -
accuracy: 0.9908 - val_loss: 0.2457 - val_accuracy: 0.9787
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.2083 -
accuracy: 0.9916 - val_loss: 0.2300 - val_accuracy: 0.9803
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.1951 -
accuracy: 0.9920 - val_loss: 0.2210 - val_accuracy: 0.9805
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.1834 -
accuracy: 0.9928 - val_loss: 0.2075 - val_accuracy: 0.9808
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.1719 -
accuracy: 0.9936 - val_loss: 0.2032 - val_accuracy: 0.9793
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.1632 -
accuracy: 0.9934 - val_loss: 0.1905 - val_accuracy: 0.9814
Epoch 20/40
469/469 [=====] - 4s 8ms/step - loss: 0.1531 -
accuracy: 0.9946 - val_loss: 0.1871 - val_accuracy: 0.9794
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.1449 -
accuracy: 0.9947 - val_loss: 0.1839 - val_accuracy: 0.9787
Epoch 22/40

469/469 [=====] - 3s 7ms/step - loss: 0.1379 -
accuracy: 0.9950 - val_loss: 0.1708 - val_accuracy: 0.9810
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.1308 -
accuracy: 0.9953 - val_loss: 0.1659 - val_accuracy: 0.9804
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.1245 -
accuracy: 0.9955 - val_loss: 0.1636 - val_accuracy: 0.9794
Epoch 25/40
469/469 [=====] - 4s 8ms/step - loss: 0.1186 -
accuracy: 0.9960 - val_loss: 0.1554 - val_accuracy: 0.9799
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.1136 -
accuracy: 0.9962 - val_loss: 0.1521 - val_accuracy: 0.9800
Epoch 27/40
469/469 [=====] - 4s 8ms/step - loss: 0.1086 -
accuracy: 0.9962 - val_loss: 0.1434 - val_accuracy: 0.9815
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.1041 -
accuracy: 0.9968 - val_loss: 0.1415 - val_accuracy: 0.9809
Epoch 29/40
469/469 [=====] - 3s 7ms/step - loss: 0.0997 -
accuracy: 0.9969 - val_loss: 0.1360 - val_accuracy: 0.9812
Epoch 30/40
469/469 [=====] - 3s 7ms/step - loss: 0.0963 -
accuracy: 0.9969 - val_loss: 0.1341 - val_accuracy: 0.9807
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0929 -
accuracy: 0.9967 - val_loss: 0.1309 - val_accuracy: 0.9809
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0898 -
accuracy: 0.9971 - val_loss: 0.1325 - val_accuracy: 0.9791
Epoch 33/40
469/469 [=====] - 3s 7ms/step - loss: 0.0886 -
accuracy: 0.9966 - val_loss: 0.1251 - val_accuracy: 0.9830
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0846 -
accuracy: 0.9969 - val_loss: 0.1251 - val_accuracy: 0.9805
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0814 -
accuracy: 0.9973 - val_loss: 0.1224 - val_accuracy: 0.9806
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0796 -
accuracy: 0.9973 - val_loss: 0.1172 - val_accuracy: 0.9819
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0767 -
accuracy: 0.9980 - val_loss: 0.1164 - val_accuracy: 0.9817
Epoch 38/40

469/469 [=====] - 3s 7ms/step - loss: 0.0752 -
accuracy: 0.9978 - val_loss: 0.1295 - val_accuracy: 0.9763
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0737 -
accuracy: 0.9976 - val_loss: 0.1464 - val_accuracy: 0.9686
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0720 -
accuracy: 0.9978 - val_loss: 0.1110 - val_accuracy: 0.9806
Epoch 1/40
469/469 [=====] - 4s 8ms/step - loss: 0.8910 -
accuracy: 0.8855 - val_loss: 0.6883 - val_accuracy: 0.9375
Epoch 2/40
469/469 [=====] - 4s 7ms/step - loss: 0.6441 -
accuracy: 0.9433 - val_loss: 0.5935 - val_accuracy: 0.9507
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.5604 -
accuracy: 0.9582 - val_loss: 0.5338 - val_accuracy: 0.9598
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.4996 -
accuracy: 0.9671 - val_loss: 0.4928 - val_accuracy: 0.9625
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.4523 -
accuracy: 0.9725 - val_loss: 0.4366 - val_accuracy: 0.9712
Epoch 6/40
469/469 [=====] - 3s 7ms/step - loss: 0.4125 -
accuracy: 0.9769 - val_loss: 0.4067 - val_accuracy: 0.9741
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.3779 -
accuracy: 0.9802 - val_loss: 0.3819 - val_accuracy: 0.9733
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.3474 -
accuracy: 0.9823 - val_loss: 0.3518 - val_accuracy: 0.9768
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.3212 -
accuracy: 0.9843 - val_loss: 0.3304 - val_accuracy: 0.9765
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.2971 -
accuracy: 0.9858 - val_loss: 0.3108 - val_accuracy: 0.9775
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.2757 -
accuracy: 0.9876 - val_loss: 0.2912 - val_accuracy: 0.9773
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.2561 -
accuracy: 0.9888 - val_loss: 0.2735 - val_accuracy: 0.9784
Epoch 13/40
469/469 [=====] - 4s 8ms/step - loss: 0.2391 -
accuracy: 0.9897 - val_loss: 0.2547 - val_accuracy: 0.9805
Epoch 14/40

