Computer Vision Assignment 5

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```
[27]: import matplotlib.pyplot as plt
      import numpy as np

      import tensorflow as tf
      # from tensorflow.keras.datassets import mnist from
      tensorflow.keras.models import Sequential from
      tensorflow.keras.layers import Dense, Dropout, Conv2D,
      MaxPooling2D,␣
        ↪Flatten, AveragePooling2D, ZeroPadding2D from
      tensorflow.keras.optimizers import
      SGD,Adam,Nadam,AdamW from tensorflow import keras
      from tensorflow.keras import layers
from keras_tuner import RandomSearch, GridSearch, BayesianOptimization
```

```
[2]: print(np.__version__)
```

```
1.24.4
```

```
[3]: from tensorflow.keras.datasets import mnist
```

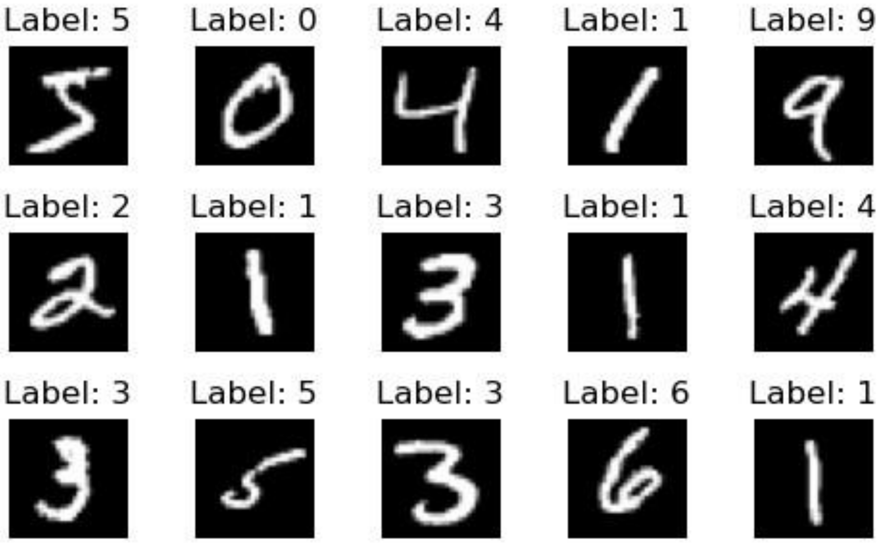
```
[4]: (train_images, train_labels), (test_images, test_labels) =
mnist.load_data()
```

```
[5]: train_images.shape, train_labels.shape, test_images.shape,
test_labels.shape
```

```
[5]: ((60000, 28, 28), (60000,), (10000, 28, 28), (10000,))
```

```
[6]: plt.figure(figsize=(5,5))
     for i in range(15):
         plt.subplot(5, 5,  +1)
         plt.imshow(train_images[i], cmap='gray')
         plt.title(f"Label: {train_labels[i]}")
         plt.axis('off')

     plt.tight_layout()
     plt.show()
```



[7]:

```
X_trn = train_images[:1000]
y_trn = train_labels[:1000]
X_tst = test_images[:500]
y_tst = test_labels[:500]
```

[9]:

```
X_trn.shape,y_trn.shape,X_tst.shape,y_tst.shape
```

[9]:

```
((1000, 28, 28), (1000,), (500, 28, 28), (500,))
```

1) . Implement convolutional neural network (CNN) models with following specifications using TensorFlow for classifying the MNIST dataset. Train the model on the MNIST training set and evaluate its performance on the test set. Write modularized code and call it 3 times and compute the mean of test accuracy for each of the following 3 Sequential models.

a. Model-1: Add a convolution layer with 32 3 × 3 filters with stride 2 and relu activation. Add a maxpooling layer with kernel size 2 × 2 with stride 1. Add a convolution layer with 16 4 × 4 filters with stride 2 and relu activation. Add a maxpooling layer with kernel size 4 × 4

with stride 2. Flatten the output and add a fully connected layer with 8 neurons with relu activation. Add a fully connected layer with 10 neurons and softmax activation. Use Adam optimizer with batch size 128, learning rate 0.01 and epochs set to 5.

[29]:

```
 model = keras.Sequential() model.add(Conv2D(32, (3,
3), strides=(2, 2), activation="relu",␣
 ↪input_shape=(28,28,1)))
model.add(MaxPooling2D(pool_size=(2, 2), strides=(1,
1)))
```

