Assignment 05

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Question 01

Download and extract the flower image dataset from https://www.kaggle.com/alxmamaev/flowers-recognition.

In [ ]:
```
# Download the dataset
import kagglehub

# Download latest version
path = kagglehub.dataset_download("alxmamaev/flowers-recognition")

path=path+'/flowers'

print("Path to dataset files:", path)
```

```
Downloading from https://www.kaggle.com/api/v1/datasets/download/alxmamaev/flowers-recognition?dataset_version_number=2...
100%|██████████| 225M/225M [00:12<00:00, 19.3MB/s]
Extracting files...
Path to dataset files: /root/.cache/kagglehub/datasets/alxmamaev/flowers-recognition/versions/2/flowers
```

In [ ]:
```
import os

os.listdir(path)
```

Out[ ]:
```
['sunflower', 'daisy', 'rose', 'tulip', 'dandelion']
```

Question 02

The dataset contains five classes of flower images of variable size namely chamomile, tulip, rose, sunflower, and dandelion. Resize all images to 80 × 80 pixels and convert all colour images to grey images.

In [ ]:

```
# Image Parameters
N_CLASSES = 5
IMG_SIZE = 80
DIR=path
FLOWER_DAISY_DIR=path+'/daisy'
FLOWER_SUNFLOWER_DIR=path+'/sunflower'
FLOWER_TULIP_DIR=path+'/tulip'
FLOWER_DANDI_DIR=path+'/dandelion'
FLOWER_ROSE_DIR=path+'/rose'
```

In [ ]:

```
X=[]  # Contains the image
Y=[]  # Contains the labels
```

In [ ]:

```
!pip install tqdm
```

```
Requirement already satisfied: tqdm in /usr/local/lib/python3.10/dist-packages (4.66.6)
```

In [ ]:

```
from tqdm import tqdm
from PIL import Image
import numpy as np

def train_data(flower_type,path_dir):
  for img in tqdm(os.listdir(path_dir)):
        label=flower_type
        path = os.path.join(path_dir,img)
        img_array = Image.open(path).convert('L')
        img_array = img_array.resize((IMG_SIZE,IMG_SIZE))
        img_array = np.array(img_array)
        X.append(np.array(img_array))
        Y.append(str(label))
```

In [ ]:

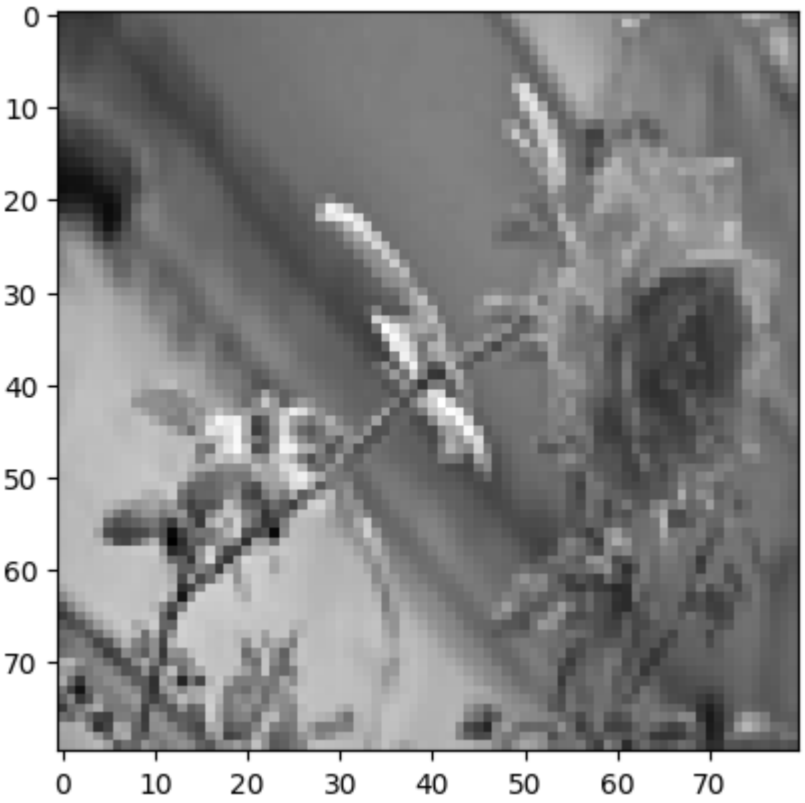
```
train_data('Daisy',FLOWER_DAISY_DIR)
train_data('Sunflower',FLOWER_SUNFLOWER_DIR)
train_data('Tulip',FLOWER_TULIP_DIR)
train_data('Dandelion',FLOWER_DANDI_DIR)
train_data('Rose',FLOWER_ROSE_DIR)
```

```
100%|██████████| 764/764 [00:01<00:00, 454.01it/s]
100%|██████████| 733/733 [00:01<00:00, 463.99it/s]
100%|██████████| 984/984 [00:02<00:00, 406.15it/s]
100%|██████████| 1052/1052 [00:02<00:00, 395.62it/s]
100%|██████████| 784/784 [00:01<00:00, 562.45it/s]
```

```
In [ ]: print(f"The number of samples in the dataset is {len(X)}")
```

```
The number of samples in the dataset is 4317
```

```
In [ ]: import matplotlib.pyplot as plt

        plt.imshow(X[4235],cmap='gray')
        plt.show()

        print(Y[4235])
```



```
Rose
```

Question 03

Randomly shuffle all images to create training, test set with ratio 90: 10, respectively. (Reduce the training size by 1/5, if computation resources are limited.)

```
In [ ]: from sklearn.model_selection import train_test_split

        X_train,X_rem,y_train,y_rem = train_test_split(X,Y,test_size=0.2,random_state=7)
```

```
X_test,X_val,y_test,y_val=train_test_split(X_rem,y_rem,test_size=0.5,random_state=7)

print(len(X_train))
print(len(y_train))
print(len(X_val))
print(len(y_val))
print(len(X_test))
print(len(y_test))
```

```
3453
3453
432
432
432
432
```

In [ ]:

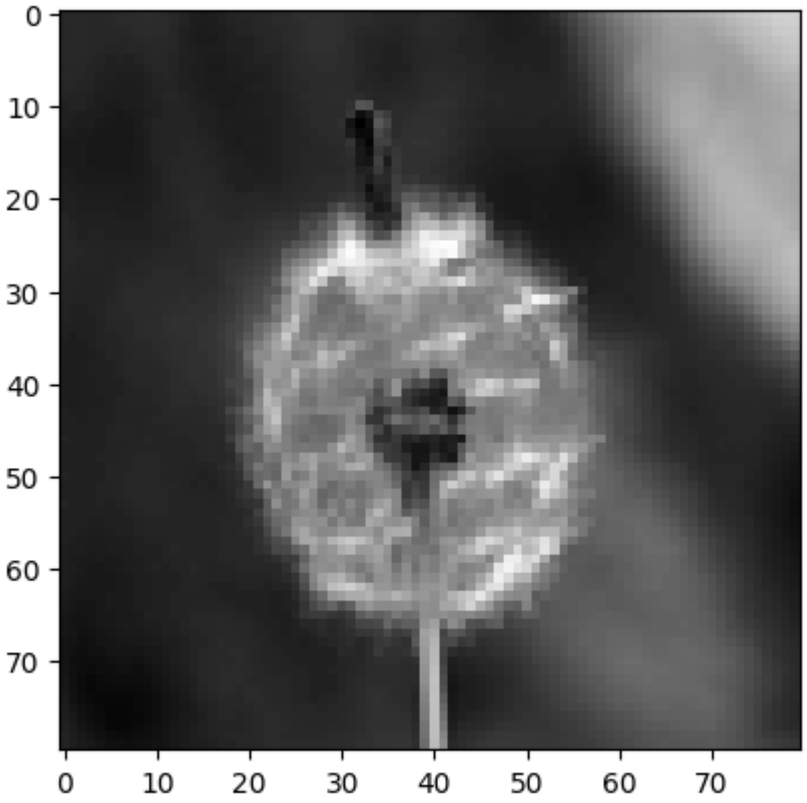
```
# Convert to np array for tf processing
X_train=np.array(X_train)
X_test=np.array(X_test)
X_val=np.array(X_val)
y_train=np.array(y_train)
y_val=np.array(y_val)
y_test=np.array(y_test)

# Reshape
X_train = X_train.reshape(-1,IMG_SIZE,IMG_SIZE,1)
X_test = X_test.reshape(-1,IMG_SIZE,IMG_SIZE,1)
X_val = X_val.reshape(-1,IMG_SIZE,IMG_SIZE,1)
```

In [ ]:

```
# One hot encode the labels
from sklearn.preprocessing import LabelEncoder

label_encoder = LabelEncoder()

label_encoder.fit(['Daisy','Sunflower','Tulip','Dandelion','Rose'])

y_train = label_encoder.transform(y_train)
y_test = label_encoder.transform(y_test)
y_val = label_encoder.transform(y_val)

import pandas as pd

y_train = pd.get_dummies(y_train,dtype='int').to_numpy()
y_test = pd.get_dummies(y_test,dtype='int').to_numpy()
y_val = pd.get_dummies(y_val,dtype='int').to_numpy()
```

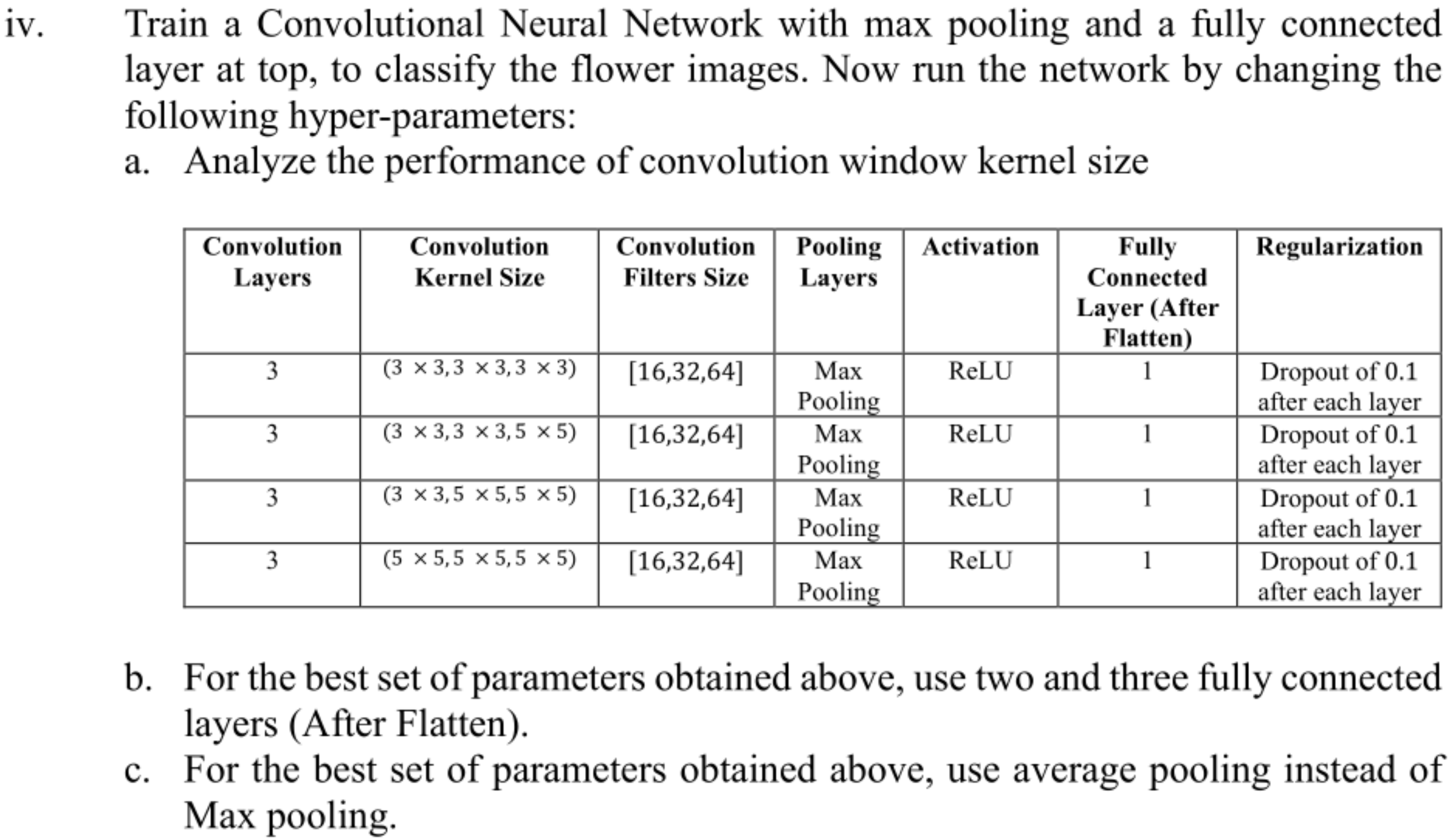
In [ ]:

```
import matplotlib.pyplot as plt

plt.imshow(X_train[135],cmap='gray')
plt.show()

print(y_train[135])
```