469/469 [=====] - 3s 7ms/step - loss: 0.2231 -
accuracy: 0.9907 - val_loss: 0.2442 - val_accuracy: 0.9793
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.2087 -
accuracy: 0.9914 - val_loss: 0.2309 - val_accuracy: 0.9800
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.1960 -
accuracy: 0.9920 - val_loss: 0.2221 - val_accuracy: 0.9797
Epoch 17/40
469/469 [=====] - 4s 8ms/step - loss: 0.1833 -
accuracy: 0.9930 - val_loss: 0.2067 - val_accuracy: 0.9811
Epoch 18/40
469/469 [=====] - 4s 8ms/step - loss: 0.1730 -
accuracy: 0.9934 - val_loss: 0.2136 - val_accuracy: 0.9772
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.1629 -
accuracy: 0.9937 - val_loss: 0.1911 - val_accuracy: 0.9800
Epoch 20/40
469/469 [=====] - 4s 8ms/step - loss: 0.1541 -
accuracy: 0.9941 - val_loss: 0.1823 - val_accuracy: 0.9810
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.1454 -
accuracy: 0.9950 - val_loss: 0.1737 - val_accuracy: 0.9811
Epoch 22/40
469/469 [=====] - 3s 7ms/step - loss: 0.1381 -
accuracy: 0.9950 - val_loss: 0.1717 - val_accuracy: 0.9802
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.1314 -
accuracy: 0.9955 - val_loss: 0.1627 - val_accuracy: 0.9810
Epoch 24/40
469/469 [=====] - 4s 7ms/step - loss: 0.1251 -
accuracy: 0.9958 - val_loss: 0.1560 - val_accuracy: 0.9818
Epoch 25/40
469/469 [=====] - 4s 8ms/step - loss: 0.1191 -
accuracy: 0.9959 - val_loss: 0.1500 - val_accuracy: 0.9833
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.1136 -
accuracy: 0.9963 - val_loss: 0.1471 - val_accuracy: 0.9809
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.1091 -
accuracy: 0.9964 - val_loss: 0.1459 - val_accuracy: 0.9805
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.1047 -
accuracy: 0.9965 - val_loss: 0.1392 - val_accuracy: 0.9808
Epoch 29/40
469/469 [=====] - 3s 6ms/step - loss: 0.1003 -
accuracy: 0.9968 - val_loss: 0.1347 - val_accuracy: 0.9818
Epoch 30/40

469/469 [=====] - 3s 6ms/step - loss: 0.0965 -
accuracy: 0.9970 - val_loss: 0.1319 - val_accuracy: 0.9820
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0934 -
accuracy: 0.9970 - val_loss: 0.1259 - val_accuracy: 0.9826
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0898 -
accuracy: 0.9973 - val_loss: 0.1243 - val_accuracy: 0.9823
Epoch 33/40
469/469 [=====] - 3s 6ms/step - loss: 0.0874 -
accuracy: 0.9971 - val_loss: 0.1215 - val_accuracy: 0.9825
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0841 -
accuracy: 0.9974 - val_loss: 0.1235 - val_accuracy: 0.9817
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0818 -
accuracy: 0.9974 - val_loss: 0.1159 - val_accuracy: 0.9828
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0797 -
accuracy: 0.9974 - val_loss: 0.1147 - val_accuracy: 0.9822
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0774 -
accuracy: 0.9978 - val_loss: 0.1120 - val_accuracy: 0.9825
Epoch 38/40
469/469 [=====] - 3s 7ms/step - loss: 0.0754 -
accuracy: 0.9978 - val_loss: 0.1105 - val_accuracy: 0.9817
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0731 -
accuracy: 0.9980 - val_loss: 0.1108 - val_accuracy: 0.9820
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0719 -
accuracy: 0.9976 - val_loss: 0.1104 - val_accuracy: 0.9821
Epoch 1/40
469/469 [=====] - 4s 7ms/step - loss: 1.3236 -
accuracy: 0.8873 - val_loss: 1.0791 - val_accuracy: 0.9347
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.9817 -
accuracy: 0.9415 - val_loss: 0.9016 - val_accuracy: 0.9439
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.8136 -
accuracy: 0.9566 - val_loss: 0.7642 - val_accuracy: 0.9532
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.6878 -
accuracy: 0.9649 - val_loss: 0.6429 - val_accuracy: 0.9622
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.5871 -
accuracy: 0.9701 - val_loss: 0.5491 - val_accuracy: 0.9694
Epoch 6/40