```
model.add(Conv2D(16, (4, 4), strides=(2, 2), activation="relu"))
model.add(MaxPooling2D(pool_size=(4, 4), strides=(2, 2)))
model.add(Flatten())

model.add(layers.Dense(8, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))

model.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
Layer (type)                Output Shape              Param #
=================================================================
 conv2d_9 (Conv2D)         (None, 13, 13, 32)        320
                                                      0
 max_pooling2d_6 (MaxPoolin (None, 12, 12,
 32) g2D)

 conv2d_10 (Conv2D)         (None, 5, 5, 16)          8208
                                                      0
 max_pooling2d_7 (MaxPoolin (None, 1, 1,
 16) g2D)

 flatten_4 (Flatten)         (None, 16)               0

 dense_8 (Dense)             (None, 8)                136

 dense_9 (Dense)             (None, 10)               90
=================================================================
Total params: 8754 (34.20 KB)
Trainable params: 8754 (34.20 KB)
Non-trainable params: 0 (0.00 Byte)

_________________________________________________________________
```

```
[30]: # Number of times to call the model
num_calls = 3
# List to store test
accuracies test_accuracies
= [] for i in
range(num_calls):
print("step: ",i+1)
    # Define, compile, and train the model
    adam_optimizer = Adam(learning_rate=0.01)
    model.compile(optimizer=adam_optimizer,␣
 ↪loss='sparse_categorical_crossentropy', metrics=['accuracy'])
    model.fit(X_trn, y_trn, batch_size=128, epochs=5)
    # Evaluate the model on test data
    _, test_accuracy = model.evaluate(X_tst, y_tst,verbose=0)
    # Append test accuracy to the list
    test_accuracies.append(test_accuracy)
    # Compute the mean of test accuracies
mean_test_accuracy = np.mean(test_accuracies)
print("Mean Test Accuracy:", mean_test_accuracy)
```

```
step: 1
Epoch 1/5
8/8 [==============================] - 1s 20ms/step - loss: 22.3398 -
accuracy:
0.1000
Epoch 2/5
8/8 [==============================] - 0s 20ms/step - loss: 2.7119 -
accuracy:
0.0850
Epoch 3/5
8/8 [==============================] - 0s 21ms/step - loss: 2.3068 -
accuracy:
0.1160
Epoch 4/5
8/8 [==============================] - 0s 19ms/step - loss: 2.3055 -
accuracy:
0.1140
Epoch 5/5
8/8 [==============================] - 0s 18ms/step - loss: 2.3037 -
accuracy:
0.1170
step: 2
Epoch 1/5
8/8 [==============================] - 1s 19ms/step - loss: 2.3030 -
accuracy:
0.1160
Epoch 2/5
8/8 [==============================] - 0s 20ms/step - loss: 2.3146 -
accuracy:
0.1220
Epoch 3/5
8/8 [==============================] - 0s 17ms/step - loss: 2.2915 -
accuracy:
0.1620
Epoch 4/5
8/8 [==============================] - 0s 16ms/step - loss: 2.1785 -
accuracy:
```

```
0.2170
Epoch 5/5
8/8 [==============================] - 0s 15ms/step - loss: 2.1038 -
accuracy:
0.2200
step: 3
Epoch 1/5
8/8 [==============================] - 1s 18ms/step - loss: 2.5215 -
accuracy:
0.1560
Epoch 2/5
8/8 [==============================] - 0s 17ms/step - loss: 2.3026 -
accuracy:
0.1160
Epoch 3/5
8/8 [==============================] - 0s 16ms/step - loss: 2.3027 -
accuracy: 0.1170
Epoch 4/5
8/8 [==============================] - 0s 18ms/step - loss: 2.3020 -
accuracy:
0.1170
Epoch 5/5
8/8 [==============================] - 0s 17ms/step - loss: 2.3015 -
accuracy:
0.1170
Mean Test Accuracy: 0.13933333257834116
```

b. Model-2: Add a convolution layer with 32 3 × 3 filters with stride 2 and relu activation. Add an average pooling layer with kernel size 2 × 2 with stride 1. Add a convolution layer with 16 4 × 4 filters with stride 2 and relu activation. Add an average pooling layer with kernel size 4 × 4 with stride 2. Flatten the output and add a fully connected layer with 8 neurons with relu activation. Add a fully connected layer with 10 neurons and softmax activation. Use Adam optimizer with batch size 128, learning rate 0.01 and epochs set to 5.

[31]:

