

Lukas Jigberg 18 h

In [3]:

```
# imports
from __future__ import print_function
import keras
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.regularizers import l2
from keras import backend as K
import tensorflow as tf
from matplotlib import pyplot as plt
from keras.utils import np_utils
import numpy as np
```

In [4]:

```
# 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()

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>

11493376/11490434 [=====] - 0s 0us/step

11501568/11490434 [=====] - 0s 0us/step

1 - Preprocessing

In [5]:

```
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)
```

In [6]:

```
## 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=tf.keras.optimizers.SGD(lr = 0.1),
              metrics=['accuracy'],)

fit_info = model.fit(x_train, y_train,
                    batch_size=batch_size,
                    epochs=epochs,
                    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]))
print(y_train)

model.summary()
model.count_params()
```

```
/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/gradient_descen
t.py:102: UserWarning: The `lr` argument is deprecated, use `learning_rate`
instead.
```

```
super(SGD, self).__init__(name, **kwargs)
```

Epoch 1/10

```
469/469 [=====] - 3s 4ms/step - loss: 0.4855 - ac
curacy: 0.8605 - val_loss: 0.2740 - val_accuracy: 0.9195
```

Epoch 2/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.2272 - ac
curacy: 0.9331 - val_loss: 0.1944 - val_accuracy: 0.9408
```

Epoch 3/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.1752 - ac
curacy: 0.9493 - val_loss: 0.1547 - val_accuracy: 0.9534
```

Epoch 4/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.1427 - ac
curacy: 0.9577 - val_loss: 0.1371 - val_accuracy: 0.9598
```

Epoch 5/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.1214 - ac
curacy: 0.9642 - val_loss: 0.1210 - val_accuracy: 0.9645
```

Epoch 6/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.1059 - ac
curacy: 0.9687 - val_loss: 0.1199 - val_accuracy: 0.9643
```

Epoch 7/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.0937 - ac
curacy: 0.9729 - val_loss: 0.1136 - val_accuracy: 0.9655
```

Epoch 8/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.0850 - ac
curacy: 0.9747 - val_loss: 0.1006 - val_accuracy: 0.9695
```

Epoch 9/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.0760 - ac
curacy: 0.9769 - val_loss: 0.0988 - val_accuracy: 0.9700
```

Epoch 10/10

```
469/469 [=====] - 2s 4ms/step - loss: 0.0700 - ac
curacy: 0.9794 - val_loss: 0.0925 - val_accuracy: 0.9711
```

```
Test loss: 0.09245414286851883, Test accuracy 0.9710999727249146
```

```
[[0. 0. 0. ... 0. 0. 0.]
 [1. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 ...
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 1. 0.]]
```

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
```

Out[6]:

55050

We first get rid of the grayscale level between 0-255 by splitting the x sets by 255 resulting in a 0 for White or 1 for Black. To perform the operation does we first need to do type conversion from integer to Float. Doing this will make it easier for us later by making us only need to focus on either 0 1 for 'filled pixel'.

We then sort out y test and train by using to_categorical changing it from [1,2,3,1] -> [0,1,0...],[0,0,1...], [0,0,0,1...] etc. Displaying a digit as, such as 5 as [0,0,0,0,0,1,0,0,0,0] , As described in the lab description.

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

a - Neurons, Functions, param, input

Layers and Neurons

Using `model.summary` can we read that there are 4 layers holding x amount of neurons each.

`flatten (Flatten): 784`

`dense (Dense): 64`

`dense_1 (Dense): 64`

`dense_2 (Dense): 10`

Totaling 922 neurons. 728 is the product of our image rows and columns, $28 \times 28 = 784$

Activation Functions

We see 2 types of activation functions used, Relu and Softmax.

Relu is used twice but we could have tried using the other activation functions Sigmoid or Tanh (Step is to inaccurate) . They activate differently and have different outputs.\ Relu is by far the simplest. It is a lightweight function that doesn't need that much processing/computing power to produce its answer compared to tanH and Sigmoid. Its does not have as big of a 'Vanishing Gradients Problem', and if the problem still was severe could you try leaky Relu.\ Relu works by taking the input and outputting the same EXCEPT for any number below 0 which is outputted as 0. Giving the range $(0 < \infty)$.

Softmax is the most common activation function for the final layer. It calculates the probability of 'arriving' at that particular output out of all our other outputs. Having the probability data is very important for us the users as well as it keeps us updated on where the AI is struggling, and we can more easily see where it might have hard time choosing. Important factors for important tasks like in the medical field.

Numbers of Parameters

`model.count_params()` gives us 55050, calculating it gives us:\ $784 \cdot 64 + 64 \cdot 64 + 64 \cdot 10 = 54912$ \ $64 + 64 + 10 + 138 = 54912 + 138 = 55050$

Input Dimensions

The input 784 is the product of our 28×28 pixel grid. The outputs is then choosen to be `num_classes = 10` because we wanted to represent the numbers [0..9]

b - Loss

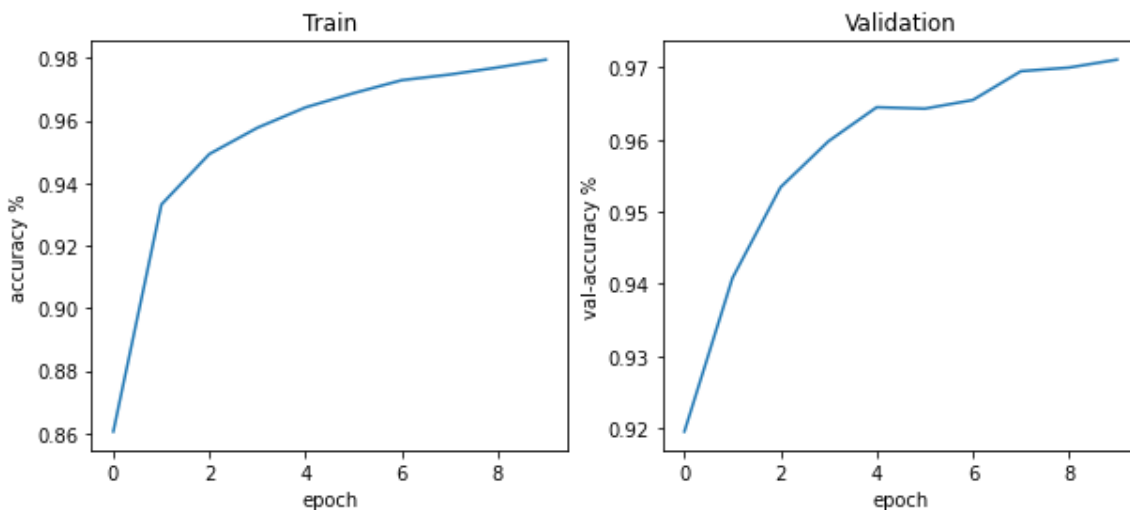
`keras.losses.categorical_crossentropy` is the function we use to determine loss. It uses the categorical cross-entropy algorithm to determine how much our loss should be ranging from 0, the best upwards to neg infinity, the worst. The input can range from 0 - 1, 0 being bad and 1 being good\ The algorithm is $\text{Loss} = - \sum_k (t_k * \log(y_k))$ Where t_k is the target value and y_k is the predicted value.\ If we are perfectly correct (1) we will receive $\log(1)=0$ loss\ Closing in on 0 will give us bigger and bigger values $\log(0.01)=-2$, $\log(0.0000001)=-7$ etc.

The reason why we want loss is because it creates a system to evaluate the models decision making process. Allowing the model to relies when its 'going in the wrong decision'. The reason why we might want to use categorical cross-entropy is because it quickly increases the loss value when the input is bad. Reaching really bad loss value when we are closing in on 0.

c - Train 10 epochs

In [7]:

```
fig, axs = plt.subplots(1,2)
axs[0].plot(fit_info.history["accuracy"])
axs[0].set(title = "Train", xlabel = "epoch", ylabel = "accuracy %")
axs[1].plot(fit_info.history["val_accuracy"])
axs[1].set(title = "Validation", xlabel = "epoch", ylabel = "val-accuracy %")
fig.set_figwidth(10)
```



d - Update model

From the graph above do we have a train accuracy of around 98% and validation accuracy of around 97%. Our hope is to increase it by implementing more units and train it for much longer. Our goal/hope is to beat Geoff Hinton's accuracy proclaimed score of 98.47%.

In [8]:

```
epochs = 40
regularizationFactors = [0.001,0.0001,0.00001,0.00005,0.000001];
result = []

def trainModel(regF):

    model2 = Sequential()
    model2.add(Flatten())
    model2.add(Dense(500, activation = 'relu', activity_regularizer=l2(regF)))
    model2.add(Dense(300, activation = 'relu', activity_regularizer=l2(regF)))
    model2.add(Dense(num_classes, activation='softmax'))

    model2.compile(loss=keras.losses.categorical_crossentropy,
                    optimizer=tf.keras.optimizers.SGD(lr = 0.1),
                    metrics=['accuracy'])

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

    return fit_info.history['val_accuracy'][-1]

for regF in regularizationFactors:
    listValidation = []
    for i in range(0,3):
        listValidation.append(trainModel(regF))
    result.append(listValidation)
```


Epoch 1/40

29/469 [>.....] - ETA: 1s - loss: 0.0610 - accuracy: 0.9820

/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/gradient_descent.py:102: UserWarning: The `lr` argument is deprecated, use `learning_rate` instead.

super(SGD, self).__init__(name, **kwargs)

469/469 [=====] - 2s 4ms/step - loss: 0.0636 - accuracy: 0.9811 - val_loss: 0.0900 - val_accuracy: 0.9727
Epoch 2/40
469/469 [=====] - 2s 4ms/step - loss: 0.0589 - accuracy: 0.9829 - val_loss: 0.0871 - val_accuracy: 0.9738
Epoch 3/40
469/469 [=====] - 2s 4ms/step - loss: 0.0545 - accuracy: 0.9837 - val_loss: 0.0922 - val_accuracy: 0.9717
Epoch 4/40
469/469 [=====] - 2s 4ms/step - loss: 0.0501 - accuracy: 0.9854 - val_loss: 0.0838 - val_accuracy: 0.9744
Epoch 5/40
469/469 [=====] - 2s 4ms/step - loss: 0.0470 - accuracy: 0.9863 - val_loss: 0.0853 - val_accuracy: 0.9740
Epoch 6/40
469/469 [=====] - 2s 4ms/step - loss: 0.0438 - accuracy: 0.9871 - val_loss: 0.0862 - val_accuracy: 0.9746
Epoch 7/40
469/469 [=====] - 2s 4ms/step - loss: 0.0407 - accuracy: 0.9880 - val_loss: 0.0827 - val_accuracy: 0.9744
Epoch 8/40
469/469 [=====] - 2s 4ms/step - loss: 0.0378 - accuracy: 0.9888 - val_loss: 0.0824 - val_accuracy: 0.9748
Epoch 9/40
469/469 [=====] - 2s 5ms/step - loss: 0.0343 - accuracy: 0.9902 - val_loss: 0.0818 - val_accuracy: 0.9759
Epoch 10/40
469/469 [=====] - 2s 4ms/step - loss: 0.0330 - accuracy: 0.9910 - val_loss: 0.0917 - val_accuracy: 0.9731
Epoch 11/40
469/469 [=====] - 2s 4ms/step - loss: 0.0302 - accuracy: 0.9918 - val_loss: 0.0823 - val_accuracy: 0.9765
Epoch 12/40
469/469 [=====] - 2s 4ms/step - loss: 0.0282 - accuracy: 0.9921 - val_loss: 0.0855 - val_accuracy: 0.9746
Epoch 13/40
469/469 [=====] - 2s 4ms/step - loss: 0.0257 - accuracy: 0.9929 - val_loss: 0.0812 - val_accuracy: 0.9766
Epoch 14/40
469/469 [=====] - 2s 4ms/step - loss: 0.0243 - accuracy: 0.9935 - val_loss: 0.0927 - val_accuracy: 0.9722
Epoch 15/40
469/469 [=====] - 2s 4ms/step - loss: 0.0226 - accuracy: 0.9942 - val_loss: 0.0853 - val_accuracy: 0.9759
Epoch 16/40
469/469 [=====] - 2s 4ms/step - loss: 0.0206 - accuracy: 0.9946 - val_loss: 0.0868 - val_accuracy: 0.9753
Epoch 17/40
469/469 [=====] - 2s 4ms/step - loss: 0.0189 - accuracy: 0.9955 - val_loss: 0.0886 - val_accuracy: 0.9762
Epoch 18/40
469/469 [=====] - 2s 4ms/step - loss: 0.0176 - accuracy: 0.9958 - val_loss: 0.0848 - val_accuracy: 0.9767
Epoch 19/40
469/469 [=====] - 2s 4ms/step - loss: 0.0167 - accuracy: 0.9960 - val_loss: 0.0845 - val_accuracy: 0.9763
Epoch 20/40
469/469 [=====] - 2s 4ms/step - loss: 0.0154 - accuracy: 0.9963 - val_loss: 0.0853 - val_accuracy: 0.9765
Epoch 21/40
469/469 [=====] - 2s 4ms/step - loss: 0.0140 - ac

curacy: 0.9969 - val_loss: 0.0923 - val_accuracy: 0.9757
Epoch 22/40
469/469 [=====] - 2s 4ms/step - loss: 0.0127 - accuracy: 0.9974 - val_loss: 0.0942 - val_accuracy: 0.9760
Epoch 23/40
469/469 [=====] - 2s 4ms/step - loss: 0.0121 - accuracy: 0.9977 - val_loss: 0.0898 - val_accuracy: 0.9744
Epoch 24/40
469/469 [=====] - 2s 4ms/step - loss: 0.0113 - accuracy: 0.9978 - val_loss: 0.0936 - val_accuracy: 0.9757
Epoch 25/40
469/469 [=====] - 2s 4ms/step - loss: 0.0101 - accuracy: 0.9983 - val_loss: 0.0915 - val_accuracy: 0.9771
Epoch 26/40
469/469 [=====] - 2s 4ms/step - loss: 0.0097 - accuracy: 0.9984 - val_loss: 0.0936 - val_accuracy: 0.9756
Epoch 27/40
469/469 [=====] - 2s 4ms/step - loss: 0.0085 - accuracy: 0.9986 - val_loss: 0.0920 - val_accuracy: 0.9758
Epoch 28/40
469/469 [=====] - 2s 4ms/step - loss: 0.0080 - accuracy: 0.9988 - val_loss: 0.0949 - val_accuracy: 0.9744
Epoch 29/40
469/469 [=====] - 2s 4ms/step - loss: 0.0075 - accuracy: 0.9989 - val_loss: 0.0954 - val_accuracy: 0.9763
Epoch 30/40
469/469 [=====] - 2s 4ms/step - loss: 0.0072 - accuracy: 0.9990 - val_loss: 0.0963 - val_accuracy: 0.9756
Epoch 31/40
469/469 [=====] - 2s 4ms/step - loss: 0.0063 - accuracy: 0.9994 - val_loss: 0.0998 - val_accuracy: 0.9754
Epoch 32/40
469/469 [=====] - 2s 4ms/step - loss: 0.0060 - accuracy: 0.9994 - val_loss: 0.0996 - val_accuracy: 0.9757
Epoch 33/40
469/469 [=====] - 2s 4ms/step - loss: 0.0055 - accuracy: 0.9995 - val_loss: 0.0973 - val_accuracy: 0.9760
Epoch 34/40
469/469 [=====] - 2s 4ms/step - loss: 0.0050 - accuracy: 0.9995 - val_loss: 0.0975 - val_accuracy: 0.9760
Epoch 35/40
469/469 [=====] - 2s 4ms/step - loss: 0.0047 - accuracy: 0.9995 - val_loss: 0.0989 - val_accuracy: 0.9759
Epoch 36/40
469/469 [=====] - 2s 4ms/step - loss: 0.0042 - accuracy: 0.9998 - val_loss: 0.1004 - val_accuracy: 0.9753
Epoch 37/40
469/469 [=====] - 2s 4ms/step - loss: 0.0039 - accuracy: 0.9998 - val_loss: 0.1021 - val_accuracy: 0.9759
Epoch 38/40
469/469 [=====] - 2s 4ms/step - loss: 0.0037 - accuracy: 0.9998 - val_loss: 0.1014 - val_accuracy: 0.9749
Epoch 39/40
469/469 [=====] - 2s 4ms/step - loss: 0.0034 - accuracy: 0.9999 - val_loss: 0.1016 - val_accuracy: 0.9756
Epoch 40/40
469/469 [=====] - 2s 5ms/step - loss: 0.0031 - accuracy: 0.9999 - val_loss: 0.1028 - val_accuracy: 0.9758
Epoch 1/40
469/469 [=====] - 2s 4ms/step - loss: 0.0030 - accuracy: 0.9999 - val_loss: 0.1043 - val_accuracy: 0.9758

Epoch 2/40

469/469 [=====] - 2s 4ms/step - loss: 0.0028 - accuracy: 1.0000 - val_loss: 0.1072 - val_accuracy: 0.9758

Epoch 3/40

469/469 [=====] - 2s 4ms/step - loss: 0.0027 - accuracy: 0.9999 - val_loss: 0.1051 - val_accuracy: 0.9756

Epoch 4/40

469/469 [=====] - 2s 4ms/step - loss: 0.0026 - accuracy: 0.9999 - val_loss: 0.1061 - val_accuracy: 0.9761

Epoch 5/40

469/469 [=====] - 2s 4ms/step - loss: 0.0024 - accuracy: 1.0000 - val_loss: 0.1073 - val_accuracy: 0.9760

Epoch 6/40

469/469 [=====] - 2s 4ms/step - loss: 0.0023 - accuracy: 1.0000 - val_loss: 0.1073 - val_accuracy: 0.9753

Epoch 7/40

469/469 [=====] - 2s 4ms/step - loss: 0.0022 - accuracy: 1.0000 - val_loss: 0.1079 - val_accuracy: 0.9757

Epoch 8/40

469/469 [=====] - 2s 4ms/step - loss: 0.0021 - accuracy: 1.0000 - val_loss: 0.1075 - val_accuracy: 0.9761

Epoch 9/40

469/469 [=====] - 2s 4ms/step - loss: 0.0020 - accuracy: 1.0000 - val_loss: 0.1087 - val_accuracy: 0.9757

Epoch 10/40

469/469 [=====] - 2s 4ms/step - loss: 0.0019 - accuracy: 1.0000 - val_loss: 0.1094 - val_accuracy: 0.9757

Epoch 11/40

469/469 [=====] - 2s 4ms/step - loss: 0.0018 - accuracy: 1.0000 - val_loss: 0.1109 - val_accuracy: 0.9761

Epoch 12/40

469/469 [=====] - 2s 4ms/step - loss: 0.0018 - accuracy: 1.0000 - val_loss: 0.1116 - val_accuracy: 0.9759