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

Question 04



iv. Train a Convolutional Neural Network with max pooling and a fully connected layer at top, to classify the flower images. Now run the network by changing the following hyper-parameters:

a. Analyze the performance of convolution window kernel size

Convolution Layers	Convolution Kernel Size	Convolution Filters Size	Pooling Layers	Activation	Fully Connected Layer (After Flatten)	Regularization
3	(3 × 3,3 × 3,3 × 3)	[16,32,64]	Max Pooling	ReLU	1	Dropout of 0.1 after each layer
3	(3 × 3,3 × 3,5 × 5)	[16,32,64]	Max Pooling	ReLU	1	Dropout of 0.1 after each layer
3	(3 × 3,5 × 5,5 × 5)	[16,32,64]	Max Pooling	ReLU	1	Dropout of 0.1 after each layer
3	(5 × 5,5 × 5,5 × 5)	[16,32,64]	Max Pooling	ReLU	1	Dropout of 0.1 after each layer

b. For the best set of parameters obtained above, use two and three fully connected layers (After Flatten).

c. For the best set of parameters obtained above, use average pooling instead of Max pooling.

In [ ]:
```
# Import necessary libraries
import tensorflow as tf
```

In [ ]:
```
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Input, Conv2D, MaxPool2D, AveragePooling2D, Flatten, Dense, \
                            Dropout, BatchNormalization, LeakyReLU

from tensorflow.keras.metrics import F1Score
from tensorflow.math import confusion_matrix
from tensorflow.keras.losses import CategoricalCrossentropy
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.optimizers import Adam
```

In [ ]:
```
# Plot the accuracy and loss metrics of the model
```

```
def plot_model_metrics(
    history: 'tf.keras.callbacks.history',
    kernels: 'list(tuple(int,int))',
    filters: 'list(int)',
    activation_func: 'str',
    pool: 'str',
    num_dense_layers: 'int'
):
  plt.plot(history.history['loss'],label='Training loss')
  plt.plot(history.history['val_loss'],label='Validation loss')

  plt.ylabel('Loss')
  plt.xlabel('Epochs')
  plt.legend()
  plt.title(f"Filters: {filters}, Kernels: {kernels}, {pool} pool, {activation_func} activation function, No. of dense layers a

  plt.show()

  plt.plot(history.history['accuracy'],label='Training accuracy')
  plt.plot(history.history['val_accuracy'],label='Validation accuracy')
  plt.ylabel('Accuracy')
  plt.xlabel('Epochs')
  plt.legend()
  plt.title(f"Filters: {filters}, Kernels: {kernels}, {pool} pool, {activation_func} activation function, No. of dense layers a

  plt.show()
```

In [ ]:

```
# Plot the confusion matrix of the model
from sklearn.metrics import ConfusionMatrixDisplay

def plot_confusion_matrix(
  y_test: 'list(int)',
  y_pred: 'list(int)'
):
  matrix = confusion_matrix(y_test,y_pred)
 # matrix = matrix.numpy()
  disp = ConfusionMatrixDisplay(confusion_matrix=matrix,display_labels=label_encoder.classes_)
  disp.plot(cmap=plt.cm.Blues)
  plt.title("Confusion Matrix for the above model")
  plt.show()
```

In [ ]:

```
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
from sklearn.preprocessing import LabelEncoder

def plot_confusion_matrix_mnist(y_test, y_pred):
  """Plots the confusion matrix for the given true and predicted labels, normalised"""
  label_encoder = LabelEncoder()
  label_encoder.fit(np.unique(np.concatenate((y_test, y_pred))))
  matrix = confusion_matrix(y_test, y_pred, labels=label_encoder.classes_)
  matrix = matrix.astype('float') / matrix.sum(axis=1)[:, np.newaxis] # Normalize the confusion matrix
  disp = ConfusionMatrixDisplay(confusion_matrix=matrix,
                                display_labels=label_encoder.classes_)
  disp.plot(cmap=plt.cm.Blues,
            xticks_rotation='vertical',
            include_values=True,
            values_format=".2f"
           )
  plt.title("Confusion Matrix for the above model")
  plt.tight_layout()
  plt.show()
```

In [ ]:

```
# Train the model

import time

def train_model(
    kernels: 'list(tuple(int,int))',
    filters: 'list(int)',
    activation_func:'str',
    pool: 'str',
    dropout_rate: 'float',
    num_dense_layers: 'int',
    X_train: 'numpy.array',
    y_train: 'numpy.array',
    X_test: 'numpy.array',
    y_test: 'numpy.array',
    add_batch_normalization=False,
    flatten_layer_size=64,
    num_epochs = 100,
    extra_conv_layers=0,
    is_rgb=False,
    is_mnist=False
):

  model = Sequential()
  input_shape=(80,80,1)
  num_classes=5
  val_data=(X_val,y_val)
  if is_rgb:
    input_shape=(80,80,3)
    val_data=(X_val_rgb,y_val_rgb)
  if is_mnist:
    num_classes=10
  for filter,kernel in zip(filters,kernels):
    if activation_func=='leaky_relu':
      model.add(Conv2D(
          filters=filter,
          kernel_size=kernel,
          activation=LeakyReLU(alpha=0.01)
          ))
    else:
      model.add(Conv2D(
          filters=filter,
          kernel_size=kernel,
          activation=activation_func
          ))

    if pool=='max':
      model.add(MaxPool2D())
    else:
      model.add(AveragePooling2D(pool_size=(2,2)))

    if add_batch_normalization:
      model.add(BatchNormalization())

    if dropout_rate>0:
      model.add(Dropout(rate=dropout_rate))

    # Extra Conv Layers
    for i in range(0,extra_conv_layers):
      filters.append(filters[-1]*2)
      kernels.append(kernels[-1])
      if activation_func=='leaky_relu':
        model.add(Conv2D(
            filters=filters[-1],
            kernel_size=kernels[-1],
            activation=LeakyReLU(alpha=0.01),
            padding='valid'
            ))
      else:
        model.add(Conv2D(
            filters=filters[-1],
            kernel_size=kernels[-1],
            activation=activation_func,
            padding='valid'
            ))

    model.add(Flatten())
```

```
for i in range(num_dense_layers):
  if activation_func=='leaky_relu':
    model.add(Dense(
        units=flatten_layer_size,
        activation=LeakyReLU(alpha=0.01)
        ))
  else:
    model.add(Dense(
        units=flatten_layer_size,
        activation=activation_func
    ))

model.add(Dense(units=num_classes,activation='softmax'))

model.summary()

model.compile(
            optimizer=Adam(learning_rate=0.002),
            loss=CategoricalCrossentropy,
            metrics=['accuracy',F1Score(average='weighted')]
            )

callback = [
    EarlyStopping(
        monitor = 'val_loss',
        patience = 10,
        restore_best_weights=True
    )
]

start_time = time.time()

history = model.fit(
    x=X_train,
    y=y_train,
    epochs=num_epochs,
    validation_data=val_data,
    callbacks=callback
)

end_time = time.time()

train_time=end_time-start_time

test_loss, test_accuracy ,test_f1 = model.evaluate(X_test,y_test)
```

```
    print(f"Test Loss: {test_loss}, Test Accuracy: {test_accuracy}, Test F1 Score: {test_f1}")

    print(f"Time required to train the model is {train_time} seconds")

    plot_model_metrics(
        history=history,
        kernels=kernels,
        filters=filters,
        activation_func=activation_func,
        pool=pool,
        num_dense_layers=num_dense_layers
    )

    y_pred = model.predict(X_test)
    y_pred_classes = np.argmax(y_pred,axis=1)
    y_true_classes = np.argmax(y_test,axis=1)

    if is_mnist:
      plot_confusion_matrix_mnist(
        y_test=y_true_classes,
        y_pred=y_pred_classes
      )
    else:
      plot_confusion_matrix(
        y_test=y_true_classes,
        y_pred=y_pred_classes
      )

    return test_loss,test_accuracy,test_f1,train_time,model
```