```
model = keras.Sequential()
model.add(Conv2D(32,  3, 3), strides=(2, 2), activation="relu",␣
 ↪input_shape=(28,28,1)))
model.add(AveragePooling2D(pool_size=(2, 2), strides=(1, 1)))

model.add(Conv2D(16,  4, 4), strides=(2, 2), activation="relu"))
model.add(AveragePooling2D(pool_size=(4, 4), strides=(2, 2)))

model.add(Flatten())

model.add(layers.Dense(8, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))

model.summary()
```

```
Model: "sequential_6"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_11 (Conv2D)          (None, 13, 13, 32)        320

 average_pooling2d_2 (Avera  (None, 12, 12, 32)        0
 gePooling2D)

 conv2d_12 (Conv2D)          (None, 5, 5, 16)          8208

 average_pooling2d_3 (Avera  (None, 1, 1, 16)          0
 gePooling2D)

 flatten_5 (Flatten)         (None, 16)                0

 dense_10 (Dense)            (None, 8)                 136
dense_11 (Dense)             (None, 10)                 90

=================================================================
Total params: 8754 (34.20 KB)
Trainable params: 8754 (34.20 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

[32]:

```
# Number of times to call the model
num_calls = 3
# List to store test
accuracies test_accuracies
= [] for i in
range(num_calls):
    print("step: ",i+1)
    # Define, compile, and train the model
    adam_optimizer = Adam(learning_rate=0.01)
    model.compile(optimizer=adam_optimizer,␣
 ↪loss='sparse_categorical_crossentropy', metrics=['accuracy'])
    model.fit(X_trn, y_trn, batch_size=128, epochs=5)
    # Evaluate the model on test data
    _, test_accuracy = model.evaluate(X_tst, y_tst,verbose=0)
    # Append test accuracy to the list
    test_accuracies.append(test_accuracy)
# Compute the mean of test accuracies
mean_test_accuracy =
np.mean(test_accuracies) print("Mean Test
Accuracy:", mean_test_accuracy)
```

```
step: 1
Epoch 1/5
8/8 [==============================] - 1s 13ms/step - loss: 8.6303 -
accuracy:
0.1030
Epoch 2/5
8/8 [==============================] - 0s 12ms/step - loss: 2.3811 -
accuracy:
0.1010
Epoch 3/5
8/8 [==============================] - 0s 12ms/step - loss: 2.3053 -
accuracy:
0.1010
Epoch 4/5
8/8 [==============================] - 0s 12ms/step - loss: 2.3025 -
accuracy:
0.0990
Epoch 5/5
8/8 [==============================] - 0s 12ms/step - loss: 2.3019 -
accuracy:
0.1030
step: 2
Epoch 1/5
8/8 [==============================] - 1s 12ms/step - loss: 2.3015 -
accuracy:
0.1170
Epoch 2/5
8/8 [==============================] - 0s 12ms/step - loss: 2.2998 -
accuracy:
0.1170
Epoch 3/5
```

```
8/8 [==============================] - 0s 12ms/step - loss: 2.2988 -
accuracy:
0.1170
Epoch 4/5
8/8 [==============================] - 0s 12ms/step - loss: 2.2986 -
accuracy:
0.1170
Epoch 5/5
8/8 [==============================] - 0s 12ms/step - loss: 2.2987 -
accuracy:
0.1170
step: 3
Epoch 1/5
8/8 [==============================] - 1s 14ms/step - loss: 2.2991 -
accuracy:
0.1170
Epoch 2/5
8/8 [==============================] - 0s 12ms/step - loss: 2.2987 -
accuracy:
0.1170
Epoch 3/5
8/8 [==============================] - 0s 12ms/step - loss: 2.2985 -
accuracy:
0.1170
Epoch 4/5
8/8 [==============================] - 0s 12ms/step - loss: 2.2986 -
accuracy:
0.1170
Epoch 5/5
8/8 [==============================] - 0s 13ms/step - loss: 2.2987 -
accuracy:
0.1050
Mean Test Accuracy: 0.10999999940395355
```