Epoch 13/40

469/469 [=====] - 2s 4ms/step - loss: 0.0017 - accuracy: 1.0000 - val_loss: 0.1105 - val_accuracy: 0.9756

Epoch 14/40

469/469 [=====] - 2s 4ms/step - loss: 0.0016 - accuracy: 1.0000 - val_loss: 0.1118 - val_accuracy: 0.9757

Epoch 15/40

469/469 [=====] - 2s 4ms/step - loss: 0.0016 - accuracy: 1.0000 - val_loss: 0.1129 - val_accuracy: 0.9757

Epoch 16/40

469/469 [=====] - 2s 4ms/step - loss: 0.0015 - accuracy: 1.0000 - val_loss: 0.1127 - val_accuracy: 0.9761

Epoch 17/40

469/469 [=====] - 2s 4ms/step - loss: 0.0015 - accuracy: 1.0000 - val_loss: 0.1126 - val_accuracy: 0.9758

Epoch 18/40

469/469 [=====] - 2s 4ms/step - loss: 0.0014 - accuracy: 1.0000 - val_loss: 0.1133 - val_accuracy: 0.9756

Epoch 19/40

469/469 [=====] - 2s 4ms/step - loss: 0.0014 - accuracy: 1.0000 - val_loss: 0.1140 - val_accuracy: 0.9759

Epoch 20/40

469/469 [=====] - 2s 4ms/step - loss: 0.0013 - accuracy: 1.0000 - val_loss: 0.1152 - val_accuracy: 0.9753

Epoch 21/40

469/469 [=====] - 2s 4ms/step - loss: 0.0013 - accuracy: 1.0000 - val_loss: 0.1156 - val_accuracy: 0.9761

Epoch 22/40

```
469/469 [=====] - 2s 4ms/step - loss: 0.0012 - ac
curacy: 1.0000 - val_loss: 0.1154 - val_accuracy: 0.9761
Epoch 23/40
469/469 [=====] - 2s 4ms/step - loss: 0.0012 - ac
curacy: 1.0000 - val_loss: 0.1159 - val_accuracy: 0.9757
Epoch 24/40
469/469 [=====] - 2s 4ms/step - loss: 0.0012 - ac
curacy: 1.0000 - val_loss: 0.1161 - val_accuracy: 0.9755
Epoch 25/40
469/469 [=====] - 2s 4ms/step - loss: 0.0012 - ac
curacy: 1.0000 - val_loss: 0.1169 - val_accuracy: 0.9757
Epoch 26/40
469/469 [=====] - 2s 4ms/step - loss: 0.0011 - ac
curacy: 1.0000 - val_loss: 0.1179 - val_accuracy: 0.9755
Epoch 27/40
469/469 [=====] - 2s 4ms/step - loss: 0.0011 - ac
curacy: 1.0000 - val_loss: 0.1172 - val_accuracy: 0.9758
Epoch 28/40
469/469 [=====] - 2s 5ms/step - loss: 0.0011 - ac
curacy: 1.0000 - val_loss: 0.1191 - val_accuracy: 0.9750
Epoch 29/40
469/469 [=====] - 2s 4ms/step - loss: 0.0010 - ac
curacy: 1.0000 - val_loss: 0.1188 - val_accuracy: 0.9756
Epoch 30/40
469/469 [=====] - 2s 4ms/step - loss: 0.0010 - ac
curacy: 1.0000 - val_loss: 0.1183 - val_accuracy: 0.9754
Epoch 31/40
469/469 [=====] - 2s 5ms/step - loss: 9.8602e-04
- accuracy: 1.0000 - val_loss: 0.1189 - val_accuracy: 0.9756
Epoch 32/40
469/469 [=====] - 2s 4ms/step - loss: 9.5600e-04
- accuracy: 1.0000 - val_loss: 0.1198 - val_accuracy: 0.9758
Epoch 33/40
469/469 [=====] - 2s 4ms/step - loss: 9.3717e-04
- accuracy: 1.0000 - val_loss: 0.1201 - val_accuracy: 0.9757
Epoch 34/40
469/469 [=====] - 2s 4ms/step - loss: 9.1971e-04
- accuracy: 1.0000 - val_loss: 0.1204 - val_accuracy: 0.9752
Epoch 35/40
469/469 [=====] - 2s 5ms/step - loss: 8.9303e-04
- accuracy: 1.0000 - val_loss: 0.1207 - val_accuracy: 0.9756
Epoch 36/40
469/469 [=====] - 2s 4ms/step - loss: 8.7198e-04
- accuracy: 1.0000 - val_loss: 0.1211 - val_accuracy: 0.9756
Epoch 37/40
469/469 [=====] - 2s 4ms/step - loss: 8.6330e-04
- accuracy: 1.0000 - val_loss: 0.1219 - val_accuracy: 0.9758
Epoch 38/40
469/469 [=====] - 2s 4ms/step - loss: 8.3340e-04
- accuracy: 1.0000 - val_loss: 0.1224 - val_accuracy: 0.9753
Epoch 39/40
469/469 [=====] - 2s 4ms/step - loss: 8.1820e-04
- accuracy: 1.0000 - val_loss: 0.1221 - val_accuracy: 0.9757
Epoch 40/40
469/469 [=====] - 2s 4ms/step - loss: 8.0563e-04
- accuracy: 1.0000 - val_loss: 0.1218 - val_accuracy: 0.9757
Epoch 1/40
469/469 [=====] - 2s 4ms/step - loss: 7.8243e-04
- accuracy: 1.0000 - val_loss: 0.1226 - val_accuracy: 0.9757
Epoch 2/40
469/469 [=====] - 2s 4ms/step - loss: 7.7106e-04
```

```
- accuracy: 1.0000 - val_loss: 0.1231 - val_accuracy: 0.9754
Epoch 3/40
469/469 [=====] - 2s 4ms/step - loss: 7.5295e-04
- accuracy: 1.0000 - val_loss: 0.1245 - val_accuracy: 0.9756
Epoch 4/40
469/469 [=====] - 2s 4ms/step - loss: 7.4243e-04
- accuracy: 1.0000 - val_loss: 0.1239 - val_accuracy: 0.9751
Epoch 5/40
469/469 [=====] - 2s 4ms/step - loss: 7.2606e-04
- accuracy: 1.0000 - val_loss: 0.1242 - val_accuracy: 0.9756
Epoch 6/40
469/469 [=====] - 2s 4ms/step - loss: 7.1486e-04
- accuracy: 1.0000 - val_loss: 0.1247 - val_accuracy: 0.9755
Epoch 7/40
469/469 [=====] - 2s 4ms/step - loss: 6.9800e-04
- accuracy: 1.0000 - val_loss: 0.1251 - val_accuracy: 0.9755
Epoch 8/40
469/469 [=====] - 2s 4ms/step - loss: 6.8788e-04
- accuracy: 1.0000 - val_loss: 0.1249 - val_accuracy: 0.9755
Epoch 9/40
469/469 [=====] - 2s 4ms/step - loss: 6.7391e-04
- accuracy: 1.0000 - val_loss: 0.1249 - val_accuracy: 0.9755
Epoch 10/40
469/469 [=====] - 2s 4ms/step - loss: 6.6103e-04
- accuracy: 1.0000 - val_loss: 0.1250 - val_accuracy: 0.9761
Epoch 11/40
469/469 [=====] - 2s 4ms/step - loss: 6.5151e-04
- accuracy: 1.0000 - val_loss: 0.1266 - val_accuracy: 0.9761
Epoch 12/40
469/469 [=====] - 2s 4ms/step - loss: 6.3808e-04
- accuracy: 1.0000 - val_loss: 0.1264 - val_accuracy: 0.9749
Epoch 13/40
469/469 [=====] - 2s 4ms/step - loss: 6.3027e-04
- accuracy: 1.0000 - val_loss: 0.1269 - val_accuracy: 0.9756
Epoch 14/40
469/469 [=====] - 2s 4ms/step - loss: 6.1683e-04
- accuracy: 1.0000 - val_loss: 0.1263 - val_accuracy: 0.9749
Epoch 15/40
469/469 [=====] - 2s 4ms/step - loss: 6.1133e-04
- accuracy: 1.0000 - val_loss: 0.1273 - val_accuracy: 0.9748
Epoch 16/40
469/469 [=====] - 2s 4ms/step - loss: 5.9845e-04
- accuracy: 1.0000 - val_loss: 0.1273 - val_accuracy: 0.9754
Epoch 17/40
469/469 [=====] - 2s 4ms/step - loss: 5.8768e-04
- accuracy: 1.0000 - val_loss: 0.1272 - val_accuracy: 0.9753
Epoch 18/40
469/469 [=====] - 2s 4ms/step - loss: 5.7689e-04
- accuracy: 1.0000 - val_loss: 0.1277 - val_accuracy: 0.9755
Epoch 19/40
469/469 [=====] - 2s 5ms/step - loss: 5.6964e-04
- accuracy: 1.0000 - val_loss: 0.1283 - val_accuracy: 0.9752
Epoch 20/40
469/469 [=====] - 2s 4ms/step - loss: 5.5643e-04
- accuracy: 1.0000 - val_loss: 0.1282 - val_accuracy: 0.9752
Epoch 21/40
469/469 [=====] - 2s 4ms/step - loss: 5.5305e-04
- accuracy: 1.0000 - val_loss: 0.1279 - val_accuracy: 0.9753
Epoch 22/40
469/469 [=====] - 2s 4ms/step - loss: 5.4470e-04
- accuracy: 1.0000 - val_loss: 0.1291 - val_accuracy: 0.9754
```

Epoch 23/40

469/469 [=====] - 2s 4ms/step - loss: 5.3440e-04
- accuracy: 1.0000 - val_loss: 0.1295 - val_accuracy: 0.9749

Epoch 24/40

469/469 [=====] - 2s 5ms/step - loss: 5.2861e-04
- accuracy: 1.0000 - val_loss: 0.1288 - val_accuracy: 0.9757

Epoch 25/40

469/469 [=====] - 2s 4ms/step - loss: 5.2202e-04
- accuracy: 1.0000 - val_loss: 0.1296 - val_accuracy: 0.9752

Epoch 26/40

469/469 [=====] - 2s 4ms/step - loss: 5.1430e-04
- accuracy: 1.0000 - val_loss: 0.1296 - val_accuracy: 0.9753

Epoch 27/40

469/469 [=====] - 2s 4ms/step - loss: 5.0326e-04
- accuracy: 1.0000 - val_loss: 0.1303 - val_accuracy: 0.9750

Epoch 28/40

469/469 [=====] - 2s 4ms/step - loss: 4.9685e-04
- accuracy: 1.0000 - val_loss: 0.1302 - val_accuracy: 0.9750

Epoch 29/40

469/469 [=====] - 2s 4ms/step - loss: 4.9111e-04
- accuracy: 1.0000 - val_loss: 0.1299 - val_accuracy: 0.9751

Epoch 30/40

469/469 [=====] - 2s 4ms/step - loss: 4.8384e-04
- accuracy: 1.0000 - val_loss: 0.1301 - val_accuracy: 0.9754

Epoch 31/40

469/469 [=====] - 2s 4ms/step - loss: 4.7854e-04
- accuracy: 1.0000 - val_loss: 0.1306 - val_accuracy: 0.9751

Epoch 32/40

469/469 [=====] - 2s 4ms/step - loss: 4.6901e-04
- accuracy: 1.0000 - val_loss: 0.1316 - val_accuracy: 0.9746

Epoch 33/40

469/469 [=====] - 2s 4ms/step - loss: 4.6455e-04
- accuracy: 1.0000 - val_loss: 0.1314 - val_accuracy: 0.9747

Epoch 34/40

469/469 [=====] - 2s 4ms/step - loss: 4.5897e-04
- accuracy: 1.0000 - val_loss: 0.1314 - val_accuracy: 0.9749

Epoch 35/40

469/469 [=====] - 2s 4ms/step - loss: 4.5331e-04
- accuracy: 1.0000 - val_loss: 0.1319 - val_accuracy: 0.9753

Epoch 36/40

469/469 [=====] - 2s 4ms/step - loss: 4.4615e-04
- accuracy: 1.0000 - val_loss: 0.1321 - val_accuracy: 0.9752

Epoch 37/40

469/469 [=====] - 2s 4ms/step - loss: 4.4033e-04
- accuracy: 1.0000 - val_loss: 0.1316 - val_accuracy: 0.9757

Epoch 38/40

469/469 [=====] - 2s 4ms/step - loss: 4.3556e-04
- accuracy: 1.0000 - val_loss: 0.1326 - val_accuracy: 0.9754

Epoch 39/40

469/469 [=====] - 2s 4ms/step - loss: 4.3006e-04
- accuracy: 1.0000 - val_loss: 0.1328 - val_accuracy: 0.9751

Epoch 40/40

469/469 [=====] - 2s 4ms/step - loss: 4.2474e-04
- accuracy: 1.0000 - val_loss: 0.1331 - val_accuracy: 0.9752

Epoch 1/40

469/469 [=====] - 2s 4ms/step - loss: 4.1947e-04
- accuracy: 1.0000 - val_loss: 0.1324 - val_accuracy: 0.9753

Epoch 2/40

469/469 [=====] - 2s 4ms/step - loss: 4.1396e-04
- accuracy: 1.0000 - val_loss: 0.1335 - val_accuracy: 0.9751

Epoch 3/40

```
469/469 [=====] - 2s 4ms/step - loss: 4.0728e-04
- accuracy: 1.0000 - val_loss: 0.1345 - val_accuracy: 0.9750
Epoch 4/40
469/469 [=====] - 2s 4ms/step - loss: 4.0400e-04
- accuracy: 1.0000 - val_loss: 0.1337 - val_accuracy: 0.9750
Epoch 5/40
469/469 [=====] - 2s 4ms/step - loss: 3.9871e-04
- accuracy: 1.0000 - val_loss: 0.1333 - val_accuracy: 0.9752
Epoch 6/40
469/469 [=====] - 2s 4ms/step - loss: 3.9438e-04
- accuracy: 1.0000 - val_loss: 0.1343 - val_accuracy: 0.9750
Epoch 7/40
469/469 [=====] - 2s 4ms/step - loss: 3.8923e-04
- accuracy: 1.0000 - val_loss: 0.1347 - val_accuracy: 0.9750
Epoch 8/40
469/469 [=====] - 2s 4ms/step - loss: 3.8465e-04
- accuracy: 1.0000 - val_loss: 0.1354 - val_accuracy: 0.9746
Epoch 9/40
469/469 [=====] - 2s 4ms/step - loss: 3.8145e-04
- accuracy: 1.0000 - val_loss: 0.1349 - val_accuracy: 0.9749
Epoch 10/40
469/469 [=====] - 2s 5ms/step - loss: 3.7528e-04
- accuracy: 1.0000 - val_loss: 0.1342 - val_accuracy: 0.9753
Epoch 11/40
469/469 [=====] - 2s 4ms/step - loss: 3.7273e-04
- accuracy: 1.0000 - val_loss: 0.1352 - val_accuracy: 0.9751
Epoch 12/40
469/469 [=====] - 2s 4ms/step - loss: 3.6803e-04
- accuracy: 1.0000 - val_loss: 0.1355 - val_accuracy: 0.9750
Epoch 13/40
469/469 [=====] - 2s 4ms/step - loss: 3.6359e-04
- accuracy: 1.0000 - val_loss: 0.1349 - val_accuracy: 0.9751
Epoch 14/40
469/469 [=====] - 2s 4ms/step - loss: 3.5918e-04
- accuracy: 1.0000 - val_loss: 0.1348 - val_accuracy: 0.9753
Epoch 15/40
469/469 [=====] - 2s 4ms/step - loss: 3.5586e-04
- accuracy: 1.0000 - val_loss: 0.1355 - val_accuracy: 0.9748
Epoch 16/40
469/469 [=====] - 2s 4ms/step - loss: 3.5258e-04
- accuracy: 1.0000 - val_loss: 0.1359 - val_accuracy: 0.9755
Epoch 17/40
469/469 [=====] - 2s 5ms/step - loss: 3.4855e-04
- accuracy: 1.0000 - val_loss: 0.1356 - val_accuracy: 0.9750
Epoch 18/40
469/469 [=====] - 2s 4ms/step - loss: 3.4552e-04
- accuracy: 1.0000 - val_loss: 0.1360 - val_accuracy: 0.9752
Epoch 19/40
469/469 [=====] - 2s 4ms/step - loss: 3.4080e-04
- accuracy: 1.0000 - val_loss: 0.1359 - val_accuracy: 0.9750
Epoch 20/40
469/469 [=====] - 2s 4ms/step - loss: 3.3764e-04
- accuracy: 1.0000 - val_loss: 0.1366 - val_accuracy: 0.9747
Epoch 21/40
469/469 [=====] - 2s 4ms/step - loss: 3.3412e-04
- accuracy: 1.0000 - val_loss: 0.1370 - val_accuracy: 0.9750
Epoch 22/40
469/469 [=====] - 2s 4ms/step - loss: 3.3132e-04
- accuracy: 1.0000 - val_loss: 0.1363 - val_accuracy: 0.9754
Epoch 23/40
469/469 [=====] - 2s 4ms/step - loss: 3.2612e-04
```