In [ ]:

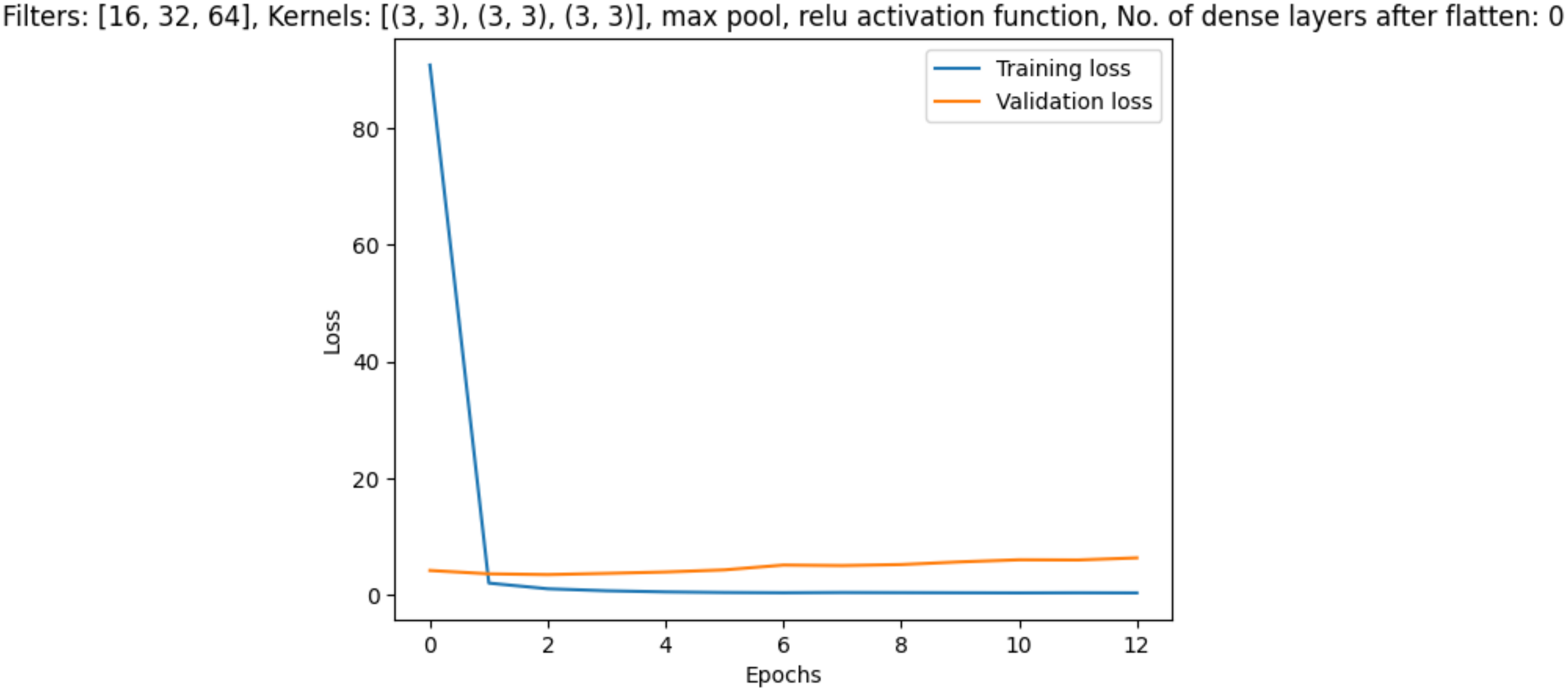
```
result_df_1 = pd.DataFrame(
    columns=[
        'Conv Kernel Size',
        'Conv Filter Size',
        'Pooling Layers',
        'Activation Function',
        'No. of Dense Layers after Flatten',
        'Dropout Rate',
        'Test Loss',
        'Test Accuracy',
        'Test F1 Score',
        'Training Time(in seconds)'
    ]
)
```