c. Model-3: Add a convolution layer with 32 3 × 3 filters with stride 2, relu activation and same padding. Add a maxpooling layer with kernel size 2 × 2 with stride 1. Add a convolution layer with 16 4 × 4 filters with stride 2 and relu activation. Add a maxpooling layer with kernel size 4 × 4 with stride 2. Flatten the output and add a fully connected layer with 8 neurons with relu activation. Add a fully connected layer with 10 neurons and softmax activation. Use Adam optimizer with batch size 128, learning rate 0.01 and epochs set to 5.

```
[33]: model = keras.Sequential() model.add(Conv2D(32, (3, 3), strides=(2,
      2), activation="relu", padding="same",␣
       ↪input_shape=(28,28,1)))
      model.add(MaxPooling2D(pool_size=(2, 2), strides=(1,
      1)))
```

```
model.add(Conv2D(16, (4, 4), strides=(2, 2), activation="relu"))

model.add(MaxPooling2D(pool_size=(4, 4), strides=(2, 2)))

model.add(Flatten())

model.add(layers.Dense(8, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))
```

```
model.summary()
```

```
Model: "sequential_7"
_________________________________________________________________
Layer (type)                Output Shape              Param #
=================================================================
 conv2d_13 (Conv2D)         (None, 14, 14, 32)        320

                                                      0
 max_pooling2d_8 (MaxPoolin (None, 13, 13,
 32) g2D)

 conv2d_14 (Conv2D)         (None, 5, 5, 16)          8208

                                                      0
 max_pooling2d_9 (MaxPoolin (None, 1, 1,
 16) g2D)

 flatten_6 (Flatten)         (None, 16)               0

 dense_12 (Dense)            (None, 8)                136

 dense_13 (Dense)            (None, 10)               90

=================================================================
Total params: 8754 (34.20 KB)
Trainable params: 8754 (34.20 KB)
Non-trainable params: 0 (0.00 Byte)

_________________________________________________________________
```

```
[34]: # Number of times to call the model
      num_calls = 3
      # List to store test
      accuracies test_accuracies
      = [] for i in
      range(num_calls):
      print("step: ",i+1)
          # Define, compile, and train the model
          adam_optimizer = Adam(learning_rate=0.01)
          model.compile(optimizer=adam_optimizer,␣
       ↪loss='sparse_categorical_crossentropy', metrics=['accuracy'])
          model.fit(X_trn, y_trn, batch_size=128, epochs=5)
          # Evaluate the model on test data
          _, test_accuracy = model.evaluate(X_tst, y_tst,verbose=0)
          # Append test accuracy to the list
          test_accuracies.append(test_accuracy)
          # Compute the mean of test accuracies
      mean_test_accuracy = np.mean(test_accuracies)
      print("Mean Test Accuracy:", mean_test_accuracy)
```

```
 step: 1
Epoch 1/5
8/8 [==============================] - 1s 19ms/step - loss: 29.0523 -
accuracy:
0.1140
Epoch 2/5
8/8 [==============================] - 0s 19ms/step - loss: 2.3447 -
accuracy:
0.1270
Epoch 3/5
8/8 [==============================] - 0s 19ms/step - loss: 2.3045 -
accuracy:
0.1160
Epoch 4/5
8/8 [==============================] - 0s 18ms/step - loss: 2.3039 -
accuracy:
0.1160
Epoch 5/5
8/8 [==============================] - 0s 19ms/step - loss: 2.3033 -
accuracy:
0.1160
step: 2
Epoch 1/5
8/8 [==============================] - 1s 19ms/step - loss: 2.3020 -
accuracy:
0.1090
Epoch 2/5
8/8 [==============================] - 0s 18ms/step - loss: 2.2997 -
accuracy:
0.1160
Epoch 3/5
8/8 [==============================] - 0s 18ms/step - loss: 2.2990 -
accuracy:
0.1160
Epoch 4/5
```

```
8/8 [==============================] - 0s 18ms/step - loss: 2.2988 -
accuracy:
0.1070
Epoch 5/5
8/8 [==============================] - 0s 19ms/step - loss: 2.2985 -
accuracy:
0.1060
step: 3
Epoch 1/5
8/8 [==============================] - 1s 18ms/step - loss: 2.2995 -
accuracy:
0.1170
Epoch 2/5
8/8 [==============================] - 0s 20ms/step - loss: 2.2986 -
accuracy:
0.1170
Epoch 3/5
8/8 [==============================] - 0s 19ms/step - loss: 2.2986 -
accuracy:
0.1170
Epoch 4/5
8/8 [==============================] - 0s 18ms/step - loss: 2.2985 -
accuracy:
0.1170
Epoch 5/5
8/8 [==============================] - 0s 20ms/step - loss: 2.2986 -
accuracy: 0.1170
Mean Test Accuracy: 0.10999999940395355
```

d. Model-4: Add a convolution layer with 32 3 × 3 filters with stride 2, relu activation and zero padding. Add a maxpooling layer with kernel size 2 × 2 with stride 1. Add a convolution layer with 16 4 × 4 filters with stride 2, relu activation and zero padding. Add a maxpooling layer with kernel size 4 × 4 with stride 2. Flatten the output and add a fully connected layer with 8 neurons with relu activation. Add a fully connected layer with 10 neurons and softmax -activation. Use Adam optimizer with batch size 128, learning rate 0.01 and epochs set to 5.