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- accuracy: 1.0000 - val_loss: 0.1372 - val_accuracy: 0.9752
Epoch 24/40
469/469 [=====] - 2s 4ms/step - loss: 3.2446e-04
- accuracy: 1.0000 - val_loss: 0.1368 - val_accuracy: 0.9749
Epoch 25/40
469/469 [=====] - 2s 4ms/step - loss: 3.2038e-04
- accuracy: 1.0000 - val_loss: 0.1371 - val_accuracy: 0.9748
Epoch 26/40
469/469 [=====] - 2s 4ms/step - loss: 3.1835e-04
- accuracy: 1.0000 - val_loss: 0.1376 - val_accuracy: 0.9748
Epoch 27/40
469/469 [=====] - 2s 4ms/step - loss: 3.1459e-04
- accuracy: 1.0000 - val_loss: 0.1377 - val_accuracy: 0.9747
Epoch 28/40
469/469 [=====] - 2s 4ms/step - loss: 3.1149e-04
- accuracy: 1.0000 - val_loss: 0.1378 - val_accuracy: 0.9751
Epoch 29/40
469/469 [=====] - 2s 4ms/step - loss: 3.0827e-04
- accuracy: 1.0000 - val_loss: 0.1383 - val_accuracy: 0.9749
Epoch 30/40
469/469 [=====] - 2s 4ms/step - loss: 3.0497e-04
- accuracy: 1.0000 - val_loss: 0.1382 - val_accuracy: 0.9747
Epoch 31/40
469/469 [=====] - 2s 4ms/step - loss: 3.0282e-04
- accuracy: 1.0000 - val_loss: 0.1383 - val_accuracy: 0.9752
Epoch 32/40
469/469 [=====] - 2s 4ms/step - loss: 2.9935e-04
- accuracy: 1.0000 - val_loss: 0.1388 - val_accuracy: 0.9749
Epoch 33/40
469/469 [=====] - 2s 4ms/step - loss: 2.9689e-04
- accuracy: 1.0000 - val_loss: 0.1386 - val_accuracy: 0.9749
Epoch 34/40
469/469 [=====] - 2s 4ms/step - loss: 2.9417e-04
- accuracy: 1.0000 - val_loss: 0.1385 - val_accuracy: 0.9748
Epoch 35/40
469/469 [=====] - 2s 4ms/step - loss: 2.9186e-04
- accuracy: 1.0000 - val_loss: 0.1389 - val_accuracy: 0.9748
Epoch 36/40
469/469 [=====] - 2s 4ms/step - loss: 2.8874e-04
- accuracy: 1.0000 - val_loss: 0.1394 - val_accuracy: 0.9749
Epoch 37/40
469/469 [=====] - 2s 4ms/step - loss: 2.8596e-04
- accuracy: 1.0000 - val_loss: 0.1399 - val_accuracy: 0.9750
Epoch 38/40
469/469 [=====] - 2s 4ms/step - loss: 2.8319e-04
- accuracy: 1.0000 - val_loss: 0.1396 - val_accuracy: 0.9752
Epoch 39/40
469/469 [=====] - 2s 4ms/step - loss: 2.8070e-04
- accuracy: 1.0000 - val_loss: 0.1400 - val_accuracy: 0.9749
Epoch 40/40
469/469 [=====] - 2s 4ms/step - loss: 2.7904e-04
- accuracy: 1.0000 - val_loss: 0.1396 - val_accuracy: 0.9748
Epoch 1/40
469/469 [=====] - 2s 5ms/step - loss: 2.7545e-04
- accuracy: 1.0000 - val_loss: 0.1397 - val_accuracy: 0.9751
Epoch 2/40
469/469 [=====] - 2s 4ms/step - loss: 2.7313e-04
- accuracy: 1.0000 - val_loss: 0.1401 - val_accuracy: 0.9751
Epoch 3/40
469/469 [=====] - 2s 4ms/step - loss: 2.7121e-04
- accuracy: 1.0000 - val_loss: 0.1402 - val_accuracy: 0.9747
```

Epoch 4/40

469/469 [=====] - 2s 5ms/step - loss: 2.6872e-04
- accuracy: 1.0000 - val_loss: 0.1408 - val_accuracy: 0.9747

Epoch 5/40

469/469 [=====] - 2s 4ms/step - loss: 2.6649e-04
- accuracy: 1.0000 - val_loss: 0.1401 - val_accuracy: 0.9755

Epoch 6/40

469/469 [=====] - 2s 4ms/step - loss: 2.6415e-04
- accuracy: 1.0000 - val_loss: 0.1404 - val_accuracy: 0.9750

Epoch 7/40

469/469 [=====] - 2s 4ms/step - loss: 2.6184e-04
- accuracy: 1.0000 - val_loss: 0.1406 - val_accuracy: 0.9746

Epoch 8/40

469/469 [=====] - 2s 4ms/step - loss: 2.5984e-04
- accuracy: 1.0000 - val_loss: 0.1411 - val_accuracy: 0.9750

Epoch 9/40

469/469 [=====] - 2s 4ms/step - loss: 2.5733e-04
- accuracy: 1.0000 - val_loss: 0.1410 - val_accuracy: 0.9745

Epoch 10/40

469/469 [=====] - 2s 4ms/step - loss: 2.5498e-04
- accuracy: 1.0000 - val_loss: 0.1407 - val_accuracy: 0.9751

Epoch 11/40

469/469 [=====] - 2s 4ms/step - loss: 2.5264e-04
- accuracy: 1.0000 - val_loss: 0.1418 - val_accuracy: 0.9749

Epoch 12/40

469/469 [=====] - 2s 4ms/step - loss: 2.5147e-04
- accuracy: 1.0000 - val_loss: 0.1417 - val_accuracy: 0.9751

Epoch 13/40

469/469 [=====] - 2s 5ms/step - loss: 2.4909e-04
- accuracy: 1.0000 - val_loss: 0.1417 - val_accuracy: 0.9749

Epoch 14/40

469/469 [=====] - 2s 4ms/step - loss: 2.4700e-04
- accuracy: 1.0000 - val_loss: 0.1420 - val_accuracy: 0.9748

Epoch 15/40

469/469 [=====] - 2s 4ms/step - loss: 2.4553e-04
- accuracy: 1.0000 - val_loss: 0.1423 - val_accuracy: 0.9750

Epoch 16/40

469/469 [=====] - 2s 4ms/step - loss: 2.4382e-04
- accuracy: 1.0000 - val_loss: 0.1421 - val_accuracy: 0.9746

Epoch 17/40

469/469 [=====] - 2s 4ms/step - loss: 2.4135e-04
- accuracy: 1.0000 - val_loss: 0.1424 - val_accuracy: 0.9749

Epoch 18/40

469/469 [=====] - 2s 4ms/step - loss: 2.3955e-04
- accuracy: 1.0000 - val_loss: 0.1421 - val_accuracy: 0.9750

Epoch 19/40

469/469 [=====] - 2s 4ms/step - loss: 2.3724e-04
- accuracy: 1.0000 - val_loss: 0.1425 - val_accuracy: 0.9747

Epoch 20/40

469/469 [=====] - 2s 4ms/step - loss: 2.3532e-04
- accuracy: 1.0000 - val_loss: 0.1427 - val_accuracy: 0.9751

Epoch 21/40

469/469 [=====] - 2s 4ms/step - loss: 2.3410e-04
- accuracy: 1.0000 - val_loss: 0.1430 - val_accuracy: 0.9748

Epoch 22/40

469/469 [=====] - 2s 4ms/step - loss: 2.3225e-04
- accuracy: 1.0000 - val_loss: 0.1430 - val_accuracy: 0.9750

Epoch 23/40

469/469 [=====] - 2s 4ms/step - loss: 2.2993e-04
- accuracy: 1.0000 - val_loss: 0.1430 - val_accuracy: 0.9747

Epoch 24/40

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469/469 [=====] - 2s 4ms/step - loss: 2.2801e-04
- accuracy: 1.0000 - val_loss: 0.1426 - val_accuracy: 0.9753
Epoch 25/40
469/469 [=====] - 2s 4ms/step - loss: 2.2652e-04
- accuracy: 1.0000 - val_loss: 0.1432 - val_accuracy: 0.9749
Epoch 26/40
469/469 [=====] - 2s 4ms/step - loss: 2.2512e-04
- accuracy: 1.0000 - val_loss: 0.1433 - val_accuracy: 0.9749
Epoch 27/40
469/469 [=====] - 2s 5ms/step - loss: 2.2287e-04
- accuracy: 1.0000 - val_loss: 0.1432 - val_accuracy: 0.9753
Epoch 28/40
469/469 [=====] - 2s 4ms/step - loss: 2.2211e-04
- accuracy: 1.0000 - val_loss: 0.1435 - val_accuracy: 0.9752
Epoch 29/40
469/469 [=====] - 2s 5ms/step - loss: 2.2025e-04
- accuracy: 1.0000 - val_loss: 0.1436 - val_accuracy: 0.9749
Epoch 30/40
469/469 [=====] - 2s 5ms/step - loss: 2.1842e-04
- accuracy: 1.0000 - val_loss: 0.1443 - val_accuracy: 0.9746
Epoch 31/40
469/469 [=====] - 2s 4ms/step - loss: 2.1687e-04
- accuracy: 1.0000 - val_loss: 0.1444 - val_accuracy: 0.9749
Epoch 32/40
469/469 [=====] - 2s 5ms/step - loss: 2.1525e-04
- accuracy: 1.0000 - val_loss: 0.1441 - val_accuracy: 0.9752
Epoch 33/40
469/469 [=====] - 2s 5ms/step - loss: 2.1360e-04
- accuracy: 1.0000 - val_loss: 0.1446 - val_accuracy: 0.9748
Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 2.1240e-04
- accuracy: 1.0000 - val_loss: 0.1446 - val_accuracy: 0.9748
Epoch 35/40
469/469 [=====] - 2s 4ms/step - loss: 2.1039e-04
- accuracy: 1.0000 - val_loss: 0.1447 - val_accuracy: 0.9749
Epoch 36/40
469/469 [=====] - 2s 4ms/step - loss: 2.0917e-04
- accuracy: 1.0000 - val_loss: 0.1453 - val_accuracy: 0.9752
Epoch 37/40
469/469 [=====] - 2s 5ms/step - loss: 2.0790e-04
- accuracy: 1.0000 - val_loss: 0.1448 - val_accuracy: 0.9748
Epoch 38/40
469/469 [=====] - 2s 4ms/step - loss: 2.0580e-04
- accuracy: 1.0000 - val_loss: 0.1444 - val_accuracy: 0.9747
Epoch 39/40
469/469 [=====] - 2s 4ms/step - loss: 2.0449e-04
- accuracy: 1.0000 - val_loss: 0.1450 - val_accuracy: 0.9752
Epoch 40/40
469/469 [=====] - 2s 4ms/step - loss: 2.0344e-04
- accuracy: 1.0000 - val_loss: 0.1451 - val_accuracy: 0.9748
Epoch 1/40
469/469 [=====] - 2s 5ms/step - loss: 2.0199e-04
- accuracy: 1.0000 - val_loss: 0.1454 - val_accuracy: 0.9748
Epoch 2/40
469/469 [=====] - 2s 4ms/step - loss: 2.0087e-04
- accuracy: 1.0000 - val_loss: 0.1455 - val_accuracy: 0.9747
Epoch 3/40
469/469 [=====] - 2s 4ms/step - loss: 1.9939e-04
- accuracy: 1.0000 - val_loss: 0.1455 - val_accuracy: 0.9749
Epoch 4/40
469/469 [=====] - 2s 4ms/step - loss: 1.9797e-04
```

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- accuracy: 1.0000 - val_loss: 0.1455 - val_accuracy: 0.9745
Epoch 5/40
469/469 [=====] - 2s 4ms/step - loss: 1.9656e-04
- accuracy: 1.0000 - val_loss: 0.1461 - val_accuracy: 0.9751
Epoch 6/40
469/469 [=====] - 2s 4ms/step - loss: 1.9499e-04
- accuracy: 1.0000 - val_loss: 0.1464 - val_accuracy: 0.9750
Epoch 7/40
469/469 [=====] - 2s 4ms/step - loss: 1.9412e-04
- accuracy: 1.0000 - val_loss: 0.1459 - val_accuracy: 0.9749
Epoch 8/40
469/469 [=====] - 2s 5ms/step - loss: 1.9252e-04
- accuracy: 1.0000 - val_loss: 0.1460 - val_accuracy: 0.9748
Epoch 9/40
469/469 [=====] - 2s 4ms/step - loss: 1.9100e-04
- accuracy: 1.0000 - val_loss: 0.1467 - val_accuracy: 0.9750
Epoch 10/40
469/469 [=====] - 2s 4ms/step - loss: 1.8978e-04
- accuracy: 1.0000 - val_loss: 0.1464 - val_accuracy: 0.9747
Epoch 11/40
469/469 [=====] - 2s 5ms/step - loss: 1.8904e-04
- accuracy: 1.0000 - val_loss: 0.1466 - val_accuracy: 0.9749
Epoch 12/40
469/469 [=====] - 2s 4ms/step - loss: 1.8785e-04
- accuracy: 1.0000 - val_loss: 0.1462 - val_accuracy: 0.9748
Epoch 13/40
469/469 [=====] - 2s 4ms/step - loss: 1.8588e-04
- accuracy: 1.0000 - val_loss: 0.1469 - val_accuracy: 0.9751
Epoch 14/40
469/469 [=====] - 2s 4ms/step - loss: 1.8527e-04
- accuracy: 1.0000 - val_loss: 0.1468 - val_accuracy: 0.9749
Epoch 15/40
469/469 [=====] - 2s 4ms/step - loss: 1.8381e-04
- accuracy: 1.0000 - val_loss: 0.1468 - val_accuracy: 0.9751
Epoch 16/40
469/469 [=====] - 2s 4ms/step - loss: 1.8292e-04
- accuracy: 1.0000 - val_loss: 0.1469 - val_accuracy: 0.9748
Epoch 17/40
469/469 [=====] - 2s 4ms/step - loss: 1.8138e-04
- accuracy: 1.0000 - val_loss: 0.1473 - val_accuracy: 0.9749
Epoch 18/40
469/469 [=====] - 2s 4ms/step - loss: 1.8042e-04
- accuracy: 1.0000 - val_loss: 0.1475 - val_accuracy: 0.9752
Epoch 19/40
469/469 [=====] - 2s 5ms/step - loss: 1.7939e-04
- accuracy: 1.0000 - val_loss: 0.1474 - val_accuracy: 0.9752
Epoch 20/40
469/469 [=====] - 2s 5ms/step - loss: 1.7833e-04
- accuracy: 1.0000 - val_loss: 0.1472 - val_accuracy: 0.9748
Epoch 21/40
469/469 [=====] - 2s 5ms/step - loss: 1.7675e-04
- accuracy: 1.0000 - val_loss: 0.1478 - val_accuracy: 0.9751
Epoch 22/40
469/469 [=====] - 2s 5ms/step - loss: 1.7560e-04
- accuracy: 1.0000 - val_loss: 0.1480 - val_accuracy: 0.9755
Epoch 23/40
469/469 [=====] - 2s 4ms/step - loss: 1.7514e-04
- accuracy: 1.0000 - val_loss: 0.1482 - val_accuracy: 0.9750
Epoch 24/40
469/469 [=====] - 2s 4ms/step - loss: 1.7395e-04
- accuracy: 1.0000 - val_loss: 0.1474 - val_accuracy: 0.9749
```

Epoch 25/40

469/469 [=====] - 2s 5ms/step - loss: 1.7292e-04
- accuracy: 1.0000 - val_loss: 0.1475 - val_accuracy: 0.9752

Epoch 26/40

469/469 [=====] - 2s 4ms/step - loss: 1.7197e-04
- accuracy: 1.0000 - val_loss: 0.1482 - val_accuracy: 0.9749

Epoch 27/40

469/469 [=====] - 2s 4ms/step - loss: 1.7097e-04
- accuracy: 1.0000 - val_loss: 0.1480 - val_accuracy: 0.9749

Epoch 28/40

469/469 [=====] - 2s 5ms/step - loss: 1.6969e-04
- accuracy: 1.0000 - val_loss: 0.1482 - val_accuracy: 0.9750

Epoch 29/40

469/469 [=====] - 2s 5ms/step - loss: 1.6894e-04
- accuracy: 1.0000 - val_loss: 0.1487 - val_accuracy: 0.9750

Epoch 30/40

469/469 [=====] - 2s 4ms/step - loss: 1.6782e-04
- accuracy: 1.0000 - val_loss: 0.1483 - val_accuracy: 0.9749

Epoch 31/40

469/469 [=====] - 2s 5ms/step - loss: 1.6698e-04
- accuracy: 1.0000 - val_loss: 0.1484 - val_accuracy: 0.9750

Epoch 32/40

469/469 [=====] - 2s 4ms/step - loss: 1.6559e-04
- accuracy: 1.0000 - val_loss: 0.1489 - val_accuracy: 0.9753

Epoch 33/40

469/469 [=====] - 2s 5ms/step - loss: 1.6490e-04
- accuracy: 1.0000 - val_loss: 0.1488 - val_accuracy: 0.9751

Epoch 34/40

469/469 [=====] - 2s 5ms/step - loss: 1.6382e-04
- accuracy: 1.0000 - val_loss: 0.1486 - val_accuracy: 0.9747

Epoch 35/40

469/469 [=====] - 2s 5ms/step - loss: 1.6304e-04
- accuracy: 1.0000 - val_loss: 0.1489 - val_accuracy: 0.9749

Epoch 36/40

469/469 [=====] - 2s 5ms/step - loss: 1.6190e-04
- accuracy: 1.0000 - val_loss: 0.1489 - val_accuracy: 0.9748

Epoch 37/40

469/469 [=====] - 2s 5ms/step - loss: 1.6104e-04
- accuracy: 1.0000 - val_loss: 0.1493 - val_accuracy: 0.9753

Epoch 38/40

469/469 [=====] - 2s 4ms/step - loss: 1.5986e-04
- accuracy: 1.0000 - val_loss: 0.1491 - val_accuracy: 0.9751

Epoch 39/40

469/469 [=====] - 2s 5ms/step - loss: 1.5916e-04
- accuracy: 1.0000 - val_loss: 0.1494 - val_accuracy: 0.9750

Epoch 40/40

469/469 [=====] - 2s 4ms/step - loss: 1.5847e-04
- accuracy: 1.0000 - val_loss: 0.1496 - val_accuracy: 0.9750

Epoch 1/40

469/469 [=====] - 2s 5ms/step - loss: 1.5727e-04
- accuracy: 1.0000 - val_loss: 0.1491 - val_accuracy: 0.9752

Epoch 2/40

469/469 [=====] - 2s 4ms/step - loss: 1.5641e-04
- accuracy: 1.0000 - val_loss: 0.1497 - val_accuracy: 0.9750

Epoch 3/40

469/469 [=====] - 2s 4ms/step - loss: 1.5565e-04
- accuracy: 1.0000 - val_loss: 0.1501 - val_accuracy: 0.9750

Epoch 4/40

469/469 [=====] - 2s 4ms/step - loss: 1.5479e-04
- accuracy: 1.0000 - val_loss: 0.1501 - val_accuracy: 0.9749

Epoch 5/40