469/469 [=====] - 3s 7ms/step - loss: 0.5052 -
accuracy: 0.9744 - val_loss: 0.4758 - val_accuracy: 0.9724
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.4379 -
accuracy: 0.9768 - val_loss: 0.4205 - val_accuracy: 0.9722
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.3826 -
accuracy: 0.9796 - val_loss: 0.3790 - val_accuracy: 0.9710
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.3375 -
accuracy: 0.9807 - val_loss: 0.3401 - val_accuracy: 0.9733
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.2992 -
accuracy: 0.9823 - val_loss: 0.2970 - val_accuracy: 0.9768
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.2676 -
accuracy: 0.9833 - val_loss: 0.2712 - val_accuracy: 0.9774
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.2409 -
accuracy: 0.9851 - val_loss: 0.2461 - val_accuracy: 0.9783
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.2186 -
accuracy: 0.9857 - val_loss: 0.2278 - val_accuracy: 0.9771
Epoch 14/40
469/469 [=====] - 3s 7ms/step - loss: 0.2006 -
accuracy: 0.9862 - val_loss: 0.2110 - val_accuracy: 0.9788
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.1842 -
accuracy: 0.9869 - val_loss: 0.1986 - val_accuracy: 0.9791
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.1719 -
accuracy: 0.9872 - val_loss: 0.1846 - val_accuracy: 0.9786
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.1602 -
accuracy: 0.9883 - val_loss: 0.1743 - val_accuracy: 0.9804
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.1510 -
accuracy: 0.9882 - val_loss: 0.1693 - val_accuracy: 0.9791
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.1427 -
accuracy: 0.9890 - val_loss: 0.1644 - val_accuracy: 0.9779
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.1362 -
accuracy: 0.9889 - val_loss: 0.1553 - val_accuracy: 0.9796
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.1298 -
accuracy: 0.9902 - val_loss: 0.1612 - val_accuracy: 0.9763
Epoch 22/40

469/469 [=====] - 3s 7ms/step - loss: 0.1245 -
accuracy: 0.9905 - val_loss: 0.1519 - val_accuracy: 0.9775
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.1200 -
accuracy: 0.9905 - val_loss: 0.1426 - val_accuracy: 0.9800
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.1166 -
accuracy: 0.9905 - val_loss: 0.1409 - val_accuracy: 0.9784
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.1131 -
accuracy: 0.9912 - val_loss: 0.1393 - val_accuracy: 0.9795
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.1100 -
accuracy: 0.9912 - val_loss: 0.1366 - val_accuracy: 0.9789
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.1078 -
accuracy: 0.9912 - val_loss: 0.1355 - val_accuracy: 0.9796
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.1050 -
accuracy: 0.9919 - val_loss: 0.1347 - val_accuracy: 0.9795
Epoch 29/40
469/469 [=====] - 3s 7ms/step - loss: 0.1026 -
accuracy: 0.9924 - val_loss: 0.1275 - val_accuracy: 0.9814
Epoch 30/40
469/469 [=====] - 3s 7ms/step - loss: 0.1005 -
accuracy: 0.9923 - val_loss: 0.1260 - val_accuracy: 0.9806
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0992 -
accuracy: 0.9923 - val_loss: 0.1250 - val_accuracy: 0.9813
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0976 -
accuracy: 0.9926 - val_loss: 0.1394 - val_accuracy: 0.9743
Epoch 33/40
469/469 [=====] - 3s 7ms/step - loss: 0.0973 -
accuracy: 0.9924 - val_loss: 0.1332 - val_accuracy: 0.9776
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0958 -
accuracy: 0.9923 - val_loss: 0.1233 - val_accuracy: 0.9813
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0938 -
accuracy: 0.9930 - val_loss: 0.1230 - val_accuracy: 0.9804
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0930 -
accuracy: 0.9932 - val_loss: 0.1198 - val_accuracy: 0.9812
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0921 -
accuracy: 0.9934 - val_loss: 0.1162 - val_accuracy: 0.9820
Epoch 38/40