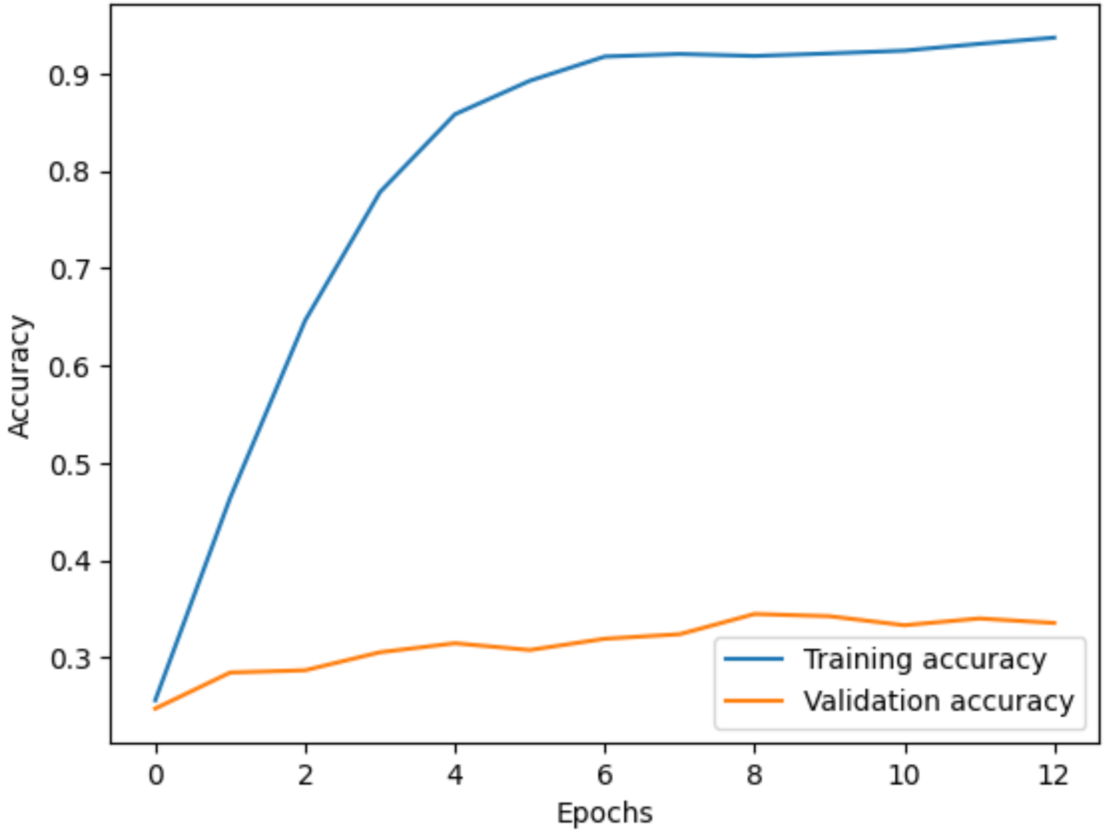
```
kernels = [
    [(3,3),(3,3),(3,3)],
    [(3,3),(3,3),(5,5)],
    [(3,3),(5,5),(5,5)],
    [(5,5),(5,5),(5,5)]
]

filters = [16,32,64]
activation='relu'
dropout_rate = 0.1
num_dense_layers = 0
pool='max'
epochs = 20

for kernel in kernels:
  test_loss,test_accuracy,test_f1,train_time,_ = train_model(
      kernels=kernel,
      filters=filters,
      activation_func=activation,
      pool=pool,
      dropout_rate=dropout_rate,
      num_dense_layers=num_dense_layers,
      X_train=X_train,
      y_train=y_train,
      X_test=X_test,
      y_test=y_test,
      num_epochs=epochs
  )

  result_df_1.loc[len(result_df_1.index)]=[
      kernel,
      filters,
      pool,
      activation,
      num_dense_layers,
      dropout_rate,
      test_loss,
      test_accuracy,
      test_f1,
      train_time
  ]
```

```
Model: "sequential"
```

```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                          ┃ Output Shape                 ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d (Conv2D)                       │ (None, 78, 78, 16)           │             160 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ max_pooling2d (MaxPooling2D)          │ (None, 39, 39, 16)           │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dropout (Dropout)                     │ (None, 39, 39, 16)           │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ flatten (Flatten)                     │ (None, 24336)                │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense (Dense)                         │ (None, 5)                    │         121,685 │
└───────────────────────────────────────┴──────────────────────────────┴─────────────────┘
 Total params: 121,845 (475.96 KB)
 Trainable params: 121,845 (475.96 KB)
 Non-trainable params: 0 (0.00 B)
```