```
469/469 [=====] - 2s 4ms/step - loss: 1.5378e-04
- accuracy: 1.0000 - val_loss: 0.1497 - val_accuracy: 0.9748
Epoch 6/40
469/469 [=====] - 2s 4ms/step - loss: 1.5338e-04
- accuracy: 1.0000 - val_loss: 0.1501 - val_accuracy: 0.9751
Epoch 7/40
469/469 [=====] - 2s 4ms/step - loss: 1.5220e-04
- accuracy: 1.0000 - val_loss: 0.1500 - val_accuracy: 0.9750
Epoch 8/40
469/469 [=====] - 2s 5ms/step - loss: 1.5152e-04
- accuracy: 1.0000 - val_loss: 0.1501 - val_accuracy: 0.9749
Epoch 9/40
469/469 [=====] - 2s 5ms/step - loss: 1.5019e-04
- accuracy: 1.0000 - val_loss: 0.1504 - val_accuracy: 0.9749
Epoch 10/40
469/469 [=====] - 2s 5ms/step - loss: 1.4968e-04
- accuracy: 1.0000 - val_loss: 0.1504 - val_accuracy: 0.9749
Epoch 11/40
469/469 [=====] - 2s 5ms/step - loss: 1.4905e-04
- accuracy: 1.0000 - val_loss: 0.1505 - val_accuracy: 0.9750
Epoch 12/40
469/469 [=====] - 2s 4ms/step - loss: 1.4839e-04
- accuracy: 1.0000 - val_loss: 0.1506 - val_accuracy: 0.9751
Epoch 13/40
469/469 [=====] - 2s 4ms/step - loss: 1.4749e-04
- accuracy: 1.0000 - val_loss: 0.1505 - val_accuracy: 0.9751
Epoch 14/40
469/469 [=====] - 2s 4ms/step - loss: 1.4631e-04
- accuracy: 1.0000 - val_loss: 0.1509 - val_accuracy: 0.9749
Epoch 15/40
469/469 [=====] - 2s 5ms/step - loss: 1.4592e-04
- accuracy: 1.0000 - val_loss: 0.1506 - val_accuracy: 0.9750
Epoch 16/40
469/469 [=====] - 2s 5ms/step - loss: 1.4500e-04
- accuracy: 1.0000 - val_loss: 0.1510 - val_accuracy: 0.9747
Epoch 17/40
469/469 [=====] - 2s 4ms/step - loss: 1.4421e-04
- accuracy: 1.0000 - val_loss: 0.1510 - val_accuracy: 0.9748
Epoch 18/40
469/469 [=====] - 2s 5ms/step - loss: 1.4373e-04
- accuracy: 1.0000 - val_loss: 0.1512 - val_accuracy: 0.9749
Epoch 19/40
469/469 [=====] - 2s 5ms/step - loss: 1.4282e-04
- accuracy: 1.0000 - val_loss: 0.1509 - val_accuracy: 0.9749
Epoch 20/40
469/469 [=====] - 2s 5ms/step - loss: 1.4217e-04
- accuracy: 1.0000 - val_loss: 0.1510 - val_accuracy: 0.9754
Epoch 21/40
469/469 [=====] - 2s 5ms/step - loss: 1.4135e-04
- accuracy: 1.0000 - val_loss: 0.1513 - val_accuracy: 0.9748
Epoch 22/40
469/469 [=====] - 2s 4ms/step - loss: 1.4053e-04
- accuracy: 1.0000 - val_loss: 0.1515 - val_accuracy: 0.9749
Epoch 23/40
469/469 [=====] - 2s 5ms/step - loss: 1.3994e-04
- accuracy: 1.0000 - val_loss: 0.1516 - val_accuracy: 0.9749
Epoch 24/40
469/469 [=====] - 2s 5ms/step - loss: 1.3914e-04
- accuracy: 1.0000 - val_loss: 0.1516 - val_accuracy: 0.9752
Epoch 25/40
469/469 [=====] - 2s 5ms/step - loss: 1.3824e-04
```

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- accuracy: 1.0000 - val_loss: 0.1518 - val_accuracy: 0.9752
Epoch 26/40
469/469 [=====] - 2s 5ms/step - loss: 1.3795e-04
- accuracy: 1.0000 - val_loss: 0.1516 - val_accuracy: 0.9752
Epoch 27/40
469/469 [=====] - 2s 4ms/step - loss: 1.3718e-04
- accuracy: 1.0000 - val_loss: 0.1518 - val_accuracy: 0.9749
Epoch 28/40
469/469 [=====] - 2s 5ms/step - loss: 1.3648e-04
- accuracy: 1.0000 - val_loss: 0.1517 - val_accuracy: 0.9748
Epoch 29/40
469/469 [=====] - 2s 5ms/step - loss: 1.3567e-04
- accuracy: 1.0000 - val_loss: 0.1522 - val_accuracy: 0.9749
Epoch 30/40
469/469 [=====] - 2s 4ms/step - loss: 1.3490e-04
- accuracy: 1.0000 - val_loss: 0.1523 - val_accuracy: 0.9751
Epoch 31/40
469/469 [=====] - 2s 4ms/step - loss: 1.3425e-04
- accuracy: 1.0000 - val_loss: 0.1522 - val_accuracy: 0.9748
Epoch 32/40
469/469 [=====] - 2s 5ms/step - loss: 1.3376e-04
- accuracy: 1.0000 - val_loss: 0.1523 - val_accuracy: 0.9752
Epoch 33/40
469/469 [=====] - 2s 5ms/step - loss: 1.3312e-04
- accuracy: 1.0000 - val_loss: 0.1526 - val_accuracy: 0.9752
Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 1.3246e-04
- accuracy: 1.0000 - val_loss: 0.1524 - val_accuracy: 0.9749
Epoch 35/40
469/469 [=====] - 2s 5ms/step - loss: 1.3167e-04
- accuracy: 1.0000 - val_loss: 0.1530 - val_accuracy: 0.9751
Epoch 36/40
469/469 [=====] - 2s 5ms/step - loss: 1.3114e-04
- accuracy: 1.0000 - val_loss: 0.1527 - val_accuracy: 0.9750
Epoch 37/40
469/469 [=====] - 2s 5ms/step - loss: 1.3058e-04
- accuracy: 1.0000 - val_loss: 0.1527 - val_accuracy: 0.9752
Epoch 38/40
469/469 [=====] - 2s 5ms/step - loss: 1.2948e-04
- accuracy: 1.0000 - val_loss: 0.1529 - val_accuracy: 0.9752
Epoch 39/40
469/469 [=====] - 2s 4ms/step - loss: 1.2922e-04
- accuracy: 1.0000 - val_loss: 0.1527 - val_accuracy: 0.9750
Epoch 40/40
469/469 [=====] - 2s 4ms/step - loss: 1.2839e-04
- accuracy: 1.0000 - val_loss: 0.1536 - val_accuracy: 0.9752
Epoch 1/40
469/469 [=====] - 2s 5ms/step - loss: 1.2818e-04
- accuracy: 1.0000 - val_loss: 0.1532 - val_accuracy: 0.9749
Epoch 2/40
469/469 [=====] - 2s 4ms/step - loss: 1.2753e-04
- accuracy: 1.0000 - val_loss: 0.1533 - val_accuracy: 0.9751
Epoch 3/40
469/469 [=====] - 2s 4ms/step - loss: 1.2670e-04
- accuracy: 1.0000 - val_loss: 0.1532 - val_accuracy: 0.9750
Epoch 4/40
469/469 [=====] - 2s 5ms/step - loss: 1.2618e-04
- accuracy: 1.0000 - val_loss: 0.1533 - val_accuracy: 0.9751
Epoch 5/40
469/469 [=====] - 2s 4ms/step - loss: 1.2560e-04
- accuracy: 1.0000 - val_loss: 0.1537 - val_accuracy: 0.9753
```

Epoch 6/40
469/469 [=====] - 2s 5ms/step - loss: 1.2510e-04
- accuracy: 1.0000 - val_loss: 0.1537 - val_accuracy: 0.9753
Epoch 7/40
469/469 [=====] - 2s 5ms/step - loss: 1.2442e-04
- accuracy: 1.0000 - val_loss: 0.1538 - val_accuracy: 0.9754
Epoch 8/40
469/469 [=====] - 2s 4ms/step - loss: 1.2373e-04
- accuracy: 1.0000 - val_loss: 0.1538 - val_accuracy: 0.9752
Epoch 9/40
469/469 [=====] - 2s 5ms/step - loss: 1.2335e-04
- accuracy: 1.0000 - val_loss: 0.1535 - val_accuracy: 0.9751
Epoch 10/40
469/469 [=====] - 2s 5ms/step - loss: 1.2292e-04
- accuracy: 1.0000 - val_loss: 0.1536 - val_accuracy: 0.9750
Epoch 11/40
469/469 [=====] - 2s 5ms/step - loss: 1.2197e-04
- accuracy: 1.0000 - val_loss: 0.1541 - val_accuracy: 0.9755
Epoch 12/40
469/469 [=====] - 2s 4ms/step - loss: 1.2171e-04
- accuracy: 1.0000 - val_loss: 0.1542 - val_accuracy: 0.9750
Epoch 13/40
469/469 [=====] - 2s 5ms/step - loss: 1.2099e-04
- accuracy: 1.0000 - val_loss: 0.1539 - val_accuracy: 0.9751
Epoch 14/40
469/469 [=====] - 2s 4ms/step - loss: 1.2058e-04
- accuracy: 1.0000 - val_loss: 0.1539 - val_accuracy: 0.9749
Epoch 15/40
469/469 [=====] - 2s 5ms/step - loss: 1.1993e-04
- accuracy: 1.0000 - val_loss: 0.1542 - val_accuracy: 0.9752
Epoch 16/40
469/469 [=====] - 2s 5ms/step - loss: 1.1945e-04
- accuracy: 1.0000 - val_loss: 0.1542 - val_accuracy: 0.9751
Epoch 17/40
469/469 [=====] - 2s 4ms/step - loss: 1.1891e-04
- accuracy: 1.0000 - val_loss: 0.1544 - val_accuracy: 0.9750
Epoch 18/40
469/469 [=====] - 2s 4ms/step - loss: 1.1846e-04
- accuracy: 1.0000 - val_loss: 0.1544 - val_accuracy: 0.9751
Epoch 19/40
469/469 [=====] - 2s 5ms/step - loss: 1.1786e-04
- accuracy: 1.0000 - val_loss: 0.1542 - val_accuracy: 0.9753
Epoch 20/40
469/469 [=====] - 2s 5ms/step - loss: 1.1736e-04
- accuracy: 1.0000 - val_loss: 0.1546 - val_accuracy: 0.9749
Epoch 21/40
469/469 [=====] - 2s 4ms/step - loss: 1.1680e-04
- accuracy: 1.0000 - val_loss: 0.1547 - val_accuracy: 0.9751
Epoch 22/40
469/469 [=====] - 2s 4ms/step - loss: 1.1620e-04
- accuracy: 1.0000 - val_loss: 0.1546 - val_accuracy: 0.9749
Epoch 23/40
469/469 [=====] - 2s 5ms/step - loss: 1.1580e-04
- accuracy: 1.0000 - val_loss: 0.1549 - val_accuracy: 0.9751
Epoch 24/40
469/469 [=====] - 2s 4ms/step - loss: 1.1525e-04
- accuracy: 1.0000 - val_loss: 0.1549 - val_accuracy: 0.9750
Epoch 25/40
469/469 [=====] - 2s 5ms/step - loss: 1.1467e-04
- accuracy: 1.0000 - val_loss: 0.1553 - val_accuracy: 0.9753
Epoch 26/40


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469/469 [=====] - 2s 5ms/step - loss: 1.1434e-04
- accuracy: 1.0000 - val_loss: 0.1548 - val_accuracy: 0.9751
Epoch 27/40
469/469 [=====] - 2s 5ms/step - loss: 1.1381e-04
- accuracy: 1.0000 - val_loss: 0.1551 - val_accuracy: 0.9750
Epoch 28/40
469/469 [=====] - 2s 4ms/step - loss: 1.1319e-04
- accuracy: 1.0000 - val_loss: 0.1551 - val_accuracy: 0.9751
Epoch 29/40
469/469 [=====] - 2s 4ms/step - loss: 1.1276e-04
- accuracy: 1.0000 - val_loss: 0.1551 - val_accuracy: 0.9752
Epoch 30/40
469/469 [=====] - 2s 4ms/step - loss: 1.1215e-04
- accuracy: 1.0000 - val_loss: 0.1548 - val_accuracy: 0.9750
Epoch 31/40
469/469 [=====] - 2s 4ms/step - loss: 1.1198e-04
- accuracy: 1.0000 - val_loss: 0.1552 - val_accuracy: 0.9753
Epoch 32/40
469/469 [=====] - 2s 5ms/step - loss: 1.1126e-04
- accuracy: 1.0000 - val_loss: 0.1556 - val_accuracy: 0.9753
Epoch 33/40
469/469 [=====] - 2s 5ms/step - loss: 1.1102e-04
- accuracy: 1.0000 - val_loss: 0.1556 - val_accuracy: 0.9751
Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 1.1043e-04
- accuracy: 1.0000 - val_loss: 0.1556 - val_accuracy: 0.9750
Epoch 35/40
469/469 [=====] - 2s 4ms/step - loss: 1.0999e-04
- accuracy: 1.0000 - val_loss: 0.1560 - val_accuracy: 0.9755
Epoch 36/40
469/469 [=====] - 2s 5ms/step - loss: 1.0960e-04
- accuracy: 1.0000 - val_loss: 0.1559 - val_accuracy: 0.9752
Epoch 37/40
469/469 [=====] - 2s 5ms/step - loss: 1.0902e-04
- accuracy: 1.0000 - val_loss: 0.1558 - val_accuracy: 0.9750
Epoch 38/40
469/469 [=====] - 2s 4ms/step - loss: 1.0845e-04
- accuracy: 1.0000 - val_loss: 0.1560 - val_accuracy: 0.9753
Epoch 39/40
469/469 [=====] - 2s 5ms/step - loss: 1.0806e-04
- accuracy: 1.0000 - val_loss: 0.1558 - val_accuracy: 0.9754
Epoch 40/40
469/469 [=====] - 2s 4ms/step - loss: 1.0775e-04
- accuracy: 1.0000 - val_loss: 0.1563 - val_accuracy: 0.9754
Epoch 1/40
469/469 [=====] - 2s 5ms/step - loss: 1.0735e-04
- accuracy: 1.0000 - val_loss: 0.1559 - val_accuracy: 0.9749
Epoch 2/40
469/469 [=====] - 2s 4ms/step - loss: 1.0676e-04
- accuracy: 1.0000 - val_loss: 0.1559 - val_accuracy: 0.9751
Epoch 3/40
469/469 [=====] - 2s 5ms/step - loss: 1.0644e-04
- accuracy: 1.0000 - val_loss: 0.1562 - val_accuracy: 0.9753
Epoch 4/40
469/469 [=====] - 2s 5ms/step - loss: 1.0604e-04
- accuracy: 1.0000 - val_loss: 0.1565 - val_accuracy: 0.9753
Epoch 5/40
469/469 [=====] - 2s 4ms/step - loss: 1.0542e-04
- accuracy: 1.0000 - val_loss: 0.1565 - val_accuracy: 0.9752
Epoch 6/40
469/469 [=====] - 2s 4ms/step - loss: 1.0512e-04
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- accuracy: 1.0000 - val_loss: 0.1566 - val_accuracy: 0.9752
Epoch 7/40
469/469 [=====] - 2s 5ms/step - loss: 1.0474e-04
- accuracy: 1.0000 - val_loss: 0.1565 - val_accuracy: 0.9752
Epoch 8/40
469/469 [=====] - 2s 5ms/step - loss: 1.0426e-04
- accuracy: 1.0000 - val_loss: 0.1568 - val_accuracy: 0.9752
Epoch 9/40
469/469 [=====] - 2s 4ms/step - loss: 1.0384e-04
- accuracy: 1.0000 - val_loss: 0.1568 - val_accuracy: 0.9755
Epoch 10/40
469/469 [=====] - 2s 4ms/step - loss: 1.0348e-04
- accuracy: 1.0000 - val_loss: 0.1568 - val_accuracy: 0.9752
Epoch 11/40
469/469 [=====] - 2s 5ms/step - loss: 1.0288e-04
- accuracy: 1.0000 - val_loss: 0.1569 - val_accuracy: 0.9751
Epoch 12/40
469/469 [=====] - 2s 5ms/step - loss: 1.0262e-04
- accuracy: 1.0000 - val_loss: 0.1572 - val_accuracy: 0.9754
Epoch 13/40
469/469 [=====] - 2s 4ms/step - loss: 1.0217e-04
- accuracy: 1.0000 - val_loss: 0.1570 - val_accuracy: 0.9751
Epoch 14/40
469/469 [=====] - 2s 5ms/step - loss: 1.0188e-04
- accuracy: 1.0000 - val_loss: 0.1570 - val_accuracy: 0.9753
Epoch 15/40
469/469 [=====] - 2s 5ms/step - loss: 1.0146e-04
- accuracy: 1.0000 - val_loss: 0.1571 - val_accuracy: 0.9752
Epoch 16/40
469/469 [=====] - 2s 4ms/step - loss: 1.0093e-04
- accuracy: 1.0000 - val_loss: 0.1570 - val_accuracy: 0.9750
Epoch 17/40
469/469 [=====] - 2s 4ms/step - loss: 1.0057e-04
- accuracy: 1.0000 - val_loss: 0.1572 - val_accuracy: 0.9753
Epoch 18/40
469/469 [=====] - 2s 4ms/step - loss: 1.0024e-04
- accuracy: 1.0000 - val_loss: 0.1574 - val_accuracy: 0.9753
Epoch 19/40
469/469 [=====] - 2s 4ms/step - loss: 9.9773e-05
- accuracy: 1.0000 - val_loss: 0.1575 - val_accuracy: 0.9751
Epoch 20/40
469/469 [=====] - 2s 4ms/step - loss: 9.9479e-05
- accuracy: 1.0000 - val_loss: 0.1576 - val_accuracy: 0.9753
Epoch 21/40
469/469 [=====] - 2s 5ms/step - loss: 9.9157e-05
- accuracy: 1.0000 - val_loss: 0.1574 - val_accuracy: 0.9751
Epoch 22/40
469/469 [=====] - 2s 4ms/step - loss: 9.8779e-05
- accuracy: 1.0000 - val_loss: 0.1577 - val_accuracy: 0.9751
Epoch 23/40
469/469 [=====] - 2s 4ms/step - loss: 9.8346e-05
- accuracy: 1.0000 - val_loss: 0.1574 - val_accuracy: 0.9752
Epoch 24/40
469/469 [=====] - 2s 5ms/step - loss: 9.7927e-05
- accuracy: 1.0000 - val_loss: 0.1578 - val_accuracy: 0.9752
Epoch 25/40
469/469 [=====] - 2s 5ms/step - loss: 9.7573e-05
- accuracy: 1.0000 - val_loss: 0.1579 - val_accuracy: 0.9755
Epoch 26/40
469/469 [=====] - 2s 4ms/step - loss: 9.7229e-05
- accuracy: 1.0000 - val_loss: 0.1579 - val_accuracy: 0.9752
```

Epoch 27/40

469/469 [=====] - 2s 5ms/step - loss: 9.6813e-05
- accuracy: 1.0000 - val_loss: 0.1579 - val_accuracy: 0.9751

Epoch 28/40

469/469 [=====] - 2s 4ms/step - loss: 9.6501e-05
- accuracy: 1.0000 - val_loss: 0.1579 - val_accuracy: 0.9754

Epoch 29/40

469/469 [=====] - 2s 4ms/step - loss: 9.6062e-05
- accuracy: 1.0000 - val_loss: 0.1579 - val_accuracy: 0.9752

Epoch 30/40

469/469 [=====] - 2s 4ms/step - loss: 9.5799e-05
- accuracy: 1.0000 - val_loss: 0.1583 - val_accuracy: 0.9754

Epoch 31/40

469/469 [=====] - 2s 4ms/step - loss: 9.5316e-05
- accuracy: 1.0000 - val_loss: 0.1580 - val_accuracy: 0.9753

Epoch 32/40

469/469 [=====] - 2s 4ms/step - loss: 9.5038e-05
- accuracy: 1.0000 - val_loss: 0.1584 - val_accuracy: 0.9752

Epoch 33/40

469/469 [=====] - 2s 5ms/step - loss: 9.4680e-05
- accuracy: 1.0000 - val_loss: 0.1584 - val_accuracy: 0.9752

Epoch 34/40

469/469 [=====] - 2s 5ms/step - loss: 9.4339e-05
- accuracy: 1.0000 - val_loss: 0.1583 - val_accuracy: 0.9751

Epoch 35/40

469/469 [=====] - 2s 4ms/step - loss: 9.3906e-05
- accuracy: 1.0000 - val_loss: 0.1584 - val_accuracy: 0.9755

Epoch 36/40

469/469 [=====] - 2s 4ms/step - loss: 9.3521e-05
- accuracy: 1.0000 - val_loss: 0.1586 - val_accuracy: 0.9754

Epoch 37/40

469/469 [=====] - 2s 4ms/step - loss: 9.3122e-05
- accuracy: 1.0000 - val_loss: 0.1585 - val_accuracy: 0.9753

Epoch 38/40

469/469 [=====] - 2s 4ms/step - loss: 9.2985e-05
- accuracy: 1.0000 - val_loss: 0.1584 - val_accuracy: 0.9755

Epoch 39/40

469/469 [=====] - 2s 4ms/step - loss: 9.2521e-05
- accuracy: 1.0000 - val_loss: 0.1590 - val_accuracy: 0.9753

Epoch 40/40

469/469 [=====] - 2s 4ms/step - loss: 9.2317e-05
- accuracy: 1.0000 - val_loss: 0.1587 - val_accuracy: 0.9753

Epoch 1/40

469/469 [=====] - 2s 5ms/step - loss: 9.1898e-05
- accuracy: 1.0000 - val_loss: 0.1586 - val_accuracy: 0.9754

Epoch 2/40

469/469 [=====] - 2s 5ms/step - loss: 9.1652e-05
- accuracy: 1.0000 - val_loss: 0.1590 - val_accuracy: 0.9753

Epoch 3/40

469/469 [=====] - 2s 5ms/step - loss: 9.1168e-05
- accuracy: 1.0000 - val_loss: 0.1585 - val_accuracy: 0.9753

Epoch 4/40

469/469 [=====] - 2s 4ms/step - loss: 9.0998e-05
- accuracy: 1.0000 - val_loss: 0.1587 - val_accuracy: 0.9752

Epoch 5/40

469/469 [=====] - 2s 4ms/step - loss: 9.0624e-05
- accuracy: 1.0000 - val_loss: 0.1591 - val_accuracy: 0.9753

Epoch 6/40

469/469 [=====] - 2s 5ms/step - loss: 9.0350e-05
- accuracy: 1.0000 - val_loss: 0.1592 - val_accuracy: 0.9753

Epoch 7/40