469/469 [=====] - 3s 7ms/step - loss: 0.0912 -
accuracy: 0.9934 - val_loss: 0.1170 - val_accuracy: 0.9820
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0893 -
accuracy: 0.9937 - val_loss: 0.1210 - val_accuracy: 0.9799
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0901 -
accuracy: 0.9930 - val_loss: 0.1169 - val_accuracy: 0.9831
Epoch 1/40
469/469 [=====] - 4s 7ms/step - loss: 1.3225 -
accuracy: 0.8890 - val_loss: 1.0845 - val_accuracy: 0.9300
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.9794 -
accuracy: 0.9437 - val_loss: 0.8875 - val_accuracy: 0.9492
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.8142 -
accuracy: 0.9568 - val_loss: 0.7468 - val_accuracy: 0.9612
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.6881 -
accuracy: 0.9648 - val_loss: 0.6500 - val_accuracy: 0.9624
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.5870 -
accuracy: 0.9703 - val_loss: 0.5493 - val_accuracy: 0.9697
Epoch 6/40
469/469 [=====] - 3s 7ms/step - loss: 0.5054 -
accuracy: 0.9743 - val_loss: 0.4832 - val_accuracy: 0.9688
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.4381 -
accuracy: 0.9768 - val_loss: 0.4255 - val_accuracy: 0.9722
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.3830 -
accuracy: 0.9794 - val_loss: 0.3757 - val_accuracy: 0.9737
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.3366 -
accuracy: 0.9816 - val_loss: 0.3349 - val_accuracy: 0.9752
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.2996 -
accuracy: 0.9822 - val_loss: 0.2967 - val_accuracy: 0.9771
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.2674 -
accuracy: 0.9836 - val_loss: 0.3171 - val_accuracy: 0.9610
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.2410 -
accuracy: 0.9847 - val_loss: 0.2486 - val_accuracy: 0.9767
Epoch 13/40
469/469 [=====] - 3s 6ms/step - loss: 0.2185 -
accuracy: 0.9858 - val_loss: 0.2255 - val_accuracy: 0.9779
Epoch 14/40

469/469 [=====] - 3s 7ms/step - loss: 0.2007 -
accuracy: 0.9864 - val_loss: 0.2155 - val_accuracy: 0.9765
Epoch 15/40
469/469 [=====] - 3s 6ms/step - loss: 0.1843 -
accuracy: 0.9874 - val_loss: 0.1949 - val_accuracy: 0.9791
Epoch 16/40
469/469 [=====] - 3s 6ms/step - loss: 0.1713 -
accuracy: 0.9875 - val_loss: 0.1832 - val_accuracy: 0.9804
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.1598 -
accuracy: 0.9886 - val_loss: 0.1777 - val_accuracy: 0.9786
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.1507 -
accuracy: 0.9886 - val_loss: 0.1746 - val_accuracy: 0.9767
Epoch 19/40
469/469 [=====] - 3s 6ms/step - loss: 0.1416 -
accuracy: 0.9894 - val_loss: 0.1679 - val_accuracy: 0.9779
Epoch 20/40
469/469 [=====] - 3s 6ms/step - loss: 0.1352 -
accuracy: 0.9901 - val_loss: 0.1617 - val_accuracy: 0.9793
Epoch 21/40
469/469 [=====] - 3s 6ms/step - loss: 0.1295 -
accuracy: 0.9899 - val_loss: 0.1511 - val_accuracy: 0.9801
Epoch 22/40
469/469 [=====] - 3s 6ms/step - loss: 0.1245 -
accuracy: 0.9903 - val_loss: 0.1461 - val_accuracy: 0.9803
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.1201 -
accuracy: 0.9902 - val_loss: 0.1491 - val_accuracy: 0.9781
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.1164 -
accuracy: 0.9907 - val_loss: 0.1385 - val_accuracy: 0.9802
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.1130 -
accuracy: 0.9915 - val_loss: 0.1390 - val_accuracy: 0.9804
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.1099 -
accuracy: 0.9913 - val_loss: 0.1354 - val_accuracy: 0.9804
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.1067 -
accuracy: 0.9919 - val_loss: 0.1395 - val_accuracy: 0.9778
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.1044 -
accuracy: 0.9917 - val_loss: 0.1345 - val_accuracy: 0.9785
Epoch 29/40
469/469 [=====] - 3s 7ms/step - loss: 0.1029 -
accuracy: 0.9917 - val_loss: 0.1444 - val_accuracy: 0.9748
Epoch 30/40