[44]:

```
model = keras.Sequential()
model.add(Conv2D(32,  3, 3), strides=(2, 2), activation="relu",␣
 ↪input_shape=(28,28,1)))
model.add(ZeroPadding2D(padding=(1, 1)))
model.add(MaxPooling2D(pool_size=(2, 2), strides=(1, 1)))

model.add(Conv2D(16,  4, 4), strides=(2, 2), activation="relu"))
model.add(ZeroPadding2D(padding=(1, 1)))
model.add(MaxPooling2D(pool_size=(4, 4), strides=(2, 2)))

model.add(Flatten())

model.add(layers.Dense(8, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))

model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                Output Shape              Param #
=================================================================
 conv2d_3 (Conv2D)          (None, 13, 13, 32)        320

                                                      0
 zero_padding2d (ZeroPaddin (None, 15, 15,
 32) g2D)

                                                      0
 max_pooling2d_2 (MaxPoolin (None, 14, 14,
 32) g2D)

 conv2d_4 (Conv2D)          (None, 6, 6, 16)          8208

                                                      0
 zero_padding2d_1 (ZeroPadd (None, 8, 8,
 16) ing2D)

                                                      0
 max_pooling2d_3 (MaxPoolin (None, 3, 3,
 16) g2D)

 flatten_1 (Flatten)         (None, 144)              0
 dense_2 (Dense)             (None, 8)                1160

 dense_3 (Dense)             (None, 10)               90
=================================================================
Total params: 9778 (38.20 KB)
Trainable params: 9778 (38.20 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
[36]: # Number of times to call the model
      num_calls = 3
      # List to store test
      accuracies test_accuracies
      = [] for i in
      range(num_calls):
          print("step: ",i+1)
          # Define, compile, and train the model
          adam_optimizer = Adam(learning_rate=0.01)
          model.compile(optimizer=adam_optimizer,␣
       ↪loss='sparse_categorical_crossentropy', metrics=['accuracy'])
          model.fit(X_trn, y_trn, batch_size=128, epochs=5)
          # Evaluate the model on test data
          _, test_accuracy = model.evaluate(X_tst, y_tst,verbose=0)
          # Append test accuracy to the list
          test_accuracies.append(test_accuracy)
      # Compute the mean of test accuracies
      mean_test_accuracy =
      np.mean(test_accuracies) print("Mean Test
      Accuracy:", mean_test_accuracy)
```

```
step: 1
Epoch 1/5
8/8 [==============================] - 1s 26ms/step - loss: 21.0322 -
accuracy:
0.0950
Epoch 2/5
8/8 [==============================] - 0s 25ms/step - loss: 2.3042 -
accuracy:
0.1150
Epoch 3/5
8/8 [==============================] - 0s 24ms/step - loss: 2.3012 -
accuracy:
0.1160
Epoch 4/5
8/8 [==============================] - 0s 25ms/step - loss: 2.3002 -
accuracy:
0.1160
Epoch 5/5
8/8 [==============================] - 0s 24ms/step - loss: 2.2995 -
accuracy:
0.1160
step: 2
Epoch 1/5
```

```
8/8 [==============================] - 1s 24ms/step - loss: 2.3000 -
accuracy:
0.1090
Epoch 2/5
8/8 [==============================] - 0s 21ms/step - loss: 2.2991 -
accuracy:
0.1120
Epoch 3/5
8/8 [==============================] - 0s 22ms/step - loss: 2.2987 -
accuracy:
0.1160
Epoch 4/5
8/8 [==============================] - 0s 22ms/step - loss: 2.2987 -
accuracy:
0.1130
Epoch 5/5
8/8 [==============================] - 0s 24ms/step - loss: 2.2985 -
accuracy:
0.1030
step: 3
Epoch 1/5
8/8 [==============================] - 1s 22ms/step - loss: 2.2995 -
accuracy:
0.1090
Epoch 2/5
8/8 [==============================] - 0s 22ms/step - loss: 2.2989 -
accuracy:
0.1170
Epoch 3/5
8/8 [==============================] - 0s 22ms/step - loss: 2.2984 -
accuracy:
0.1170
Epoch 4/5
8/8 [==============================] - 0s 24ms/step - loss: 2.2985 -
accuracy:
0.1140
Epoch 5/5
8/8 [==============================] - 0s 23ms/step - loss: 2.2985 -
accuracy:
0.1100
Mean Test Accuracy: 0.12200000137090683
```