```
469/469 [=====] - 2s 4ms/step - loss: 8.9982e-05
- accuracy: 1.0000 - val_loss: 0.1591 - val_accuracy: 0.9753
Epoch 8/40
469/469 [=====] - 2s 5ms/step - loss: 8.9572e-05
- accuracy: 1.0000 - val_loss: 0.1595 - val_accuracy: 0.9753
Epoch 9/40
469/469 [=====] - 2s 5ms/step - loss: 8.9389e-05
- accuracy: 1.0000 - val_loss: 0.1591 - val_accuracy: 0.9755
Epoch 10/40
469/469 [=====] - 2s 4ms/step - loss: 8.8992e-05
- accuracy: 1.0000 - val_loss: 0.1591 - val_accuracy: 0.9754
Epoch 11/40
469/469 [=====] - 2s 4ms/step - loss: 8.8663e-05
- accuracy: 1.0000 - val_loss: 0.1596 - val_accuracy: 0.9754
Epoch 12/40
469/469 [=====] - 2s 4ms/step - loss: 8.8343e-05
- accuracy: 1.0000 - val_loss: 0.1600 - val_accuracy: 0.9755
Epoch 13/40
469/469 [=====] - 2s 4ms/step - loss: 8.8131e-05
- accuracy: 1.0000 - val_loss: 0.1593 - val_accuracy: 0.9753
Epoch 14/40
469/469 [=====] - 2s 5ms/step - loss: 8.7808e-05
- accuracy: 1.0000 - val_loss: 0.1596 - val_accuracy: 0.9754
Epoch 15/40
469/469 [=====] - 2s 4ms/step - loss: 8.7426e-05
- accuracy: 1.0000 - val_loss: 0.1598 - val_accuracy: 0.9752
Epoch 16/40
469/469 [=====] - 2s 4ms/step - loss: 8.7156e-05
- accuracy: 1.0000 - val_loss: 0.1595 - val_accuracy: 0.9754
Epoch 17/40
469/469 [=====] - 2s 4ms/step - loss: 8.6822e-05
- accuracy: 1.0000 - val_loss: 0.1599 - val_accuracy: 0.9753
Epoch 18/40
469/469 [=====] - 2s 5ms/step - loss: 8.6587e-05
- accuracy: 1.0000 - val_loss: 0.1599 - val_accuracy: 0.9752
Epoch 19/40
469/469 [=====] - 2s 5ms/step - loss: 8.6209e-05
- accuracy: 1.0000 - val_loss: 0.1598 - val_accuracy: 0.9754
Epoch 20/40
469/469 [=====] - 2s 5ms/step - loss: 8.5929e-05
- accuracy: 1.0000 - val_loss: 0.1602 - val_accuracy: 0.9752
Epoch 21/40
469/469 [=====] - 2s 4ms/step - loss: 8.5681e-05
- accuracy: 1.0000 - val_loss: 0.1600 - val_accuracy: 0.9753
Epoch 22/40
469/469 [=====] - 2s 5ms/step - loss: 8.5442e-05
- accuracy: 1.0000 - val_loss: 0.1602 - val_accuracy: 0.9754
Epoch 23/40
469/469 [=====] - 2s 4ms/step - loss: 8.5161e-05
- accuracy: 1.0000 - val_loss: 0.1603 - val_accuracy: 0.9752
Epoch 24/40
469/469 [=====] - 2s 5ms/step - loss: 8.4856e-05
- accuracy: 1.0000 - val_loss: 0.1605 - val_accuracy: 0.9756
Epoch 25/40
469/469 [=====] - 2s 4ms/step - loss: 8.4542e-05
- accuracy: 1.0000 - val_loss: 0.1602 - val_accuracy: 0.9753
Epoch 26/40
469/469 [=====] - 2s 5ms/step - loss: 8.4245e-05
- accuracy: 1.0000 - val_loss: 0.1604 - val_accuracy: 0.9754
Epoch 27/40
469/469 [=====] - 2s 5ms/step - loss: 8.3883e-05
```

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- accuracy: 1.0000 - val_loss: 0.1603 - val_accuracy: 0.9754
Epoch 28/40
469/469 [=====] - 2s 5ms/step - loss: 8.3675e-05
- accuracy: 1.0000 - val_loss: 0.1606 - val_accuracy: 0.9752
Epoch 29/40
469/469 [=====] - 2s 5ms/step - loss: 8.3499e-05
- accuracy: 1.0000 - val_loss: 0.1604 - val_accuracy: 0.9754
Epoch 30/40
469/469 [=====] - 2s 5ms/step - loss: 8.3097e-05
- accuracy: 1.0000 - val_loss: 0.1610 - val_accuracy: 0.9754
Epoch 31/40
469/469 [=====] - 2s 5ms/step - loss: 8.2879e-05
- accuracy: 1.0000 - val_loss: 0.1608 - val_accuracy: 0.9753
Epoch 32/40
469/469 [=====] - 2s 5ms/step - loss: 8.2504e-05
- accuracy: 1.0000 - val_loss: 0.1606 - val_accuracy: 0.9754
Epoch 33/40
469/469 [=====] - 2s 4ms/step - loss: 8.2352e-05
- accuracy: 1.0000 - val_loss: 0.1606 - val_accuracy: 0.9753
Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 8.2085e-05
- accuracy: 1.0000 - val_loss: 0.1609 - val_accuracy: 0.9754
Epoch 35/40
469/469 [=====] - 2s 5ms/step - loss: 8.1756e-05
- accuracy: 1.0000 - val_loss: 0.1611 - val_accuracy: 0.9754
Epoch 36/40
469/469 [=====] - 2s 4ms/step - loss: 8.1510e-05
- accuracy: 1.0000 - val_loss: 0.1609 - val_accuracy: 0.9754
Epoch 37/40
469/469 [=====] - 2s 4ms/step - loss: 8.1257e-05
- accuracy: 1.0000 - val_loss: 0.1607 - val_accuracy: 0.9754
Epoch 38/40
469/469 [=====] - 2s 4ms/step - loss: 8.0973e-05
- accuracy: 1.0000 - val_loss: 0.1612 - val_accuracy: 0.9752
Epoch 39/40
469/469 [=====] - 2s 4ms/step - loss: 8.0750e-05
- accuracy: 1.0000 - val_loss: 0.1612 - val_accuracy: 0.9753
Epoch 40/40
469/469 [=====] - 2s 4ms/step - loss: 8.0401e-05
- accuracy: 1.0000 - val_loss: 0.1612 - val_accuracy: 0.9754
Epoch 1/40
469/469 [=====] - 2s 5ms/step - loss: 8.0192e-05
- accuracy: 1.0000 - val_loss: 0.1611 - val_accuracy: 0.9754
Epoch 2/40
469/469 [=====] - 2s 4ms/step - loss: 7.9904e-05
- accuracy: 1.0000 - val_loss: 0.1611 - val_accuracy: 0.9754
Epoch 3/40
469/469 [=====] - 2s 4ms/step - loss: 7.9641e-05
- accuracy: 1.0000 - val_loss: 0.1612 - val_accuracy: 0.9754
Epoch 4/40
469/469 [=====] - 2s 5ms/step - loss: 7.9384e-05
- accuracy: 1.0000 - val_loss: 0.1613 - val_accuracy: 0.9755
Epoch 5/40
469/469 [=====] - 2s 4ms/step - loss: 7.9117e-05
- accuracy: 1.0000 - val_loss: 0.1613 - val_accuracy: 0.9755
Epoch 6/40
469/469 [=====] - 2s 5ms/step - loss: 7.8929e-05
- accuracy: 1.0000 - val_loss: 0.1617 - val_accuracy: 0.9752
Epoch 7/40
469/469 [=====] - 2s 5ms/step - loss: 7.8662e-05
- accuracy: 1.0000 - val_loss: 0.1613 - val_accuracy: 0.9754
```

Epoch 8/40

469/469 [=====] - 2s 5ms/step - loss: 7.8386e-05
- accuracy: 1.0000 - val_loss: 0.1617 - val_accuracy: 0.9754

Epoch 9/40

469/469 [=====] - 2s 5ms/step - loss: 7.8113e-05
- accuracy: 1.0000 - val_loss: 0.1616 - val_accuracy: 0.9756

Epoch 10/40

469/469 [=====] - 2s 4ms/step - loss: 7.7781e-05
- accuracy: 1.0000 - val_loss: 0.1617 - val_accuracy: 0.9754

Epoch 11/40

469/469 [=====] - 2s 4ms/step - loss: 7.7685e-05
- accuracy: 1.0000 - val_loss: 0.1617 - val_accuracy: 0.9753

Epoch 12/40

469/469 [=====] - 2s 4ms/step - loss: 7.7445e-05
- accuracy: 1.0000 - val_loss: 0.1617 - val_accuracy: 0.9754

Epoch 13/40

469/469 [=====] - 2s 4ms/step - loss: 7.7148e-05
- accuracy: 1.0000 - val_loss: 0.1619 - val_accuracy: 0.9753

Epoch 14/40

469/469 [=====] - 2s 5ms/step - loss: 7.6986e-05
- accuracy: 1.0000 - val_loss: 0.1619 - val_accuracy: 0.9755

Epoch 15/40

469/469 [=====] - 2s 5ms/step - loss: 7.6673e-05
- accuracy: 1.0000 - val_loss: 0.1618 - val_accuracy: 0.9756

Epoch 16/40

469/469 [=====] - 2s 5ms/step - loss: 7.6411e-05
- accuracy: 1.0000 - val_loss: 0.1619 - val_accuracy: 0.9754

Epoch 17/40

469/469 [=====] - 2s 5ms/step - loss: 7.6238e-05
- accuracy: 1.0000 - val_loss: 0.1622 - val_accuracy: 0.9755

Epoch 18/40

469/469 [=====] - 2s 5ms/step - loss: 7.5966e-05
- accuracy: 1.0000 - val_loss: 0.1620 - val_accuracy: 0.9755

Epoch 19/40

469/469 [=====] - 2s 5ms/step - loss: 7.5754e-05
- accuracy: 1.0000 - val_loss: 0.1624 - val_accuracy: 0.9754

Epoch 20/40

469/469 [=====] - 2s 5ms/step - loss: 7.5484e-05
- accuracy: 1.0000 - val_loss: 0.1622 - val_accuracy: 0.9755

Epoch 21/40

469/469 [=====] - 2s 5ms/step - loss: 7.5287e-05
- accuracy: 1.0000 - val_loss: 0.1624 - val_accuracy: 0.9756

Epoch 22/40

469/469 [=====] - 2s 4ms/step - loss: 7.5020e-05
- accuracy: 1.0000 - val_loss: 0.1626 - val_accuracy: 0.9753

Epoch 23/40

469/469 [=====] - 2s 5ms/step - loss: 7.4802e-05
- accuracy: 1.0000 - val_loss: 0.1623 - val_accuracy: 0.9754

Epoch 24/40

469/469 [=====] - 2s 4ms/step - loss: 7.4623e-05
- accuracy: 1.0000 - val_loss: 0.1623 - val_accuracy: 0.9755

Epoch 25/40

469/469 [=====] - 2s 5ms/step - loss: 7.4385e-05
- accuracy: 1.0000 - val_loss: 0.1624 - val_accuracy: 0.9756

Epoch 26/40

469/469 [=====] - 2s 5ms/step - loss: 7.4154e-05
- accuracy: 1.0000 - val_loss: 0.1627 - val_accuracy: 0.9753

Epoch 27/40

469/469 [=====] - 2s 5ms/step - loss: 7.3900e-05
- accuracy: 1.0000 - val_loss: 0.1629 - val_accuracy: 0.9753

Epoch 28/40

```
469/469 [=====] - 2s 5ms/step - loss: 7.3714e-05
- accuracy: 1.0000 - val_loss: 0.1626 - val_accuracy: 0.9755
Epoch 29/40
469/469 [=====] - 2s 4ms/step - loss: 7.3460e-05
- accuracy: 1.0000 - val_loss: 0.1627 - val_accuracy: 0.9756
Epoch 30/40
469/469 [=====] - 2s 4ms/step - loss: 7.3254e-05
- accuracy: 1.0000 - val_loss: 0.1628 - val_accuracy: 0.9754
Epoch 31/40
469/469 [=====] - 2s 5ms/step - loss: 7.3056e-05
- accuracy: 1.0000 - val_loss: 0.1626 - val_accuracy: 0.9755
Epoch 32/40
469/469 [=====] - 2s 4ms/step - loss: 7.2844e-05
- accuracy: 1.0000 - val_loss: 0.1628 - val_accuracy: 0.9755
Epoch 33/40
469/469 [=====] - 2s 5ms/step - loss: 7.2639e-05
- accuracy: 1.0000 - val_loss: 0.1629 - val_accuracy: 0.9755
Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 7.2432e-05
- accuracy: 1.0000 - val_loss: 0.1629 - val_accuracy: 0.9754
Epoch 35/40
469/469 [=====] - 2s 4ms/step - loss: 7.2149e-05
- accuracy: 1.0000 - val_loss: 0.1630 - val_accuracy: 0.9754
Epoch 36/40
469/469 [=====] - 2s 5ms/step - loss: 7.1955e-05
- accuracy: 1.0000 - val_loss: 0.1630 - val_accuracy: 0.9754
Epoch 37/40
469/469 [=====] - 2s 5ms/step - loss: 7.1694e-05
- accuracy: 1.0000 - val_loss: 0.1632 - val_accuracy: 0.9759
Epoch 38/40
469/469 [=====] - 2s 4ms/step - loss: 7.1590e-05
- accuracy: 1.0000 - val_loss: 0.1632 - val_accuracy: 0.9755
Epoch 39/40
469/469 [=====] - 2s 4ms/step - loss: 7.1324e-05
- accuracy: 1.0000 - val_loss: 0.1632 - val_accuracy: 0.9757
Epoch 40/40
469/469 [=====] - 2s 5ms/step - loss: 7.1088e-05
- accuracy: 1.0000 - val_loss: 0.1633 - val_accuracy: 0.9754
Epoch 1/40
469/469 [=====] - 2s 5ms/step - loss: 7.0899e-05
- accuracy: 1.0000 - val_loss: 0.1632 - val_accuracy: 0.9755
Epoch 2/40
469/469 [=====] - 2s 5ms/step - loss: 7.0703e-05
- accuracy: 1.0000 - val_loss: 0.1633 - val_accuracy: 0.9756
Epoch 3/40
469/469 [=====] - 2s 5ms/step - loss: 7.0519e-05
- accuracy: 1.0000 - val_loss: 0.1634 - val_accuracy: 0.9755
Epoch 4/40
469/469 [=====] - 2s 5ms/step - loss: 7.0348e-05
- accuracy: 1.0000 - val_loss: 0.1636 - val_accuracy: 0.9753
Epoch 5/40
469/469 [=====] - 2s 5ms/step - loss: 7.0079e-05
- accuracy: 1.0000 - val_loss: 0.1634 - val_accuracy: 0.9757
Epoch 6/40
469/469 [=====] - 2s 5ms/step - loss: 6.9853e-05
- accuracy: 1.0000 - val_loss: 0.1639 - val_accuracy: 0.9756
Epoch 7/40
469/469 [=====] - 2s 5ms/step - loss: 6.9701e-05
- accuracy: 1.0000 - val_loss: 0.1636 - val_accuracy: 0.9754
Epoch 8/40
469/469 [=====] - 2s 5ms/step - loss: 6.9401e-05
```

```
- accuracy: 1.0000 - val_loss: 0.1641 - val_accuracy: 0.9759
Epoch 9/40
469/469 [=====] - 2s 5ms/step - loss: 6.9212e-05
- accuracy: 1.0000 - val_loss: 0.1638 - val_accuracy: 0.9757
Epoch 10/40
469/469 [=====] - 2s 5ms/step - loss: 6.9117e-05
- accuracy: 1.0000 - val_loss: 0.1639 - val_accuracy: 0.9755
Epoch 11/40
469/469 [=====] - 2s 5ms/step - loss: 6.8847e-05
- accuracy: 1.0000 - val_loss: 0.1638 - val_accuracy: 0.9756
Epoch 12/40
469/469 [=====] - 2s 5ms/step - loss: 6.8699e-05
- accuracy: 1.0000 - val_loss: 0.1639 - val_accuracy: 0.9755
Epoch 13/40
469/469 [=====] - 2s 5ms/step - loss: 6.8486e-05
- accuracy: 1.0000 - val_loss: 0.1639 - val_accuracy: 0.9755
Epoch 14/40
469/469 [=====] - 2s 5ms/step - loss: 6.8286e-05
- accuracy: 1.0000 - val_loss: 0.1639 - val_accuracy: 0.9754
Epoch 15/40
469/469 [=====] - 2s 5ms/step - loss: 6.8107e-05
- accuracy: 1.0000 - val_loss: 0.1641 - val_accuracy: 0.9755
Epoch 16/40
469/469 [=====] - 2s 5ms/step - loss: 6.7921e-05
- accuracy: 1.0000 - val_loss: 0.1641 - val_accuracy: 0.9754
Epoch 17/40
469/469 [=====] - 2s 5ms/step - loss: 6.7714e-05
- accuracy: 1.0000 - val_loss: 0.1641 - val_accuracy: 0.9757
Epoch 18/40
469/469 [=====] - 2s 5ms/step - loss: 6.7535e-05
- accuracy: 1.0000 - val_loss: 0.1641 - val_accuracy: 0.9753
Epoch 19/40
469/469 [=====] - 2s 5ms/step - loss: 6.7420e-05
- accuracy: 1.0000 - val_loss: 0.1642 - val_accuracy: 0.9756
Epoch 20/40
469/469 [=====] - 2s 5ms/step - loss: 6.7050e-05
- accuracy: 1.0000 - val_loss: 0.1644 - val_accuracy: 0.9753
Epoch 21/40
469/469 [=====] - 2s 5ms/step - loss: 6.7032e-05
- accuracy: 1.0000 - val_loss: 0.1645 - val_accuracy: 0.9755
Epoch 22/40
469/469 [=====] - 2s 5ms/step - loss: 6.6748e-05
- accuracy: 1.0000 - val_loss: 0.1642 - val_accuracy: 0.9756
Epoch 23/40
469/469 [=====] - 2s 5ms/step - loss: 6.6624e-05
- accuracy: 1.0000 - val_loss: 0.1645 - val_accuracy: 0.9754
Epoch 24/40
469/469 [=====] - 2s 5ms/step - loss: 6.6429e-05
- accuracy: 1.0000 - val_loss: 0.1646 - val_accuracy: 0.9755
Epoch 25/40
469/469 [=====] - 2s 5ms/step - loss: 6.6238e-05
- accuracy: 1.0000 - val_loss: 0.1646 - val_accuracy: 0.9756
Epoch 26/40
469/469 [=====] - 2s 5ms/step - loss: 6.6058e-05
- accuracy: 1.0000 - val_loss: 0.1644 - val_accuracy: 0.9757
Epoch 27/40
469/469 [=====] - 2s 5ms/step - loss: 6.5881e-05
- accuracy: 1.0000 - val_loss: 0.1649 - val_accuracy: 0.9759
Epoch 28/40
469/469 [=====] - 2s 5ms/step - loss: 6.5695e-05
- accuracy: 1.0000 - val_loss: 0.1647 - val_accuracy: 0.9754
```