469/469 [=====] - 3s 7ms/step - loss: 0.1015 -
accuracy: 0.9919 - val_loss: 0.1259 - val_accuracy: 0.9816
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.0999 -
accuracy: 0.9921 - val_loss: 0.1280 - val_accuracy: 0.9818
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0986 -
accuracy: 0.9923 - val_loss: 0.1237 - val_accuracy: 0.9816
Epoch 33/40
469/469 [=====] - 3s 7ms/step - loss: 0.0969 -
accuracy: 0.9925 - val_loss: 0.1311 - val_accuracy: 0.9785
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0963 -
accuracy: 0.9925 - val_loss: 0.1287 - val_accuracy: 0.9803
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0949 -
accuracy: 0.9925 - val_loss: 0.1227 - val_accuracy: 0.9818
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0934 -
accuracy: 0.9934 - val_loss: 0.1195 - val_accuracy: 0.9810
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0925 -
accuracy: 0.9929 - val_loss: 0.1177 - val_accuracy: 0.9828
Epoch 38/40
469/469 [=====] - 3s 7ms/step - loss: 0.0917 -
accuracy: 0.9932 - val_loss: 0.1392 - val_accuracy: 0.9735
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0900 -
accuracy: 0.9934 - val_loss: 0.1177 - val_accuracy: 0.9817
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0893 -
accuracy: 0.9935 - val_loss: 0.1152 - val_accuracy: 0.9822
Epoch 1/40
469/469 [=====] - 4s 7ms/step - loss: 1.3250 -
accuracy: 0.8876 - val_loss: 1.0963 - val_accuracy: 0.9253
Epoch 2/40
469/469 [=====] - 3s 7ms/step - loss: 0.9777 -
accuracy: 0.9440 - val_loss: 0.9012 - val_accuracy: 0.9469
Epoch 3/40
469/469 [=====] - 3s 7ms/step - loss: 0.8122 -
accuracy: 0.9571 - val_loss: 0.7436 - val_accuracy: 0.9619
Epoch 4/40
469/469 [=====] - 3s 7ms/step - loss: 0.6859 -
accuracy: 0.9662 - val_loss: 0.6433 - val_accuracy: 0.9636
Epoch 5/40
469/469 [=====] - 3s 7ms/step - loss: 0.5866 -
accuracy: 0.9703 - val_loss: 0.5646 - val_accuracy: 0.9632
Epoch 6/40