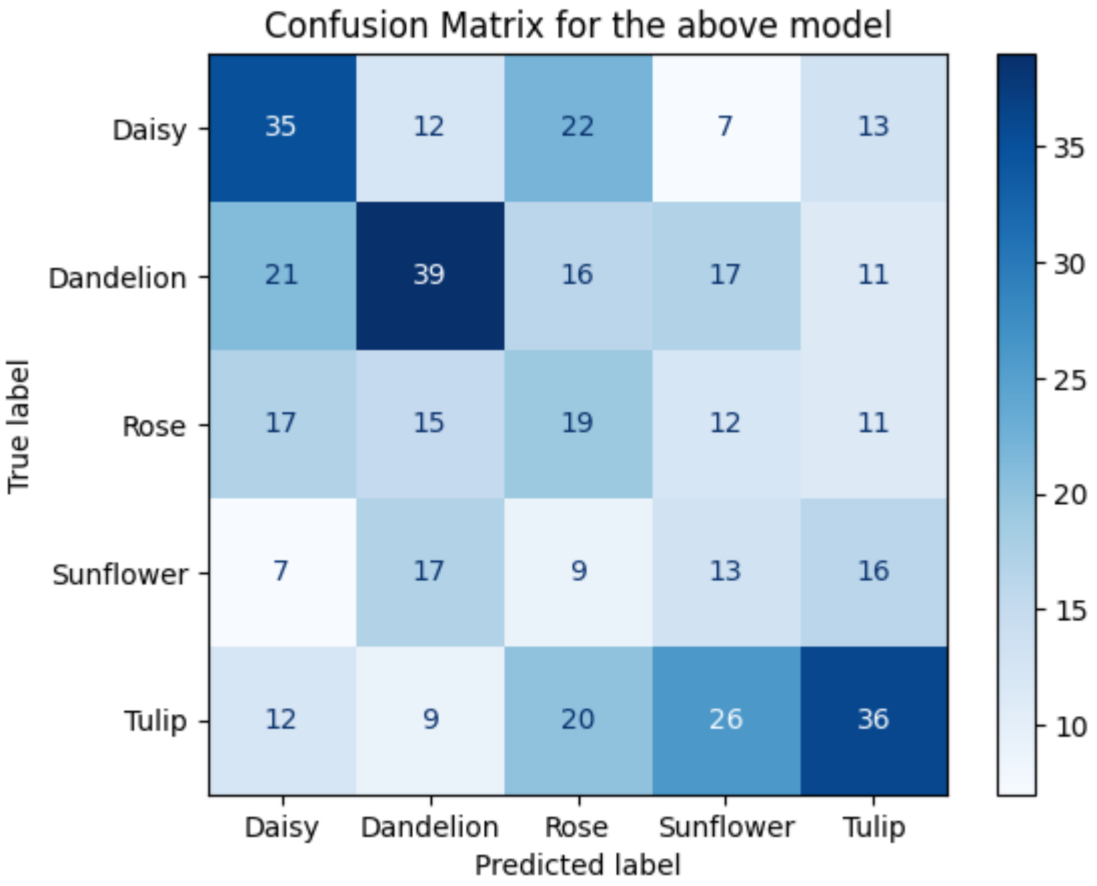
```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 147ms/step - accuracy: 0.2377 - f1_score: 0.2347 - loss: 233.4431 - val_accuracy: 0.2477 - val_
f1_score: 0.2424 - val_loss: 4.1256
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 93ms/step - accuracy: 0.4580 - f1_score: 0.4575 - loss: 1.9968 - val_accuracy: 0.2847 - val_f1_
score: 0.2793 - val_loss: 3.5507
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 98ms/step - accuracy: 0.6470 - f1_score: 0.6464 - loss: 0.9763 - val_accuracy: 0.2870 - val_f1_
score: 0.2894 - val_loss: 3.4204
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 90ms/step - accuracy: 0.7677 - f1_score: 0.7674 - loss: 0.6549 - val_accuracy: 0.3056 - val_f1_
score: 0.2988 - val_loss: 3.6281
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 93ms/step - accuracy: 0.8737 - f1_score: 0.8738 - loss: 0.4159 - val_accuracy: 0.3148 - val_f1_
score: 0.3075 - val_loss: 3.8635
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 100ms/step - accuracy: 0.8997 - f1_score: 0.8999 - loss: 0.3422 - val_accuracy: 0.3079 - val_f1
_score: 0.2994 - val_loss: 4.2288
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 91ms/step - accuracy: 0.9322 - f1_score: 0.9324 - loss: 0.2716 - val_accuracy: 0.3194 - val_f1_
score: 0.3144 - val_loss: 5.0555
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 88ms/step - accuracy: 0.9266 - f1_score: 0.9267 - loss: 0.3030 - val_accuracy: 0.3241 - val_f1_
score: 0.3181 - val_loss: 4.9665
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 94ms/step - accuracy: 0.9281 - f1_score: 0.9282 - loss: 0.2895 - val_accuracy: 0.3449 - val_f1_
score: 0.3406 - val_loss: 5.1423
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 102ms/step - accuracy: 0.9286 - f1_score: 0.9288 - loss: 0.2704 - val_accuracy: 0.3426 - val_f1
_score: 0.3261 - val_loss: 5.6000
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 95ms/step - accuracy: 0.9363 - f1_score: 0.9363 - loss: 0.2558 - val_accuracy: 0.3333 - val_f1_
score: 0.3300 - val_loss: 5.9610
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 99ms/step - accuracy: 0.9401 - f1_score: 0.9402 - loss: 0.2430 - val_accuracy: 0.3403 - val_f1_
score: 0.3412 - val_loss: 5.9284
Epoch 13/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 105ms/step - accuracy: 0.9434 - f1_score: 0.9434 - loss: 0.2411 - val_accuracy: 0.3356 - val_f1
_score: 0.3386 - val_loss: 6.2893
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 26ms/step - accuracy: 0.3013 - f1_score: 0.3062 - loss: 3.1925
Test Loss: 3.092764377593994, Test Accuracy: 0.32870370149612427, Test F1 Score: 0.3337514400482178
Time required to train the model is 197.24697875976562 seconds
```


Filters: [16, 32, 64], Kernels: [(3, 3), (3, 3), (3, 3)], max pool, relu activation function, No. of dense layers after flatten: 0
Training loss
Validation loss
Loss
0
20
40
60
80
Epochs
0
2
4
6
8
10
12



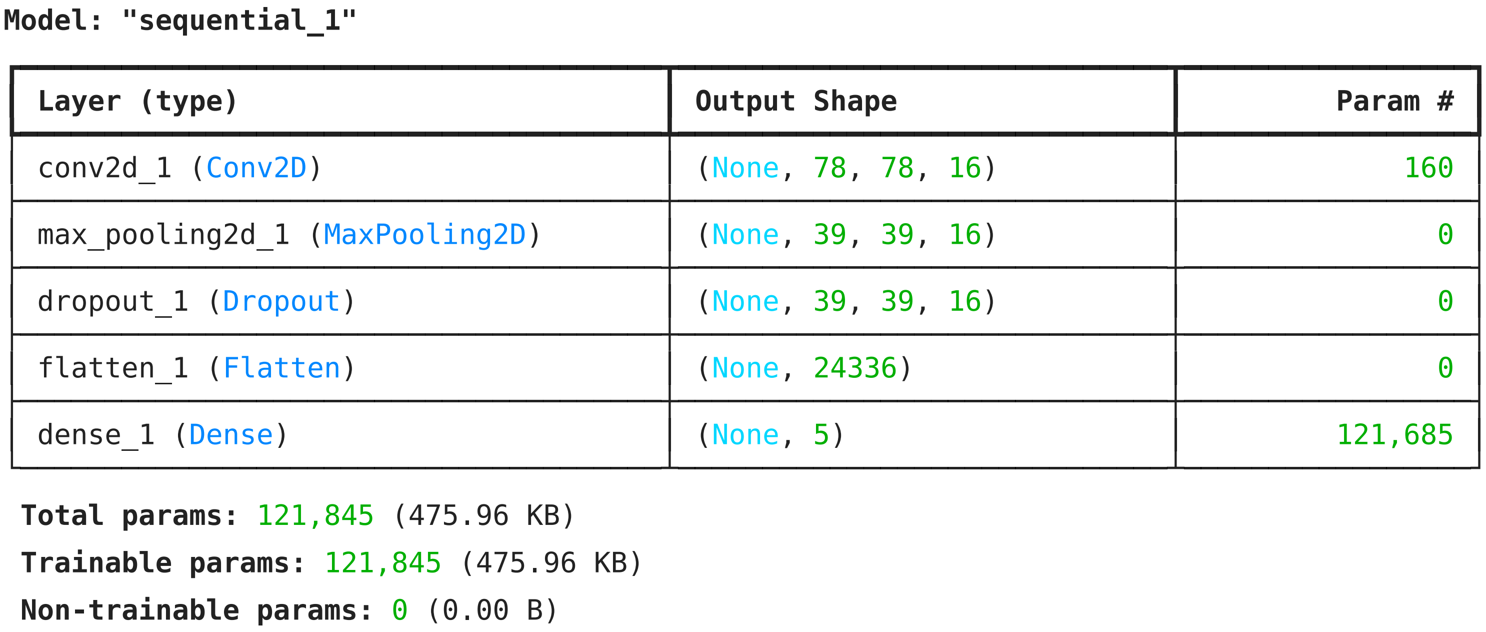
Filters: [16, 32, 64], Kernels: [(3, 3), (3, 3), (3, 3)], max pool, relu activation function, No. of dense layers after flatten: 0

```
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 28ms/step
```