Epoch 29/40
469/469 [=====] - 2s 4ms/step - loss: 6.5515e-05
- accuracy: 1.0000 - val_loss: 0.1648 - val_accuracy: 0.9758

Epoch 30/40
469/469 [=====] - 2s 5ms/step - loss: 6.5354e-05
- accuracy: 1.0000 - val_loss: 0.1648 - val_accuracy: 0.9756

Epoch 31/40
469/469 [=====] - 2s 5ms/step - loss: 6.5136e-05
- accuracy: 1.0000 - val_loss: 0.1648 - val_accuracy: 0.9756

Epoch 32/40
469/469 [=====] - 2s 5ms/step - loss: 6.4962e-05
- accuracy: 1.0000 - val_loss: 0.1649 - val_accuracy: 0.9754

Epoch 33/40
469/469 [=====] - 2s 5ms/step - loss: 6.4767e-05
- accuracy: 1.0000 - val_loss: 0.1651 - val_accuracy: 0.9758

Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 6.4614e-05
- accuracy: 1.0000 - val_loss: 0.1652 - val_accuracy: 0.9756

Epoch 35/40
469/469 [=====] - 2s 5ms/step - loss: 6.4438e-05
- accuracy: 1.0000 - val_loss: 0.1648 - val_accuracy: 0.9755

Epoch 36/40
469/469 [=====] - 2s 5ms/step - loss: 6.4299e-05
- accuracy: 1.0000 - val_loss: 0.1650 - val_accuracy: 0.9757

Epoch 37/40
469/469 [=====] - 2s 5ms/step - loss: 6.4115e-05
- accuracy: 1.0000 - val_loss: 0.1651 - val_accuracy: 0.9758

Epoch 38/40
469/469 [=====] - 2s 5ms/step - loss: 6.3933e-05
- accuracy: 1.0000 - val_loss: 0.1650 - val_accuracy: 0.9756

Epoch 39/40
469/469 [=====] - 2s 5ms/step - loss: 6.3755e-05
- accuracy: 1.0000 - val_loss: 0.1652 - val_accuracy: 0.9757

Epoch 40/40
469/469 [=====] - 2s 5ms/step - loss: 6.3508e-05
- accuracy: 1.0000 - val_loss: 0.1653 - val_accuracy: 0.9757

Epoch 1/40
469/469 [=====] - 2s 5ms/step - loss: 6.3405e-05
- accuracy: 1.0000 - val_loss: 0.1654 - val_accuracy: 0.9756

Epoch 2/40
469/469 [=====] - 2s 5ms/step - loss: 6.3253e-05
- accuracy: 1.0000 - val_loss: 0.1654 - val_accuracy: 0.9757

Epoch 3/40
469/469 [=====] - 2s 5ms/step - loss: 6.3084e-05
- accuracy: 1.0000 - val_loss: 0.1655 - val_accuracy: 0.9755

Epoch 4/40
469/469 [=====] - 2s 5ms/step - loss: 6.2928e-05
- accuracy: 1.0000 - val_loss: 0.1655 - val_accuracy: 0.9758

Epoch 5/40
469/469 [=====] - 2s 5ms/step - loss: 6.2747e-05
- accuracy: 1.0000 - val_loss: 0.1655 - val_accuracy: 0.9757

Epoch 6/40
469/469 [=====] - 2s 5ms/step - loss: 6.2549e-05
- accuracy: 1.0000 - val_loss: 0.1653 - val_accuracy: 0.9755

Epoch 7/40
469/469 [=====] - 2s 5ms/step - loss: 6.2394e-05
- accuracy: 1.0000 - val_loss: 0.1655 - val_accuracy: 0.9757

Epoch 8/40
469/469 [=====] - 2s 5ms/step - loss: 6.2269e-05
- accuracy: 1.0000 - val_loss: 0.1657 - val_accuracy: 0.9754

Epoch 9/40

```
469/469 [=====] - 2s 5ms/step - loss: 6.2087e-05
- accuracy: 1.0000 - val_loss: 0.1656 - val_accuracy: 0.9753
Epoch 10/40
469/469 [=====] - 2s 5ms/step - loss: 6.1897e-05
- accuracy: 1.0000 - val_loss: 0.1655 - val_accuracy: 0.9755
Epoch 11/40
469/469 [=====] - 2s 4ms/step - loss: 6.1735e-05
- accuracy: 1.0000 - val_loss: 0.1658 - val_accuracy: 0.9753
Epoch 12/40
469/469 [=====] - 2s 5ms/step - loss: 6.1613e-05
- accuracy: 1.0000 - val_loss: 0.1658 - val_accuracy: 0.9757
Epoch 13/40
469/469 [=====] - 2s 5ms/step - loss: 6.1476e-05
- accuracy: 1.0000 - val_loss: 0.1658 - val_accuracy: 0.9754
Epoch 14/40
469/469 [=====] - 2s 5ms/step - loss: 6.1300e-05
- accuracy: 1.0000 - val_loss: 0.1660 - val_accuracy: 0.9757
Epoch 15/40
469/469 [=====] - 2s 5ms/step - loss: 6.1121e-05
- accuracy: 1.0000 - val_loss: 0.1662 - val_accuracy: 0.9755
Epoch 16/40
469/469 [=====] - 2s 5ms/step - loss: 6.0990e-05
- accuracy: 1.0000 - val_loss: 0.1659 - val_accuracy: 0.9755
Epoch 17/40
469/469 [=====] - 2s 5ms/step - loss: 6.0860e-05
- accuracy: 1.0000 - val_loss: 0.1660 - val_accuracy: 0.9757
Epoch 18/40
469/469 [=====] - 2s 5ms/step - loss: 6.0645e-05
- accuracy: 1.0000 - val_loss: 0.1663 - val_accuracy: 0.9756
Epoch 19/40
469/469 [=====] - 2s 5ms/step - loss: 6.0499e-05
- accuracy: 1.0000 - val_loss: 0.1662 - val_accuracy: 0.9757
Epoch 20/40
469/469 [=====] - 2s 5ms/step - loss: 6.0351e-05
- accuracy: 1.0000 - val_loss: 0.1662 - val_accuracy: 0.9757
Epoch 21/40
469/469 [=====] - 2s 5ms/step - loss: 6.0186e-05
- accuracy: 1.0000 - val_loss: 0.1660 - val_accuracy: 0.9755
Epoch 22/40
469/469 [=====] - 2s 5ms/step - loss: 6.0070e-05
- accuracy: 1.0000 - val_loss: 0.1663 - val_accuracy: 0.9757
Epoch 23/40
469/469 [=====] - 3s 5ms/step - loss: 5.9831e-05
- accuracy: 1.0000 - val_loss: 0.1665 - val_accuracy: 0.9757
Epoch 24/40
469/469 [=====] - 2s 5ms/step - loss: 5.9763e-05
- accuracy: 1.0000 - val_loss: 0.1664 - val_accuracy: 0.9757
Epoch 25/40
469/469 [=====] - 2s 5ms/step - loss: 5.9612e-05
- accuracy: 1.0000 - val_loss: 0.1663 - val_accuracy: 0.9757
Epoch 26/40
469/469 [=====] - 2s 5ms/step - loss: 5.9452e-05
- accuracy: 1.0000 - val_loss: 0.1663 - val_accuracy: 0.9757
Epoch 27/40
469/469 [=====] - 2s 5ms/step - loss: 5.9295e-05
- accuracy: 1.0000 - val_loss: 0.1664 - val_accuracy: 0.9757
Epoch 28/40
469/469 [=====] - 2s 5ms/step - loss: 5.9147e-05
- accuracy: 1.0000 - val_loss: 0.1665 - val_accuracy: 0.9758
Epoch 29/40
469/469 [=====] - 2s 4ms/step - loss: 5.8956e-05
```

```
- accuracy: 1.0000 - val_loss: 0.1669 - val_accuracy: 0.9757
Epoch 30/40
469/469 [=====] - 2s 4ms/step - loss: 5.8861e-05
- accuracy: 1.0000 - val_loss: 0.1665 - val_accuracy: 0.9756
Epoch 31/40
469/469 [=====] - 2s 5ms/step - loss: 5.8696e-05
- accuracy: 1.0000 - val_loss: 0.1667 - val_accuracy: 0.9756
Epoch 32/40
469/469 [=====] - 2s 5ms/step - loss: 5.8509e-05
- accuracy: 1.0000 - val_loss: 0.1668 - val_accuracy: 0.9756
Epoch 33/40
469/469 [=====] - 2s 5ms/step - loss: 5.8423e-05
- accuracy: 1.0000 - val_loss: 0.1667 - val_accuracy: 0.9757
Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 5.8278e-05
- accuracy: 1.0000 - val_loss: 0.1668 - val_accuracy: 0.9758
Epoch 35/40
469/469 [=====] - 2s 5ms/step - loss: 5.8132e-05
- accuracy: 1.0000 - val_loss: 0.1667 - val_accuracy: 0.9757
Epoch 36/40
469/469 [=====] - 2s 5ms/step - loss: 5.7963e-05
- accuracy: 1.0000 - val_loss: 0.1668 - val_accuracy: 0.9756
Epoch 37/40
469/469 [=====] - 2s 5ms/step - loss: 5.7796e-05
- accuracy: 1.0000 - val_loss: 0.1667 - val_accuracy: 0.9758
Epoch 38/40
469/469 [=====] - 2s 4ms/step - loss: 5.7716e-05
- accuracy: 1.0000 - val_loss: 0.1669 - val_accuracy: 0.9755
Epoch 39/40
469/469 [=====] - 2s 5ms/step - loss: 5.7541e-05
- accuracy: 1.0000 - val_loss: 0.1671 - val_accuracy: 0.9758
Epoch 40/40
469/469 [=====] - 2s 5ms/step - loss: 5.7442e-05
- accuracy: 1.0000 - val_loss: 0.1670 - val_accuracy: 0.9757
Epoch 1/40
469/469 [=====] - 2s 5ms/step - loss: 5.7269e-05
- accuracy: 1.0000 - val_loss: 0.1672 - val_accuracy: 0.9758
Epoch 2/40
469/469 [=====] - 2s 5ms/step - loss: 5.7139e-05
- accuracy: 1.0000 - val_loss: 0.1672 - val_accuracy: 0.9759
Epoch 3/40
469/469 [=====] - 2s 5ms/step - loss: 5.6997e-05
- accuracy: 1.0000 - val_loss: 0.1672 - val_accuracy: 0.9758
Epoch 4/40
469/469 [=====] - 2s 4ms/step - loss: 5.6839e-05
- accuracy: 1.0000 - val_loss: 0.1672 - val_accuracy: 0.9758
Epoch 5/40
469/469 [=====] - 2s 5ms/step - loss: 5.6680e-05
- accuracy: 1.0000 - val_loss: 0.1673 - val_accuracy: 0.9757
Epoch 6/40
469/469 [=====] - 2s 5ms/step - loss: 5.6563e-05
- accuracy: 1.0000 - val_loss: 0.1674 - val_accuracy: 0.9758
Epoch 7/40
469/469 [=====] - 2s 5ms/step - loss: 5.6393e-05
- accuracy: 1.0000 - val_loss: 0.1674 - val_accuracy: 0.9757
Epoch 8/40
469/469 [=====] - 2s 5ms/step - loss: 5.6286e-05
- accuracy: 1.0000 - val_loss: 0.1673 - val_accuracy: 0.9757
Epoch 9/40
469/469 [=====] - 2s 5ms/step - loss: 5.6158e-05
- accuracy: 1.0000 - val_loss: 0.1674 - val_accuracy: 0.9757
```

Epoch 10/40

469/469 [=====] - 2s 5ms/step - loss: 5.6072e-05
- accuracy: 1.0000 - val_loss: 0.1676 - val_accuracy: 0.9757

Epoch 11/40

469/469 [=====] - 3s 5ms/step - loss: 5.5868e-05
- accuracy: 1.0000 - val_loss: 0.1674 - val_accuracy: 0.9757

Epoch 12/40

469/469 [=====] - 2s 5ms/step - loss: 5.5755e-05
- accuracy: 1.0000 - val_loss: 0.1676 - val_accuracy: 0.9758

Epoch 13/40

469/469 [=====] - 2s 5ms/step - loss: 5.5658e-05
- accuracy: 1.0000 - val_loss: 0.1676 - val_accuracy: 0.9758

Epoch 14/40

469/469 [=====] - 2s 5ms/step - loss: 5.5522e-05
- accuracy: 1.0000 - val_loss: 0.1676 - val_accuracy: 0.9758

Epoch 15/40

469/469 [=====] - 2s 5ms/step - loss: 5.5360e-05
- accuracy: 1.0000 - val_loss: 0.1677 - val_accuracy: 0.9757

Epoch 16/40

469/469 [=====] - 2s 5ms/step - loss: 5.5208e-05
- accuracy: 1.0000 - val_loss: 0.1679 - val_accuracy: 0.9756

Epoch 17/40

469/469 [=====] - 2s 5ms/step - loss: 5.5132e-05
- accuracy: 1.0000 - val_loss: 0.1678 - val_accuracy: 0.9758

Epoch 18/40

469/469 [=====] - 2s 5ms/step - loss: 5.4961e-05
- accuracy: 1.0000 - val_loss: 0.1681 - val_accuracy: 0.9758

Epoch 19/40

469/469 [=====] - 2s 5ms/step - loss: 5.4844e-05
- accuracy: 1.0000 - val_loss: 0.1679 - val_accuracy: 0.9757

Epoch 20/40

469/469 [=====] - 2s 5ms/step - loss: 5.4727e-05
- accuracy: 1.0000 - val_loss: 0.1679 - val_accuracy: 0.9758

Epoch 21/40

469/469 [=====] - 2s 5ms/step - loss: 5.4602e-05
- accuracy: 1.0000 - val_loss: 0.1679 - val_accuracy: 0.9757

Epoch 22/40

469/469 [=====] - 2s 5ms/step - loss: 5.4454e-05
- accuracy: 1.0000 - val_loss: 0.1679 - val_accuracy: 0.9757

Epoch 23/40

469/469 [=====] - 2s 5ms/step - loss: 5.4349e-05
- accuracy: 1.0000 - val_loss: 0.1680 - val_accuracy: 0.9757

Epoch 24/40

469/469 [=====] - 2s 5ms/step - loss: 5.4206e-05
- accuracy: 1.0000 - val_loss: 0.1681 - val_accuracy: 0.9759

Epoch 25/40

469/469 [=====] - 2s 5ms/step - loss: 5.4065e-05
- accuracy: 1.0000 - val_loss: 0.1681 - val_accuracy: 0.9757

Epoch 26/40

469/469 [=====] - 2s 5ms/step - loss: 5.3949e-05
- accuracy: 1.0000 - val_loss: 0.1683 - val_accuracy: 0.9758

Epoch 27/40

469/469 [=====] - 2s 5ms/step - loss: 5.3838e-05
- accuracy: 1.0000 - val_loss: 0.1682 - val_accuracy: 0.9758

Epoch 28/40

469/469 [=====] - 2s 5ms/step - loss: 5.3704e-05
- accuracy: 1.0000 - val_loss: 0.1682 - val_accuracy: 0.9757