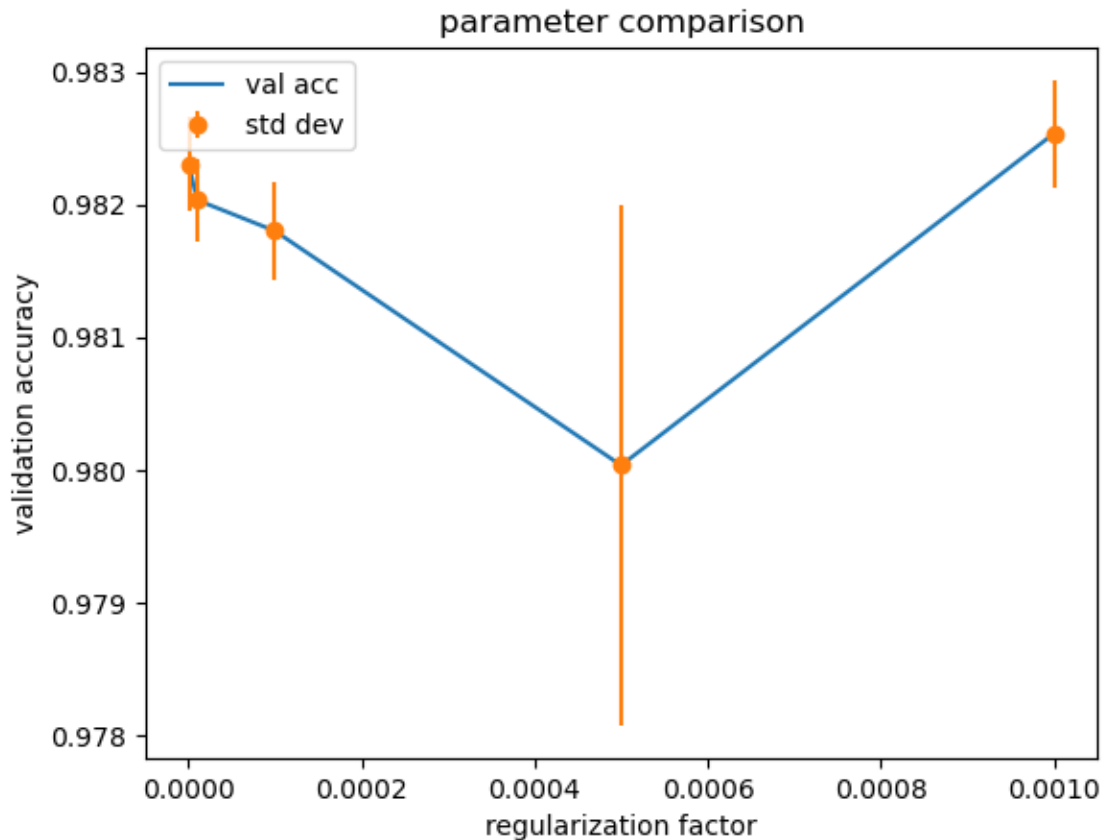
469/469 [=====] - 3s 7ms/step - loss: 0.5042 -
accuracy: 0.9747 - val_loss: 0.4810 - val_accuracy: 0.9696
Epoch 7/40
469/469 [=====] - 3s 7ms/step - loss: 0.4375 -
accuracy: 0.9776 - val_loss: 0.4228 - val_accuracy: 0.9723
Epoch 8/40
469/469 [=====] - 3s 7ms/step - loss: 0.3826 -
accuracy: 0.9796 - val_loss: 0.3706 - val_accuracy: 0.9750
Epoch 9/40
469/469 [=====] - 3s 7ms/step - loss: 0.3373 -
accuracy: 0.9815 - val_loss: 0.3315 - val_accuracy: 0.9766
Epoch 10/40
469/469 [=====] - 3s 7ms/step - loss: 0.2992 -
accuracy: 0.9827 - val_loss: 0.3107 - val_accuracy: 0.9715
Epoch 11/40
469/469 [=====] - 3s 7ms/step - loss: 0.2667 -
accuracy: 0.9845 - val_loss: 0.2752 - val_accuracy: 0.9770
Epoch 12/40
469/469 [=====] - 3s 7ms/step - loss: 0.2406 -
accuracy: 0.9854 - val_loss: 0.2472 - val_accuracy: 0.9768
Epoch 13/40
469/469 [=====] - 3s 7ms/step - loss: 0.2183 -
accuracy: 0.9860 - val_loss: 0.2246 - val_accuracy: 0.9791
Epoch 14/40
469/469 [=====] - 3s 7ms/step - loss: 0.2003 -
accuracy: 0.9860 - val_loss: 0.2133 - val_accuracy: 0.9775
Epoch 15/40
469/469 [=====] - 3s 7ms/step - loss: 0.1842 -
accuracy: 0.9874 - val_loss: 0.1988 - val_accuracy: 0.9787
Epoch 16/40
469/469 [=====] - 3s 7ms/step - loss: 0.1711 -
accuracy: 0.9879 - val_loss: 0.1846 - val_accuracy: 0.9785
Epoch 17/40
469/469 [=====] - 3s 7ms/step - loss: 0.1600 -
accuracy: 0.9881 - val_loss: 0.1778 - val_accuracy: 0.9793
Epoch 18/40
469/469 [=====] - 3s 7ms/step - loss: 0.1506 -
accuracy: 0.9888 - val_loss: 0.1703 - val_accuracy: 0.9790
Epoch 19/40
469/469 [=====] - 3s 7ms/step - loss: 0.1426 -
accuracy: 0.9891 - val_loss: 0.1620 - val_accuracy: 0.9788
Epoch 20/40
469/469 [=====] - 3s 7ms/step - loss: 0.1355 -
accuracy: 0.9896 - val_loss: 0.1619 - val_accuracy: 0.9772
Epoch 21/40
469/469 [=====] - 3s 7ms/step - loss: 0.1295 -
accuracy: 0.9898 - val_loss: 0.1551 - val_accuracy: 0.9784
Epoch 22/40

