**Midterm**

The following piece of code is given for recognizing hand-written digits. You are required to fill in the box which includes “?” as given below so that you find moments based on the set of input images. Then, the moments will be classified thanks to the piece of code which follows the box.

import matplotlib.pyplot as plt

import pandas as pd

import cv2

import numpy as np

import collections

import tensorflow as tf

from sklearn import datasets

from sklearn.model\_selection import train\_test\_split

**?**

df\_data = pd.DataFrame(data)

df\_data=df\_data.astype('float32')

X\_train, X\_test, y\_train, y\_test = train\_test\_split(

    df\_data, digits.target, test\_size=0.2, shuffle=False

)

model = tf.keras.Sequential([

    tf.keras.layers.Flatten(input\_shape=(totalItems, 1)),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.Dense(10)

])

model.compile(optimizer='adam',

              loss=tf.keras.losses.SparseCategoricalCrossentropy(from\_logits=True),

              metrics=['accuracy'])

model.fit(X\_train, y\_train, epochs=100)

test\_loss, test\_acc = model.evaluate(X\_test,  y\_test, verbose=2)

print('\nTest accuracy:', test\_acc)

**Sample output:**

Epoch 1/100

45/45 [==============================] - 1s 2ms/step - loss: 112.0440 - accuracy: 0.1955

Epoch 2/100

45/45 [==============================] - 0s 2ms/step - loss: 11.2741 - accuracy: 0.4168

Epoch 3/100

45/45 [==============================] - 0s 1ms/step - loss: 5.3626 - accuracy: 0.5282

Epoch 4/100

45/45 [==============================] - 0s 1ms/step - loss: 3.7984 - accuracy: 0.5581

Epoch 5/100

45/45 [==============================] - 0s 1ms/step - loss: 3.2087 - accuracy: 0.6019

Epoch 6/100

45/45 [==============================] - 0s 2ms/step - loss: 2.6356 - accuracy: 0.6465

Epoch 7/100

45/45 [==============================] - 0s 1ms/step - loss: 2.6102 - accuracy: 0.6374

Epoch 8/100

45/45 [==============================] - 0s 1ms/step - loss: 2.2738 - accuracy: 0.6507

Epoch 9/100

45/45 [==============================] - 0s 1ms/step - loss: 2.1819 - accuracy: 0.6514

Epoch 10/100

45/45 [==============================] - 0s 2ms/step - loss: 2.0753 - accuracy: 0.6695

Epoch 11/100

45/45 [==============================] - 0s 1ms/step - loss: 2.2878 - accuracy: 0.6827

Epoch 12/100

45/45 [==============================] - 0s 1ms/step - loss: 1.9943 - accuracy: 0.6848

Epoch 13/100

45/45 [==============================] - 0s 1ms/step - loss: 1.6953 - accuracy: 0.7203

Epoch 14/100

45/45 [==============================] - 0s 1ms/step - loss: 1.5795 - accuracy: 0.7022

Epoch 15/100

45/45 [==============================] - 0s 1ms/step - loss: 2.0943 - accuracy: 0.6562

Epoch 16/100

45/45 [==============================] - 0s 1ms/step - loss: 1.6693 - accuracy: 0.7418

Epoch 17/100

45/45 [==============================] - 0s 1ms/step - loss: 1.6666 - accuracy: 0.7015

Epoch 18/100

45/45 [==============================] - 0s 1ms/step - loss: 1.3935 - accuracy: 0.7543

Epoch 19/100

45/45 [==============================] - 0s 1ms/step - loss: 2.4236 - accuracy: 0.6820

Epoch 20/100

45/45 [==============================] - 0s 1ms/step - loss: 1.8911 - accuracy: 0.7112

Epoch 21/100

45/45 [==============================] - 0s 1ms/step - loss: 1.5160 - accuracy: 0.7564

Epoch 22/100

45/45 [==============================] - 0s 1ms/step - loss: 1.7041 - accuracy: 0.7307

Epoch 23/100

45/45 [==============================] - 0s 1ms/step - loss: 1.6046 - accuracy: 0.7286

Epoch 24/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2665 - accuracy: 0.7850

Epoch 25/100

45/45 [==============================] - 0s 1ms/step - loss: 1.5802 - accuracy: 0.7509

Epoch 26/100

45/45 [==============================] - 0s 1ms/step - loss: 1.8633 - accuracy: 0.7286

Epoch 27/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1310 - accuracy: 0.7905

Epoch 28/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2302 - accuracy: 0.7683

Epoch 29/100

45/45 [==============================] - 0s 1ms/step - loss: 1.4019 - accuracy: 0.7516

Epoch 30/100

45/45 [==============================] - 0s 1ms/step - loss: 1.5928 - accuracy: 0.7530

Epoch 31/100

45/45 [==============================] - 0s 1ms/step - loss: 2.1941 - accuracy: 0.7140

Epoch 32/100

45/45 [==============================] - 0s 1ms/step - loss: 1.5500 - accuracy: 0.7509

Epoch 33/100

45/45 [==============================] - 0s 1ms/step - loss: 1.6080 - accuracy: 0.7592

Epoch 34/100

45/45 [==============================] - 0s 1ms/step - loss: 1.3664 - accuracy: 0.7683

Epoch 35/100

45/45 [==============================] - 0s 1ms/step - loss: 1.4854 - accuracy: 0.7641

Epoch 36/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1904 - accuracy: 0.7996

Epoch 37/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2169 - accuracy: 0.7738

Epoch 38/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2682 - accuracy: 0.7829

Epoch 39/100

45/45 [==============================] - 0s 1ms/step - loss: 1.5598 - accuracy: 0.7481