Epoch 29/40

469/469 [=====] - 2s 5ms/step - loss: 5.3569e-05
- accuracy: 1.0000 - val_loss: 0.1684 - val_accuracy: 0.9759

Epoch 30/40

```
469/469 [=====] - 2s 5ms/step - loss: 5.3461e-05
- accuracy: 1.0000 - val_loss: 0.1682 - val_accuracy: 0.9758
Epoch 31/40
469/469 [=====] - 2s 5ms/step - loss: 5.3310e-05
- accuracy: 1.0000 - val_loss: 0.1684 - val_accuracy: 0.9757
Epoch 32/40
469/469 [=====] - 2s 5ms/step - loss: 5.3184e-05
- accuracy: 1.0000 - val_loss: 0.1684 - val_accuracy: 0.9760
Epoch 33/40
469/469 [=====] - 2s 5ms/step - loss: 5.3078e-05
- accuracy: 1.0000 - val_loss: 0.1682 - val_accuracy: 0.9756
Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 5.2949e-05
- accuracy: 1.0000 - val_loss: 0.1684 - val_accuracy: 0.9758
Epoch 35/40
469/469 [=====] - 2s 5ms/step - loss: 5.2848e-05
- accuracy: 1.0000 - val_loss: 0.1685 - val_accuracy: 0.9759
Epoch 36/40
469/469 [=====] - 2s 5ms/step - loss: 5.2693e-05
- accuracy: 1.0000 - val_loss: 0.1687 - val_accuracy: 0.9759
Epoch 37/40
469/469 [=====] - 2s 5ms/step - loss: 5.2564e-05
- accuracy: 1.0000 - val_loss: 0.1688 - val_accuracy: 0.9758
Epoch 38/40
469/469 [=====] - 2s 5ms/step - loss: 5.2501e-05
- accuracy: 1.0000 - val_loss: 0.1687 - val_accuracy: 0.9757
Epoch 39/40
469/469 [=====] - 2s 5ms/step - loss: 5.2364e-05
- accuracy: 1.0000 - val_loss: 0.1687 - val_accuracy: 0.9757
Epoch 40/40
469/469 [=====] - 2s 5ms/step - loss: 5.2254e-05
- accuracy: 1.0000 - val_loss: 0.1688 - val_accuracy: 0.9757
Epoch 1/40
469/469 [=====] - 3s 6ms/step - loss: 5.2116e-05
- accuracy: 1.0000 - val_loss: 0.1687 - val_accuracy: 0.9758
Epoch 2/40
469/469 [=====] - 2s 5ms/step - loss: 5.1960e-05
- accuracy: 1.0000 - val_loss: 0.1689 - val_accuracy: 0.9758
Epoch 3/40
469/469 [=====] - 2s 5ms/step - loss: 5.1891e-05
- accuracy: 1.0000 - val_loss: 0.1688 - val_accuracy: 0.9758
Epoch 4/40
469/469 [=====] - 2s 5ms/step - loss: 5.1735e-05
- accuracy: 1.0000 - val_loss: 0.1690 - val_accuracy: 0.9757
Epoch 5/40
469/469 [=====] - 2s 5ms/step - loss: 5.1663e-05
- accuracy: 1.0000 - val_loss: 0.1690 - val_accuracy: 0.9758
Epoch 6/40
469/469 [=====] - 2s 5ms/step - loss: 5.1433e-05
- accuracy: 1.0000 - val_loss: 0.1688 - val_accuracy: 0.9756
Epoch 7/40
469/469 [=====] - 2s 5ms/step - loss: 5.1418e-05
- accuracy: 1.0000 - val_loss: 0.1689 - val_accuracy: 0.9757
Epoch 8/40
469/469 [=====] - 2s 5ms/step - loss: 5.1319e-05
- accuracy: 1.0000 - val_loss: 0.1690 - val_accuracy: 0.9758
Epoch 9/40
469/469 [=====] - 2s 5ms/step - loss: 5.1166e-05
- accuracy: 1.0000 - val_loss: 0.1692 - val_accuracy: 0.9760
Epoch 10/40
469/469 [=====] - 2s 5ms/step - loss: 5.1094e-05
```

```
- accuracy: 1.0000 - val_loss: 0.1691 - val_accuracy: 0.9759
Epoch 11/40
469/469 [=====] - 2s 5ms/step - loss: 5.0986e-05
- accuracy: 1.0000 - val_loss: 0.1693 - val_accuracy: 0.9757
Epoch 12/40
469/469 [=====] - 2s 5ms/step - loss: 5.0856e-05
- accuracy: 1.0000 - val_loss: 0.1691 - val_accuracy: 0.9757
Epoch 13/40
469/469 [=====] - 2s 5ms/step - loss: 5.0741e-05
- accuracy: 1.0000 - val_loss: 0.1692 - val_accuracy: 0.9757
Epoch 14/40
469/469 [=====] - 2s 5ms/step - loss: 5.0661e-05
- accuracy: 1.0000 - val_loss: 0.1693 - val_accuracy: 0.9759
Epoch 15/40
469/469 [=====] - 2s 5ms/step - loss: 5.0534e-05
- accuracy: 1.0000 - val_loss: 0.1692 - val_accuracy: 0.9758
Epoch 16/40
469/469 [=====] - 2s 5ms/step - loss: 5.0375e-05
- accuracy: 1.0000 - val_loss: 0.1694 - val_accuracy: 0.9757
Epoch 17/40
469/469 [=====] - 2s 5ms/step - loss: 5.0299e-05
- accuracy: 1.0000 - val_loss: 0.1693 - val_accuracy: 0.9759
Epoch 18/40
469/469 [=====] - 2s 5ms/step - loss: 5.0169e-05
- accuracy: 1.0000 - val_loss: 0.1694 - val_accuracy: 0.9758
Epoch 19/40
469/469 [=====] - 2s 5ms/step - loss: 5.0076e-05
- accuracy: 1.0000 - val_loss: 0.1694 - val_accuracy: 0.9759
Epoch 20/40
469/469 [=====] - 2s 5ms/step - loss: 4.9994e-05
- accuracy: 1.0000 - val_loss: 0.1694 - val_accuracy: 0.9757
Epoch 21/40
469/469 [=====] - 2s 5ms/step - loss: 4.9865e-05
- accuracy: 1.0000 - val_loss: 0.1696 - val_accuracy: 0.9758
Epoch 22/40
469/469 [=====] - 2s 5ms/step - loss: 4.9752e-05
- accuracy: 1.0000 - val_loss: 0.1696 - val_accuracy: 0.9758
Epoch 23/40
469/469 [=====] - 2s 5ms/step - loss: 4.9648e-05
- accuracy: 1.0000 - val_loss: 0.1697 - val_accuracy: 0.9759
Epoch 24/40
469/469 [=====] - 2s 5ms/step - loss: 4.9522e-05
- accuracy: 1.0000 - val_loss: 0.1695 - val_accuracy: 0.9756
Epoch 25/40
469/469 [=====] - 2s 5ms/step - loss: 4.9426e-05
- accuracy: 1.0000 - val_loss: 0.1698 - val_accuracy: 0.9759
Epoch 26/40
469/469 [=====] - 2s 5ms/step - loss: 4.9294e-05
- accuracy: 1.0000 - val_loss: 0.1697 - val_accuracy: 0.9758
Epoch 27/40
469/469 [=====] - 2s 5ms/step - loss: 4.9237e-05
- accuracy: 1.0000 - val_loss: 0.1698 - val_accuracy: 0.9757
Epoch 28/40
469/469 [=====] - 2s 5ms/step - loss: 4.9112e-05
- accuracy: 1.0000 - val_loss: 0.1698 - val_accuracy: 0.9758
Epoch 29/40
469/469 [=====] - 2s 5ms/step - loss: 4.9022e-05
- accuracy: 1.0000 - val_loss: 0.1699 - val_accuracy: 0.9759
Epoch 30/40
469/469 [=====] - 2s 5ms/step - loss: 4.8889e-05
- accuracy: 1.0000 - val_loss: 0.1698 - val_accuracy: 0.9757
```

```

Epoch 31/40
469/469 [=====] - 2s 5ms/step - loss: 4.8765e-05
- accuracy: 1.0000 - val_loss: 0.1699 - val_accuracy: 0.9759
Epoch 32/40
469/469 [=====] - 2s 5ms/step - loss: 4.8642e-05
- accuracy: 1.0000 - val_loss: 0.1699 - val_accuracy: 0.9758
Epoch 33/40
469/469 [=====] - 2s 5ms/step - loss: 4.8624e-05
- accuracy: 1.0000 - val_loss: 0.1700 - val_accuracy: 0.9759
Epoch 34/40
469/469 [=====] - 2s 5ms/step - loss: 4.8456e-05
- accuracy: 1.0000 - val_loss: 0.1701 - val_accuracy: 0.9762
Epoch 35/40
469/469 [=====] - 2s 5ms/step - loss: 4.8384e-05
- accuracy: 1.0000 - val_loss: 0.1701 - val_accuracy: 0.9759
Epoch 36/40
469/469 [=====] - 2s 5ms/step - loss: 4.8272e-05
- accuracy: 1.0000 - val_loss: 0.1700 - val_accuracy: 0.9757
Epoch 37/40
469/469 [=====] - 2s 5ms/step - loss: 4.8168e-05
- accuracy: 1.0000 - val_loss: 0.1701 - val_accuracy: 0.9760
Epoch 38/40
469/469 [=====] - 2s 5ms/step - loss: 4.8058e-05
- accuracy: 1.0000 - val_loss: 0.1702 - val_accuracy: 0.9759
Epoch 39/40
469/469 [=====] - 2s 5ms/step - loss: 4.7945e-05
- accuracy: 1.0000 - val_loss: 0.1701 - val_accuracy: 0.9758
Epoch 40/40
469/469 [=====] - 2s 5ms/step - loss: 4.7897e-05
- accuracy: 1.0000 - val_loss: 0.1702 - val_accuracy: 0.9759

```

In [9]:

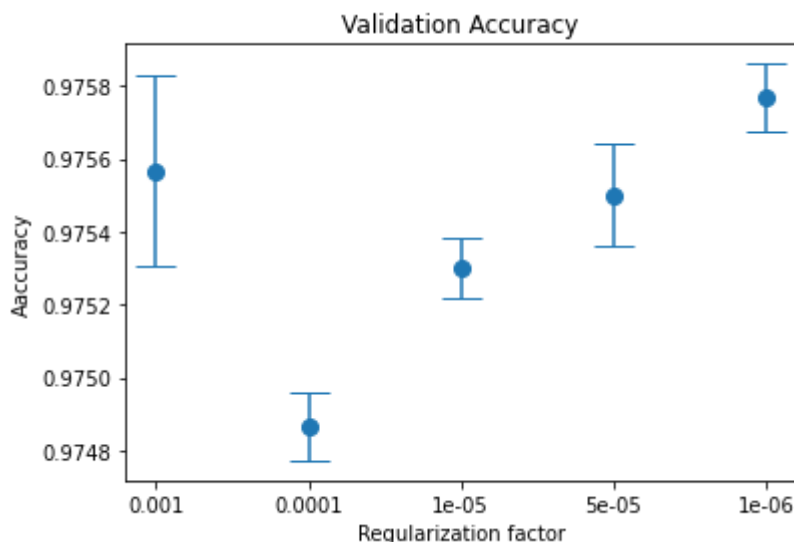
```

plt.xlabel("Regularization factor")
plt.ylabel("Accuracy")
plt.title("Validation Accuracy")

plt.errorbar(list(map(str, [0.001,0.0001,0.00001,0.00005,0.000001])),
             list(map(np.mean, result)), list(map(np.std, result)),
             linestyle='None', fmt='o', markersize=8, capsize=10)

plt.show()

```



We unfortunately do not reach the 98.47% but do get pretty close.

3 - Convolutional layers

a - Design Model

In [10]:

```
from keras.layers import MaxPool2D
epochs = 10

model3 = Sequential()

#CNN
model3.add(Conv2D(25, kernel_size=(3,3), strides=(1,1), padding='valid', activation='relu', input_shape=(28,28,1)))
#MaxPool
model3.add(MaxPool2D(pool_size=(2,2)))
#Flatten
model3.add(Flatten())
#Hidden
model3.add(Dense(100, activation='relu'))
#Output
model3.add(Dense(num_classes, activation='softmax'))

model3.compile(loss=keras.losses.categorical_crossentropy,
                optimizer=tf.keras.optimizers.SGD(lr = 0.1),
                metrics=['accuracy'])

fit_info = model3.fit(x_train, y_train,
                      batch_size=batch_size,
                      epochs=epochs,
                      verbose=1,
                      validation_data=(x_test, y_test))
```

Epoch 1/10

```
/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/gradient_descen
t.py:102: UserWarning: The `lr` argument is deprecated, use `learning_rate`
` instead.
  super(SGD, self).__init__(name, **kwargs)
```

```
469/469 [=====] - 23s 48ms/step - loss: 0.3792 -
accuracy: 0.8855 - val_loss: 0.1783 - val_accuracy: 0.9474
```

Epoch 2/10

```
469/469 [=====] - 23s 48ms/step - loss: 0.1568 -
accuracy: 0.9523 - val_loss: 0.1433 - val_accuracy: 0.9572
```

Epoch 3/10

```
469/469 [=====] - 23s 48ms/step - loss: 0.1151 -
accuracy: 0.9650 - val_loss: 0.1182 - val_accuracy: 0.9644
```

Epoch 4/10

```
469/469 [=====] - 22s 48ms/step - loss: 0.0925 -
accuracy: 0.9711 - val_loss: 0.1031 - val_accuracy: 0.9653
```

Epoch 5/10

```
469/469 [=====] - 23s 49ms/step - loss: 0.0774 -
accuracy: 0.9764 - val_loss: 0.0857 - val_accuracy: 0.9722
```

Epoch 6/10

```
469/469 [=====] - 22s 48ms/step - loss: 0.0652 -
accuracy: 0.9797 - val_loss: 0.1023 - val_accuracy: 0.9683
```

Epoch 7/10

```
469/469 [=====] - 22s 48ms/step - loss: 0.0563 -
accuracy: 0.9829 - val_loss: 0.0634 - val_accuracy: 0.9796
```

Epoch 8/10

```
469/469 [=====] - 22s 48ms/step - loss: 0.0494 -
accuracy: 0.9845 - val_loss: 0.0785 - val_accuracy: 0.9744
```

Epoch 9/10

```
469/469 [=====] - 22s 48ms/step - loss: 0.0434 -
accuracy: 0.9868 - val_loss: 0.0590 - val_accuracy: 0.9800
```

Epoch 10/10

```
469/469 [=====] - 23s 48ms/step - loss: 0.0380 -
accuracy: 0.9885 - val_loss: 0.0615 - val_accuracy: 0.9789
```

We are so close to 99%, only 0.0012% away this time so I am going to count it rather than redoing it and waiting. The top Cnn layers is described more below but we also add another layer, MaxPooling2D with the size 2x2. Maxpooling works by filtering the 2d grid and saving the highest number from x amount of items. Since we choose 2x2 will a 2x2 square (a strider) move around our grid and filter out the max value from those items 'highlighted' by it. The MaxPooling has also shrunk our image by its strider size. 2x2 strider means that side z and y is divided by 2. Resulting in image 1/4 of the original, which speeds up the computing part.

If we would want to improve our score is there a number of factors we could try and change. CNN has plenty; padding, striders, dilation rate etc.

b - Discuss CNN vs FCNN

FCNN is described in most articles and keras as being 'general use'. Every neuron is connected to every neuron in the previous layer resulting in many connections with its own weights, demanding a lot of computational power. CNN on the other hand is only connected to a few neurons in the previous layer (local) and uses the same weights, not creating as many connections and is therefore faster computed. The reason to this is because CNN does care about the placement of pixels in our images, it wants to look at local pixels. It only works if pieces of items on the picture are grouped (remain local). The number in our images for example are clearly connected together and have (in most cases) clear straight edges, it should be able to recognise these edges easily. It cannot make sense of a number image if we make a jigsaw out of it and shuffle the pieces. It will see many edges but will not understand that they may be connected together.

A clearer example is to think of an image with a car on the left and a bear on the right with white space between them. The bear does look like a bear regardless of what the car looks like and CNN only focus on that when looking at the bear. FCNN gathers information without 'spacing items apart' resulting in more broad result. Which might slow down the learning process as we only want to focus on a particular item and not the whole picture. In another case we might need to regard the space of the whole image.

Our numbers fit the CNN requirements and my computer can't / don't want to compute FCNN.

4 - Auto-Encoders for denoising

a - Explain Functions

The models Task

The model is supposed to add noise (random bit of pixels, black and white) to the image to train the model to disregard them as they won't be serving any purpose. It does this in simple terms by compressing and decompressing the image.

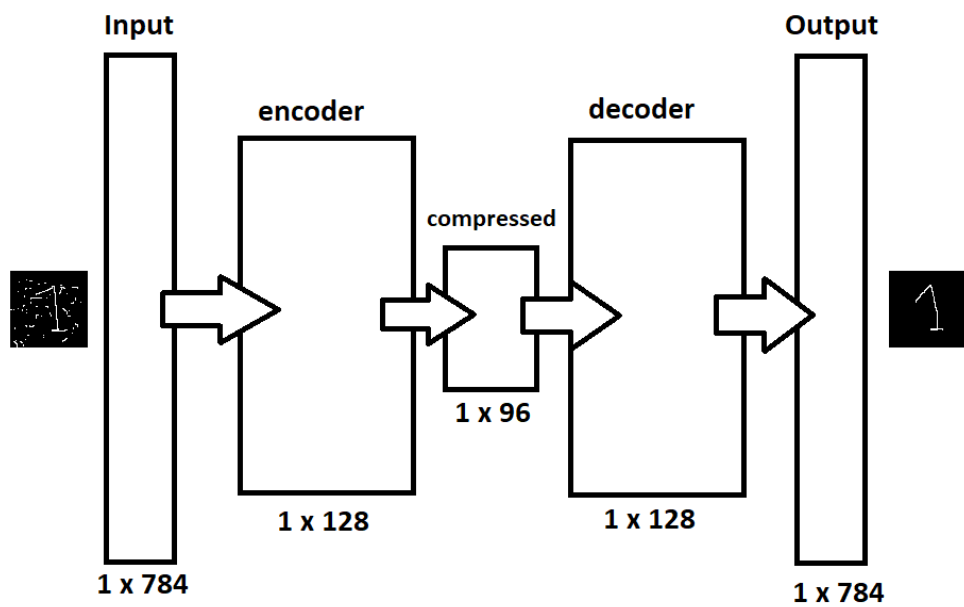
By compressing the image does the model have to remove certain elements to make it all fit, this will presumably be the noise we created. Once small will we enlarge / decompress it having the model try to recreate it at the best of its abilities.