469/469 [=====] - 3s 7ms/step - loss: 0.1242 -
accuracy: 0.9901 - val_loss: 0.1465 - val_accuracy: 0.9808
Epoch 23/40
469/469 [=====] - 3s 7ms/step - loss: 0.1200 -
accuracy: 0.9906 - val_loss: 0.1452 - val_accuracy: 0.9793
Epoch 24/40
469/469 [=====] - 3s 7ms/step - loss: 0.1161 -
accuracy: 0.9906 - val_loss: 0.1384 - val_accuracy: 0.9800
Epoch 25/40
469/469 [=====] - 3s 7ms/step - loss: 0.1126 -
accuracy: 0.9912 - val_loss: 0.1431 - val_accuracy: 0.9782
Epoch 26/40
469/469 [=====] - 3s 7ms/step - loss: 0.1092 -
accuracy: 0.9915 - val_loss: 0.1338 - val_accuracy: 0.9802
Epoch 27/40
469/469 [=====] - 3s 7ms/step - loss: 0.1072 -
accuracy: 0.9914 - val_loss: 0.1305 - val_accuracy: 0.9818
Epoch 28/40
469/469 [=====] - 3s 7ms/step - loss: 0.1050 -
accuracy: 0.9918 - val_loss: 0.1429 - val_accuracy: 0.9787
Epoch 29/40
469/469 [=====] - 3s 6ms/step - loss: 0.1030 -
accuracy: 0.9917 - val_loss: 0.1395 - val_accuracy: 0.9779
Epoch 30/40
469/469 [=====] - 3s 7ms/step - loss: 0.1011 -
accuracy: 0.9922 - val_loss: 0.1307 - val_accuracy: 0.9804
Epoch 31/40
469/469 [=====] - 3s 7ms/step - loss: 0.1000 -
accuracy: 0.9920 - val_loss: 0.1347 - val_accuracy: 0.9777
Epoch 32/40
469/469 [=====] - 3s 7ms/step - loss: 0.0985 -
accuracy: 0.9921 - val_loss: 0.1241 - val_accuracy: 0.9811
Epoch 33/40
469/469 [=====] - 3s 7ms/step - loss: 0.0962 -
accuracy: 0.9931 - val_loss: 0.1223 - val_accuracy: 0.9809
Epoch 34/40
469/469 [=====] - 3s 7ms/step - loss: 0.0954 -
accuracy: 0.9929 - val_loss: 0.1200 - val_accuracy: 0.9820
Epoch 35/40
469/469 [=====] - 3s 7ms/step - loss: 0.0947 -
accuracy: 0.9929 - val_loss: 0.1230 - val_accuracy: 0.9808
Epoch 36/40
469/469 [=====] - 3s 7ms/step - loss: 0.0925 -
accuracy: 0.9930 - val_loss: 0.1212 - val_accuracy: 0.9808
Epoch 37/40
469/469 [=====] - 3s 7ms/step - loss: 0.0921 -
accuracy: 0.9933 - val_loss: 0.1230 - val_accuracy: 0.9802
Epoch 38/40

```

469/469 [=====] - 3s 7ms/step - loss: 0.0915 -
accuracy: 0.9930 - val_loss: 0.1185 - val_accuracy: 0.9817
Epoch 39/40
469/469 [=====] - 3s 7ms/step - loss: 0.0900 -
accuracy: 0.9936 - val_loss: 0.1154 - val_accuracy: 0.9822
Epoch 40/40
469/469 [=====] - 3s 7ms/step - loss: 0.0895 -
accuracy: 0.9934 - val_loss: 0.1165 - val_accuracy: 0.9823
Test loss: 0.11649343371391296, Test accuracy 0.9822999835014343

```



Task 2.4 The best validation accuracy we could get is 0.9823. One of the reasons, why we haven't got the same result as Hinton might be that we don't know the exact regularization factors and number of epochs he has used.

3. Convolutional layers

Task 3.1 Design a model that makes use of at least one convolutional layer – how performant a model can you get? – According to the MNIST database it should be possible reach to 99% accuracy on the validation data. If you choose to use any layers apart from the convolutional layers

and layers that you used in previous questions, you must describe what they do. If you do not reach 99% accuracy, report your best performance, and explain your attempts and thought process.

```
[ ]: ## Define model ##

def train_conv():
    model = Sequential()

    #model.add(Flatten())
    # Multiple Conv2D layer
    model.add(Conv2D(32, kernel_size=3, padding="valid", input_shape=(28, 28, 1), activation = 'relu')),
    model.add(MaxPooling2D(pool_size=(2, 2), strides=(1, 1))),
    model.add(Conv2D(64, kernel_size=3, padding="valid", activation = 'relu')),
    model.add(MaxPooling2D(pool_size=(2, 2), strides=(1, 1))),
    model.add(Conv2D(100, kernel_size=3, padding="valid", activation = 'relu')),
    model.add(MaxPooling2D(pool_size=(2, 2), strides=(1, 1))),
    model.add(Flatten()),
    model.add(Dense(200, activation='relu')),
    model.add(Dense(num_classes, activation='softmax'))

    model.compile(loss=keras.losses.categorical_crossentropy,
                  optimizer="adam",
                  metrics=['accuracy'],)

    fit_info = model.fit(x_train, y_train,
                        batch_size=batch_size,
                        epochs=10,
                        verbose=1,
                        validation_data=(x_test, y_test))
    score = model.evaluate(x_test, y_test, verbose=0)
    print('Test loss: {}, Test accuracy {}'.format(score[0], score[1]))
    return fit_info
train_conv()
```