Confusion Matrix for the above model

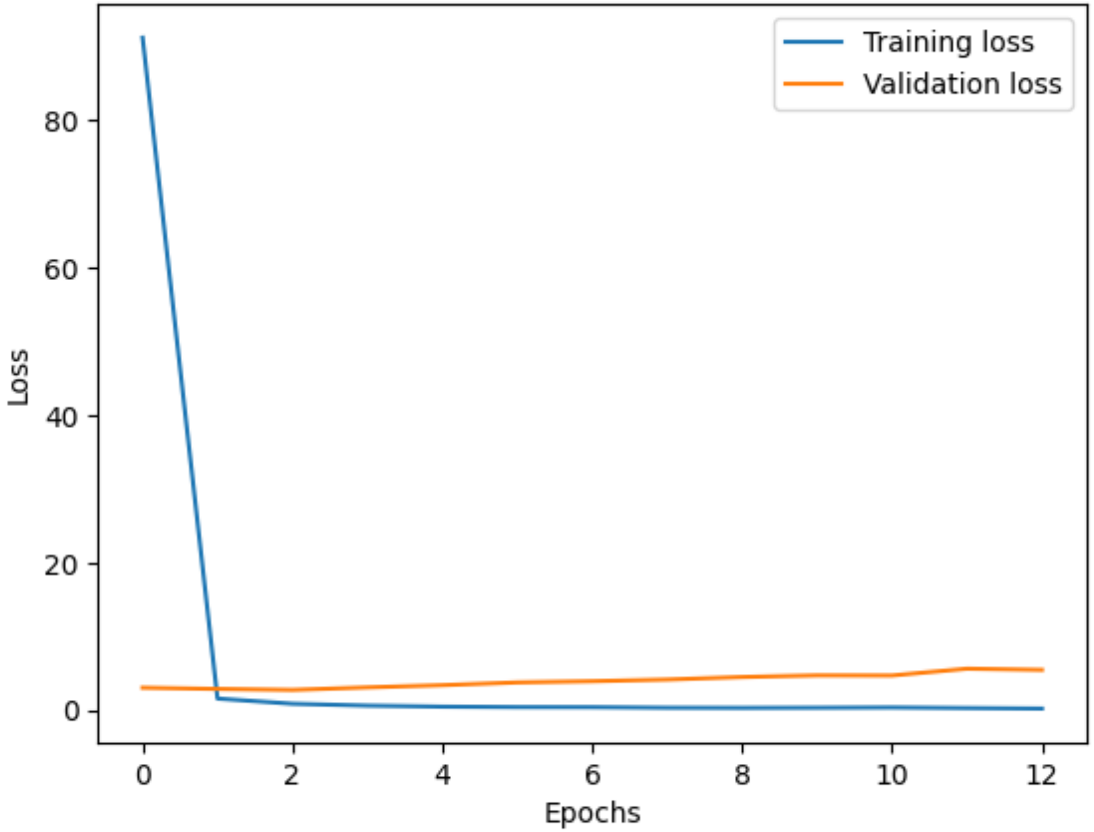
True label \ Predicted label	Daisy	Dandelion	Rose	Sunflower	Tulip
Daisy	35	12	22	7	13
Dandelion	21	39	16	17	11
Rose	17	15	19	12	11
Sunflower	7	17	9	13	16
Tulip	12	9	20	26	36