2. What have you observed from Question 1. Rewrite the Question-1 using kerastuner to select the best hyperparameters.

```
[38]: def build_model(hp): hp_neurons = hp.Int('neurons', min_value=32,
          max_value=128,   step=32)   hp_filters   =   hp.Int('filters',
          min_value=32, max_value=512, step=32) model = Sequential()
          model.add(Conv2D(filters=hp_filters, kernel_size=(3, 3),
          strides=(2,␣
       ↪2), activation='relu',input_shape=(28,28,1)))
          model.add(MaxPooling2D(pool_size=(2, 2), strides=(1, 1)))
          model.add(Conv2D(16, kernel_size=(4, 4), strides=(2, 2),␣
       ↪activation='relu'))
          model.add(MaxPooling2D(pool_size=(4, 4),
          strides=(2, 2))) model.add(Flatten())
          model.add(Dense(units=hp_neurons,
          activation='relu')) model.add(Dense(10,
          activation='softmax'))
          # Tune learning rate and batch
          size
          hp_learning_rate = hp.Choice('learning_rate', values=[0.1, 0.01, 0.15])
          hp_batch_size = hp.Choice('batch_size', values=[4, 8, 16])
          # Compile the model
          model.compile(optimizer=keras.optimizers.
       ↪SGD(learning_rate=hp_learning_rate),
          loss='sparse_categorical_crossentropy',
          metrics=['accuracy'])
          return model
```

```
[40]: # Configure the tuner
      tuner = RandomSearch(
      build_model,
      objective='val_accuracy',
      max_trials=3,
      executions_per_trial=1,
      directory='keras_tuner_a',
      project_name='mnist_hyperparameters'
      )
      hp_batch_size = tuner.oracle.get_space()['batch_size']
      tuner.search(X_trn, y_trn, epochs=5, validation_data=(X_tst, y_tst),␣
       ↪batch_size=hp_batch_size)
```

```
Trial 3 Complete [00h 00m 06s]
val_accuracy: 0.1340000033378601

Best val_accuracy So Far: 0.1340000033378601
Total elapsed time: 00h 00m 30s
```

```
[41]:  # Get the best hyperparameters best_hps =
      tuner.get_best_hyperparameters(num_trials=1)[0] best_neurons =
best_hps.get('neurons') best_filters = best_hps.get('filters')
best_learning_rate = best_hps.get('learning_rate')
best_batch_size = best_hps.get('batch_size') print(f"Best number
of neurons and fillters: {best_neurons,best_filters}")
print(f"Best learning rate: {best_learning_rate}") print(f"Best
batch size: {best_batch_size}")
# Get the best model
best_model = tuner.get_best_models(num_models=1)[0]
# Evaluate the best model
loss, accuracy = best_model.evaluate(X_tst, y_tst)
print(f"Test accuracy of the best model: {accuracy}")
```

```
Best number of neurons and fillters: (96, 96)
Best learning rate: 0.01
Best batch size: 8
WARNING:tensorflow:From
C:\Users\Admin\AppData\Roaming\Python\Python39\sitepackages\keras\src
\saving\legacy\save.py:538: The name tf.train.NewCheckpointReader is
deprecated. Please use tf.compat.v1.train.NewCheckpointReader
instead.

16/16 [==============================] - 0s 5ms/step - loss: 2.3005 -
accuracy:
0.1340
Test accuracy of the best model: 0.1340000033378601
```

[42]:

```
best_model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)            (None, 13, 13, 96)        960

                                                      0
 max_pooling2d (MaxPooling2 (None, 12,
 12, 96) D)

 conv2d_1 (Conv2D)          (None, 5, 5, 16)          24592

                                                      0
 max_pooling2d_1 (MaxPoolin (None, 1, 1,
 16) g2D)

 flatten (Flatten)           (None, 16)               0

 dense (Dense)               (None, 96)               1632

 dense_1 (Dense)             (None, 10)               970
```

```
=================================================================
Total params: 28154 (109.98 KB)
Trainable params: 28154 (109.98 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```