We use loss to grade how well the model was able to match the original image (noise less) with its own deconstruction. This way we add a system so that the model keeps on improving until the reconstruction gets close to the original.

In [17]:

```
from IPython.display import Image  
Image('CNN.png')
```

Out[17]:



b - Noice Levels

In [12]:

```
import numpy as np
def salt_and_pepper(input, noise_level=0.5):
    """
    This applies salt and pepper noise to the input tensor - randomly setting bits to 1
    or 0.
    Parameters
    -----
    input : tensor
        The tensor to apply salt and pepper noise to.
    noise_level : float
        The amount of salt and pepper noise to add.
    Returns
    -----
    tensor
        Tensor with salt and pepper noise applied.
    """
    # salt and pepper noise
    a = np.random.binomial(size=input.shape, n=1, p=(1 - noise_level))
    b = np.random.binomial(size=input.shape, n=1, p=noise_level)
    c = (a==0) * b
    return input * a + c

#data preparation
flattened_x_train = x_train.reshape(-1,784)
flattened_x_train_seasoned = salt_and_pepper(flattened_x_train, noise_level=0.4)

flattened_x_test = x_test.reshape(-1,784)
flattened_x_test_seasoned = salt_and_pepper(flattened_x_test, noise_level=0.4)
```

In [13]:

```
latent_dim = 96

input_image = keras.Input(shape=(784,))
encoded = Dense(128, activation='relu')(input_image)
encoded = Dense(latent_dim, activation='relu')(encoded)
decoded = Dense(128, activation='relu')(encoded)
decoded = Dense(784, activation='sigmoid')(decoded)

autoencoder = keras.Model(input_image, decoded)
encoder_only = keras.Model(input_image, encoded)

encoded_input = keras.Input(shape=(latent_dim,))
decoder_layer = Sequential(autoencoder.layers[-2:])
decoder = keras.Model(encoded_input, decoder_layer(encoded_input))

autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
```

In [14]:

```
fit_info_AE = autoencoder.fit(flattened_x_train_seasoned, flattened_x_train,  
                             epochs=32,  
                             batch_size=64,  
                             shuffle=True,  
                             validation_data=(flattened_x_test_seasoned, flattened_x_test))
```

```
Epoch 1/32
938/938 [=====] - 8s 8ms/step - loss: 0.1916 - va
l_loss: 0.1535
Epoch 2/32
938/938 [=====] - 8s 8ms/step - loss: 0.1465 - va
l_loss: 0.1387
Epoch 3/32
938/938 [=====] - 8s 8ms/step - loss: 0.1368 - va
l_loss: 0.1332
Epoch 4/32
938/938 [=====] - 8s 8ms/step - loss: 0.1318 - va
l_loss: 0.1305
Epoch 5/32
938/938 [=====] - 8s 8ms/step - loss: 0.1287 - va
l_loss: 0.1284
Epoch 6/32
938/938 [=====] - 8s 8ms/step - loss: 0.1266 - va
l_loss: 0.1265
Epoch 7/32
938/938 [=====] - 8s 8ms/step - loss: 0.1250 - va
l_loss: 0.1258
Epoch 8/32
938/938 [=====] - 8s 8ms/step - loss: 0.1236 - va
l_loss: 0.1251
Epoch 9/32
938/938 [=====] - 8s 8ms/step - loss: 0.1228 - va
l_loss: 0.1241
Epoch 10/32
938/938 [=====] - 8s 8ms/step - loss: 0.1218 - va
l_loss: 0.1233
Epoch 11/32
938/938 [=====] - 8s 8ms/step - loss: 0.1211 - va
l_loss: 0.1238
Epoch 12/32
938/938 [=====] - 8s 8ms/step - loss: 0.1204 - va
l_loss: 0.1223
Epoch 13/32
938/938 [=====] - 8s 8ms/step - loss: 0.1199 - va
l_loss: 0.1218
Epoch 14/32
938/938 [=====] - 8s 9ms/step - loss: 0.1194 - va
l_loss: 0.1216
Epoch 15/32
938/938 [=====] - 8s 9ms/step - loss: 0.1190 - va
l_loss: 0.1215
Epoch 16/32
938/938 [=====] - 8s 9ms/step - loss: 0.1186 - va
l_loss: 0.1210
Epoch 17/32
938/938 [=====] - 8s 8ms/step - loss: 0.1182 - va
l_loss: 0.1214
Epoch 18/32
938/938 [=====] - 8s 9ms/step - loss: 0.1179 - va
l_loss: 0.1210
Epoch 19/32
938/938 [=====] - 8s 9ms/step - loss: 0.1176 - va
l_loss: 0.1212
Epoch 20/32
938/938 [=====] - 8s 8ms/step - loss: 0.1174 - va
l_loss: 0.1207
Epoch 21/32
```

```
938/938 [=====] - 8s 8ms/step - loss: 0.1171 - va
l_loss: 0.1207
Epoch 22/32
938/938 [=====] - 8s 8ms/step - loss: 0.1169 - va
l_loss: 0.1212
Epoch 23/32
938/938 [=====] - 8s 8ms/step - loss: 0.1167 - va
l_loss: 0.1206
Epoch 24/32
938/938 [=====] - 8s 8ms/step - loss: 0.1165 - va
l_loss: 0.1208
Epoch 25/32
938/938 [=====] - 8s 8ms/step - loss: 0.1163 - va
l_loss: 0.1199
Epoch 26/32
938/938 [=====] - 8s 8ms/step - loss: 0.1161 - va
l_loss: 0.1201
Epoch 27/32
938/938 [=====] - 8s 8ms/step - loss: 0.1159 - va
l_loss: 0.1200
Epoch 28/32
938/938 [=====] - 8s 8ms/step - loss: 0.1158 - va
l_loss: 0.1205
Epoch 29/32
938/938 [=====] - 8s 8ms/step - loss: 0.1156 - va
l_loss: 0.1199
Epoch 30/32
938/938 [=====] - 8s 8ms/step - loss: 0.1155 - va
l_loss: 0.1193
Epoch 31/32
938/938 [=====] - 8s 8ms/step - loss: 0.1153 - va
l_loss: 0.1201
Epoch 32/32
938/938 [=====] - 8s 8ms/step - loss: 0.1152 - va
l_loss: 0.1198
```


In [15]:

```
import random
noise = [0.2, 0.4, 0.6, 0.8, 1]

def plotMachine(numbersDrawn, index):

    ax = plt.subplot(3, numbersDrawn, index + 1)
    plt.imshow(x_test[index].reshape(28, 28))

    ax = plt.subplot(3, numbersDrawn, index + 1 + numbersDrawn)
    plt.imshow(flattened_x_test_seasoned[index].reshape(28, 28))

    ax = plt.subplot(3, numbersDrawn, index + 1 + 2*numbersDrawn)
    plt.imshow(decoded_imgs[index].reshape(28, 28))

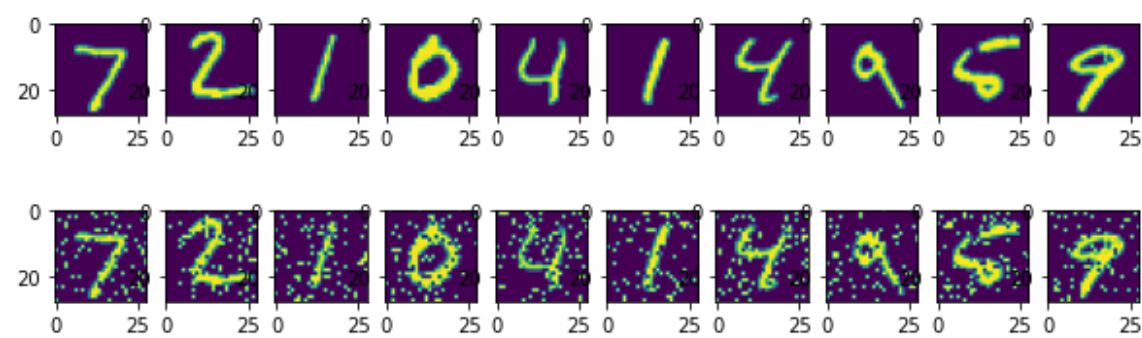
for pltN in range(5):

    flattened_x_test_seasoned = salt_and_pepper(flattened_x_test, noise[pltN])
    decoded_imgs = autoencoder.predict(flattened_x_test_seasoned)
    print("Noise: " + str(noise[pltN]))
    plt.figure(figsize=(10, 5))
    numbersDrawn = 10

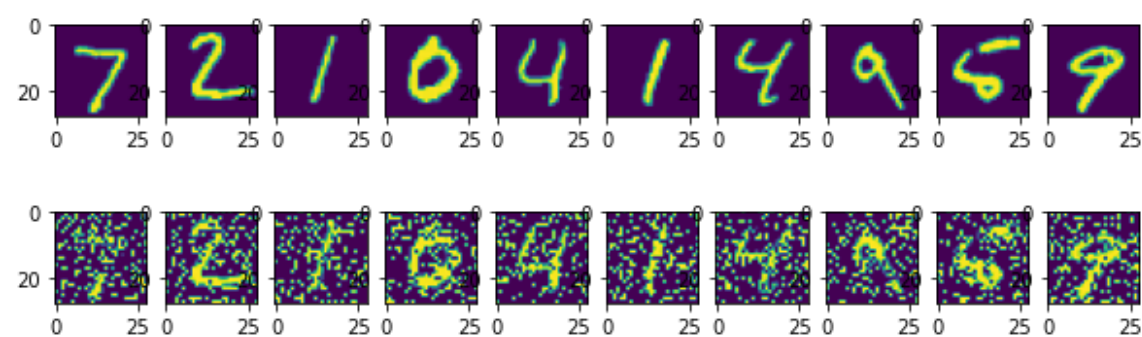
    for i in range(numbersDrawn):
        plotMachine(numbersDrawn, i)

plt.show()
```

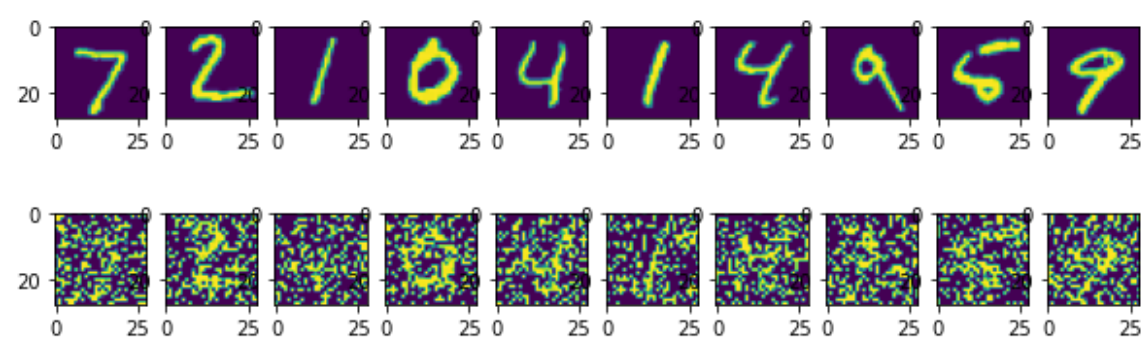
Noise: 0.2



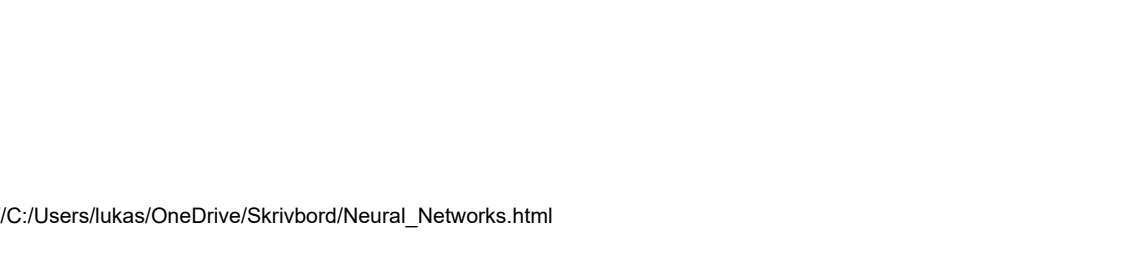
Noise: 0.4

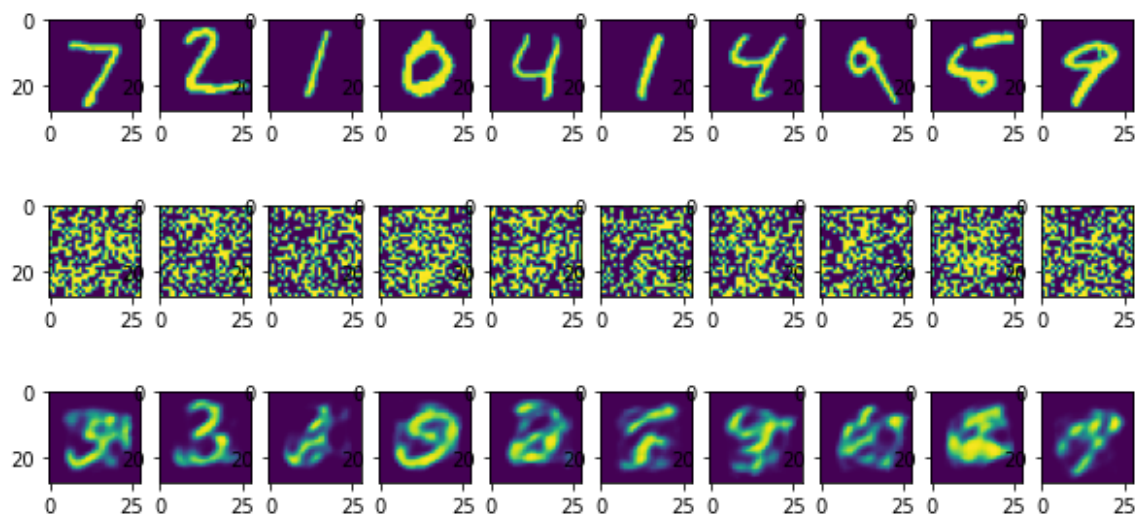


Noise: 0.6

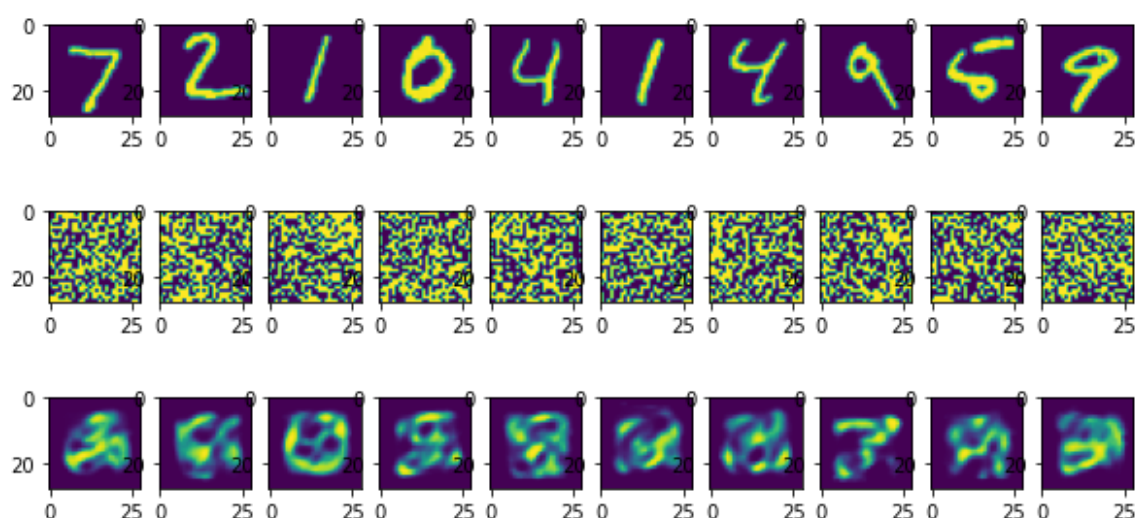


Noise: 0.8





Noise: 1



We see that at or after 0.6 does some numbers become hard or impossible to identify. The model still does a fantastic job, its way better than any normal human. Only someone who had actually trained at classifying seasoned images might stand a slight chance against the model.

c - Try denoising

In [22]:

```
noise = np.linspace(0,1,15)
unseasoned = []
seasoned = []

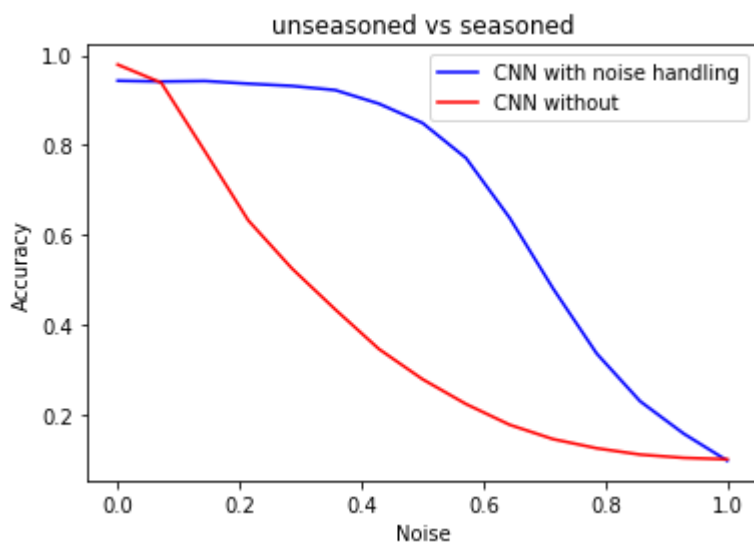
for j in range (len(noise)):

    seasonedTest = salt_and_pepper(flattened_x_test, noise[j])
    decodedImage = autoencoder.predict(seasonedTest)

    decodedImage_ = decodedImage.reshape(len(decodedImage), 28, 28, 1)
    x_test_seasoned = seasonedTest.reshape(len(seasonedTest), 28, 28, 1)

    unseasoned.append(model3.evaluate(decodedImage_, y_test, verbose=0)[1])
    seasoned.append(model3.evaluate(x_test_seasoned, y_test, verbose=0)[1])

plt.plot(noise, unseasoned, color='blue', label = 'CNN with noise handling')
plt.plot(noise, seasoned, color='red', label = 'CNN without')
plt.xlabel("Noise")
plt.ylabel("Accuracy")
plt.title("unseasoned vs seasoned")
plt.legend()
plt.show()
```



Using the CNN model from task 3.

We see that at the beginning does the CNN model without 'notice handling' preform better. This might because it doesn't need to compress and decompress the image making it easier for itself, but we see that when the noise increases does it begin to struggle. Which confirms that the 'noise handling' does have a very good use. We also see that around 0.6 does the cnn with noise handling start to struggle a lot, which we had seen before and isn't that weird considering that the images are almost all static.