Epoch 40/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1654 - accuracy: 0.7926

Epoch 41/100

45/45 [==============================] - 0s 1ms/step - loss: 1.3753 - accuracy: 0.7815

Epoch 42/100

45/45 [==============================] - 0s 1ms/step - loss: 1.6003 - accuracy: 0.7495

Epoch 43/100

45/45 [==============================] - 0s 1ms/step - loss: 1.4424 - accuracy: 0.7780

Epoch 44/100

45/45 [==============================] - 0s 1ms/step - loss: 1.6023 - accuracy: 0.7585

Epoch 45/100

45/45 [==============================] - 0s 1ms/step - loss: 1.6163 - accuracy: 0.7453

Epoch 46/100

45/45 [==============================] - 0s 1ms/step - loss: 1.5185 - accuracy: 0.7641

Epoch 47/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9921 - accuracy: 0.8219

Epoch 48/100

45/45 [==============================] - 0s 2ms/step - loss: 1.2613 - accuracy: 0.7961

Epoch 49/100

45/45 [==============================] - 0s 1ms/step - loss: 1.3347 - accuracy: 0.7940

Epoch 50/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0804 - accuracy: 0.8156

Epoch 51/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9667 - accuracy: 0.8086

Epoch 52/100

45/45 [==============================] - 0s 1ms/step - loss: 1.3185 - accuracy: 0.7933

Epoch 53/100

45/45 [==============================] - 0s 2ms/step - loss: 1.3824 - accuracy: 0.7759

Epoch 54/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1561 - accuracy: 0.7982

Epoch 55/100

45/45 [==============================] - 0s 1ms/step - loss: 1.8855 - accuracy: 0.7467

Epoch 56/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1518 - accuracy: 0.8017

Epoch 57/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2565 - accuracy: 0.7954

Epoch 58/100

45/45 [==============================] - 0s 1ms/step - loss: 1.3624 - accuracy: 0.7752

Epoch 59/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2632 - accuracy: 0.7787

Epoch 60/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0917 - accuracy: 0.8135

Epoch 61/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0855 - accuracy: 0.8010

Epoch 62/100

45/45 [==============================] - 0s 1ms/step - loss: 1.3113 - accuracy: 0.7891

Epoch 63/100

45/45 [==============================] - 0s 1ms/step - loss: 1.4222 - accuracy: 0.7745

Epoch 64/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0420 - accuracy: 0.8156

Epoch 65/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9924 - accuracy: 0.8170

Epoch 66/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1273 - accuracy: 0.8072

Epoch 67/100

45/45 [==============================] - 0s 1ms/step - loss: 1.4507 - accuracy: 0.7947

Epoch 68/100

45/45 [==============================] - 0s 1ms/step - loss: 1.7111 - accuracy: 0.7599

Epoch 69/100

45/45 [==============================] - 0s 2ms/step - loss: 1.5063 - accuracy: 0.7857

Epoch 70/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0996 - accuracy: 0.8128

Epoch 71/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9425 - accuracy: 0.8267

Epoch 72/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0987 - accuracy: 0.8260

Epoch 73/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2385 - accuracy: 0.8024

Epoch 74/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9279 - accuracy: 0.8358

Epoch 75/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9507 - accuracy: 0.8274

Epoch 76/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1579 - accuracy: 0.7947

Epoch 77/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0719 - accuracy: 0.8184

Epoch 78/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9553 - accuracy: 0.8219

Epoch 79/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9058 - accuracy: 0.8365

Epoch 80/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2656 - accuracy: 0.7926

Epoch 81/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1576 - accuracy: 0.8079

Epoch 82/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1354 - accuracy: 0.8156

Epoch 83/100

45/45 [==============================] - 0s 1ms/step - loss: 1.2931 - accuracy: 0.8024

Epoch 84/100

45/45 [==============================] - 0s 2ms/step - loss: 1.0064 - accuracy: 0.8184

Epoch 85/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9360 - accuracy: 0.8462

Epoch 86/100

45/45 [==============================] - 0s 1ms/step - loss: 0.8723 - accuracy: 0.8239

Epoch 87/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1157 - accuracy: 0.8281

Epoch 88/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0438 - accuracy: 0.8288

Epoch 89/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1266 - accuracy: 0.8170

Epoch 90/100

45/45 [==============================] - 0s 1ms/step - loss: 0.7459 - accuracy: 0.8532

Epoch 91/100

45/45 [==============================] - 0s 1ms/step - loss: 1.1049 - accuracy: 0.8114

Epoch 92/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0279 - accuracy: 0.8323

Epoch 93/100

45/45 [==============================] - 0s 1ms/step - loss: 0.9190 - accuracy: 0.8365

Epoch 94/100

45/45 [==============================] - 0s 1ms/step - loss: 0.7037 - accuracy: 0.8525

Epoch 95/100

45/45 [==============================] - 0s 1ms/step - loss: 0.7925 - accuracy: 0.8379

Epoch 96/100

45/45 [==============================] - 0s 1ms/step - loss: 1.0766 - accuracy: 0.8212

Epoch 97/100

45/45 [==============================] - 0s 1ms/step - loss: 0.7443 - accuracy: 0.8483

Epoch 98/100

45/45 [==============================] - 0s 1ms/step - loss: 0.8555 - accuracy: 0.8455

Epoch 99/100

45/45 [==============================] - 0s 1ms/step - loss: 0.7401 - accuracy: 0.8587

Epoch 100/100

45/45 [==============================] - 0s 1ms/step - loss: 0.7517 - accuracy: 0.8615

12/12 - 0s - loss: 2.0868 - accuracy: 0.7278 - 107ms/epoch - 9ms/step

Test accuracy: 0.7277777791023254