Epoch 1/10

469/469 [=====] - 133s 280ms/step - loss: 0.1133 - accuracy: 0.9652 - val_loss: 0.0374 - val_accuracy: 0.9879

Epoch 2/10

469/469 [=====] - 131s 280ms/step - loss: 0.0352 - accuracy: 0.9891 - val_loss: 0.0328 - val_accuracy: 0.9886

Epoch 3/10

469/469 [=====] - 132s 282ms/step - loss: 0.0228 - accuracy: 0.9927 - val_loss: 0.0262 - val_accuracy: 0.9921

Epoch 4/10

469/469 [=====] - 132s 282ms/step - loss: 0.0171 - accuracy: 0.9945 - val_loss: 0.0320 - val_accuracy: 0.9910

Epoch 5/10

```

469/469 [=====] - 133s 283ms/step - loss: 0.0129 -
accuracy: 0.9956 - val_loss: 0.0373 - val_accuracy: 0.9901
Epoch 6/10
469/469 [=====] - 135s 289ms/step - loss: 0.0101 -
accuracy: 0.9968 - val_loss: 0.0274 - val_accuracy: 0.9933
Epoch 7/10
469/469 [=====] - 140s 299ms/step - loss: 0.0090 -
accuracy: 0.9973 - val_loss: 0.0339 - val_accuracy: 0.9903
Epoch 8/10
469/469 [=====] - 143s 304ms/step - loss: 0.0087 -
accuracy: 0.9971 - val_loss: 0.0284 - val_accuracy: 0.9926
Epoch 9/10
469/469 [=====] - 148s 316ms/step - loss: 0.0063 -
accuracy: 0.9978 - val_loss: 0.0311 - val_accuracy: 0.9930
Epoch 10/10
124/469 [=====>...] - ETA: 1:43 - loss: 0.0077 - accuracy:
0.9976

```

We created a simple ConvNet of three hidden convolutional layer respectively with 32 , 64 and 100 filters with Maxpooling layer between each, and one Flatten layer and finally two fully-connected layer with 100 and 10 neurons at the end for the classification (softmax activation). We could achieve with the Adam optimizer (not stochastic gradient descent this time) a Test loss of **0.007** and a Test accuracy of **0.9976**. For the convolutional layer we have put a padding of 0 meaning that there is no "starting gap" between the filter and the image matrix. We let the strides to 1 meaning a step of 1 on every filter (we don't loose information but the training speed can be a bit slow). And for the feature we gently increased it until we achieve good accuracy. Our method was to put multiple convolutional layer, not too much because the dataset was not highdimensional and some MaxPooling layer to speed-up the training and get the most interesting part of the features. Starting with features size of 16, 32 ,64 and then we find that 32 ,64 ,100 was enough. After testing different features size and neurons size, we came to this model.

Task 3.2 Convolutional layers works well on images classification and more generally in image processing application. Since it's using convolutional filters on matrix represented by an image, it can detect abstracts features like objects or small geometric forms. One issue with convolutional layer is when dealing with high dimensional data (full-hd image for example) it can be tricky and slow to trained model like that. So we put MapPooling layer to speed-up training without loosing too much information. One other issue is that convolutional neural networks tend to detect very small and abstract features, this has trouble detecting an whole geometric form on images. While a children just have to see one time a cat to classify it at a cat next time, for a convolutional network it can takes thousand of good quality images to achieve same accuracy. Another related problem is when dealing with adversarial attack, in fact by just putting a noise in the image that human cannot discern, this can dramatically changed the accuracy of the model. Also , Convolutional layers exploit the spatial structure of data by using small receptive fields (kernels) that slide across the input. This allows them to capture local patterns and relationships within the data. In contrast, fully connected layers connect every neuron to every neuron in the previous layer, ignoring the spatial structure. For images, this means that fully connected layers would treat each pixel as an independent feature, neglecting the important locality information.