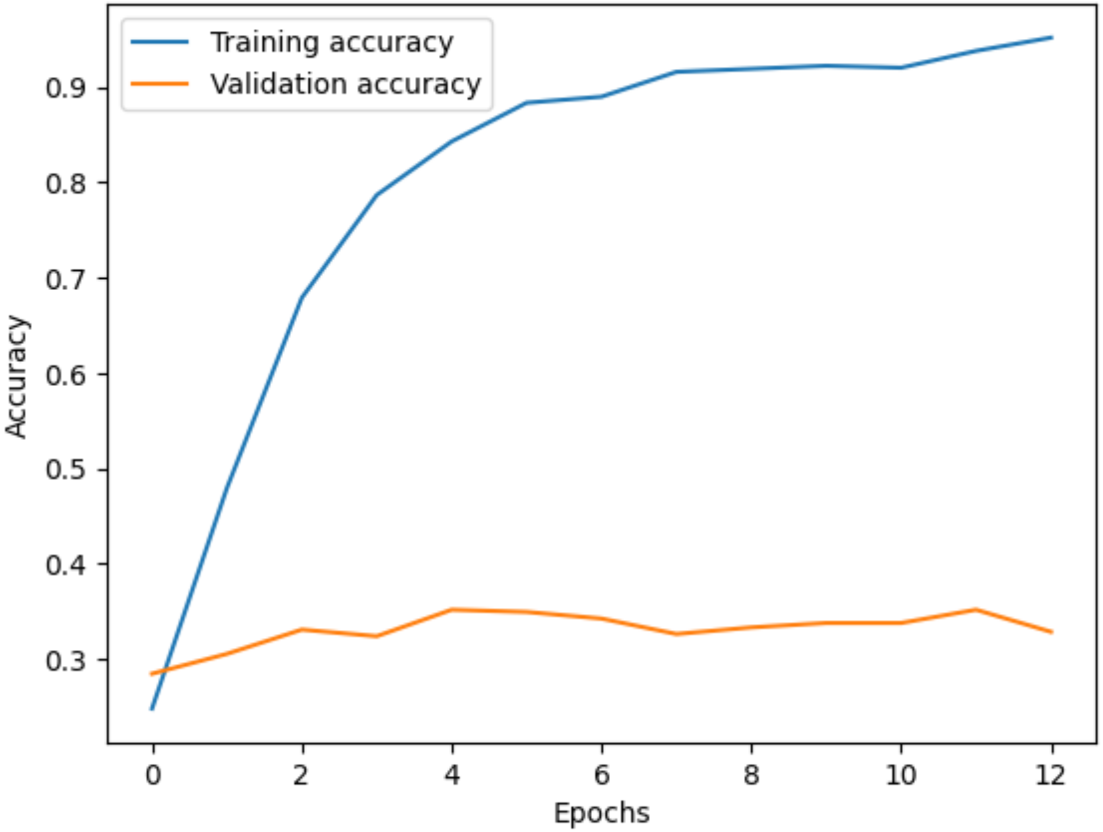
```
Model: "sequential_1"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_1 (Conv2D)                    │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_1 (MaxPooling2D)       │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_1 (Dropout)                  │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_1 (Flatten)                  │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_1 (Dense)                      │ (None, 5)                   │         121,685 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 121,845 (475.96 KB)
 Trainable params: 121,845 (475.96 KB)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 100ms/step - accuracy: 0.2314 - f1_score: 0.2294 - loss: 237.6128 - val_accuracy: 0.2847 - val_
f1_score: 0.2807 - val_loss: 3.0241
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 105ms/step - accuracy: 0.4779 - f1_score: 0.4776 - loss: 1.6270 - val_accuracy: 0.3056 - val_f1
_score: 0.3026 - val_loss: 2.8588
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 88ms/step - accuracy: 0.6713 - f1_score: 0.6697 - loss: 0.8670 - val_accuracy: 0.3310 - val_f1_
score: 0.3266 - val_loss: 2.7278
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 97ms/step - accuracy: 0.8005 - f1_score: 0.8005 - loss: 0.5713 - val_accuracy: 0.3241 - val_f1_
score: 0.3199 - val_loss: 3.0708
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 101ms/step - accuracy: 0.8475 - f1_score: 0.8482 - loss: 0.4564 - val_accuracy: 0.3519 - val_f1
_score: 0.3450 - val_loss: 3.3716
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 86ms/step - accuracy: 0.8912 - f1_score: 0.8917 - loss: 0.3845 - val_accuracy: 0.3495 - val_f1_
score: 0.3378 - val_loss: 3.7420
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 12s 100ms/step - accuracy: 0.9026 - f1_score: 0.9028 - loss: 0.3535 - val_accuracy: 0.3426 - val_f1
_score: 0.3333 - val_loss: 3.9093
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 101ms/step - accuracy: 0.9235 - f1_score: 0.9240 - loss: 0.2933 - val_accuracy: 0.3264 - val_f1
_score: 0.3184 - val_loss: 4.1339
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 94ms/step - accuracy: 0.9190 - f1_score: 0.9192 - loss: 0.2744 - val_accuracy: 0.3333 - val_f1_
score: 0.3247 - val_loss: 4.4774
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 103ms/step - accuracy: 0.9277 - f1_score: 0.9282 - loss: 0.2795 - val_accuracy: 0.3380 - val_f1
_score: 0.3361 - val_loss: 4.6995
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 98ms/step - accuracy: 0.9259 - f1_score: 0.9264 - loss: 0.3327 - val_accuracy: 0.3380 - val_f1_
score: 0.3302 - val_loss: 4.6844
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 95ms/step - accuracy: 0.9408 - f1_score: 0.9415 - loss: 0.2403 - val_accuracy: 0.3519 - val_f1_
score: 0.3288 - val_loss: 5.6084
Epoch 13/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 99ms/step - accuracy: 0.9542 - f1_score: 0.9545 - loss: 0.1861 - val_accuracy: 0.3287 - val_f1_
score: 0.3192 - val_loss: 5.4493
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step - accuracy: 0.2739 - f1_score: 0.2678 - loss: 3.1269
Test Loss: 2.8645572662353516, Test Accuracy: 0.31018519401550293, Test F1 Score: 0.30755409598350525
Time required to train the model is 198.43842554092407 seconds
```

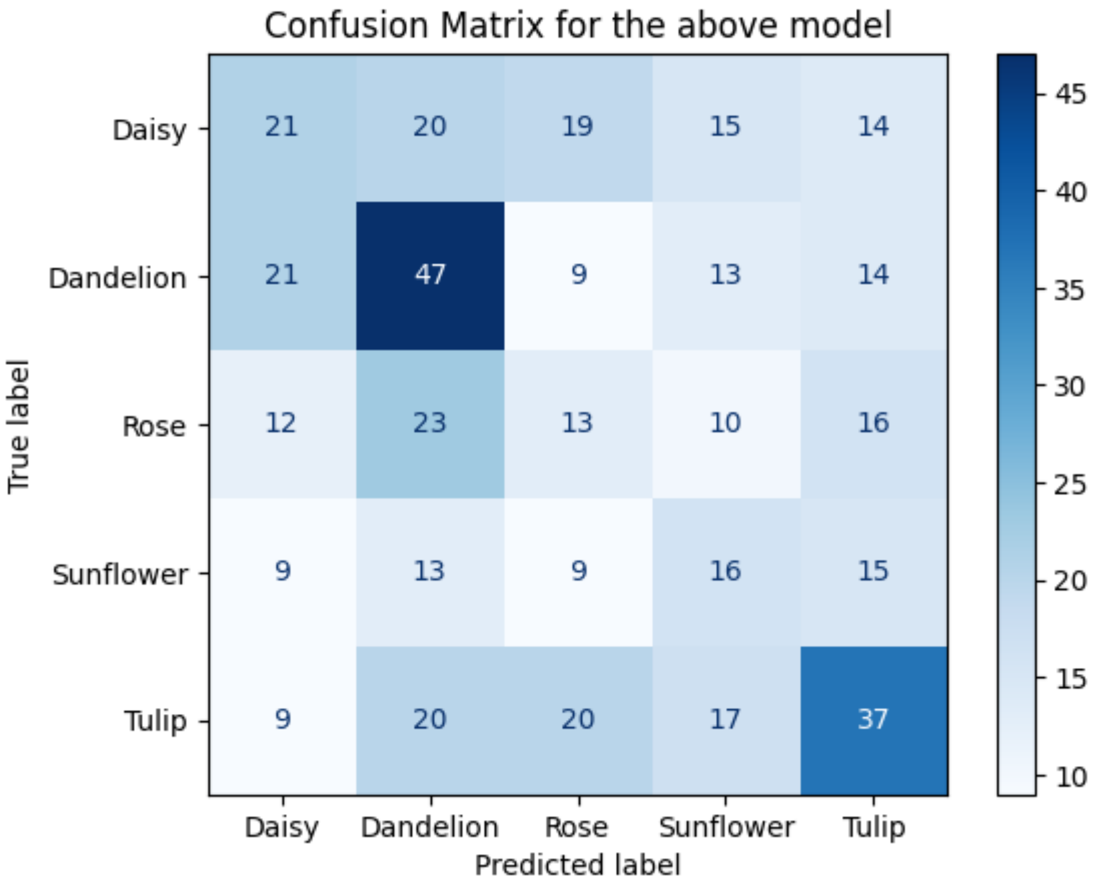
Filters: [16, 32, 64], Kernels: [(3, 3), (3, 3), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 0



```
Filters: [16, 32, 64], Kernels: [(3, 3), (3, 3), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 0
```

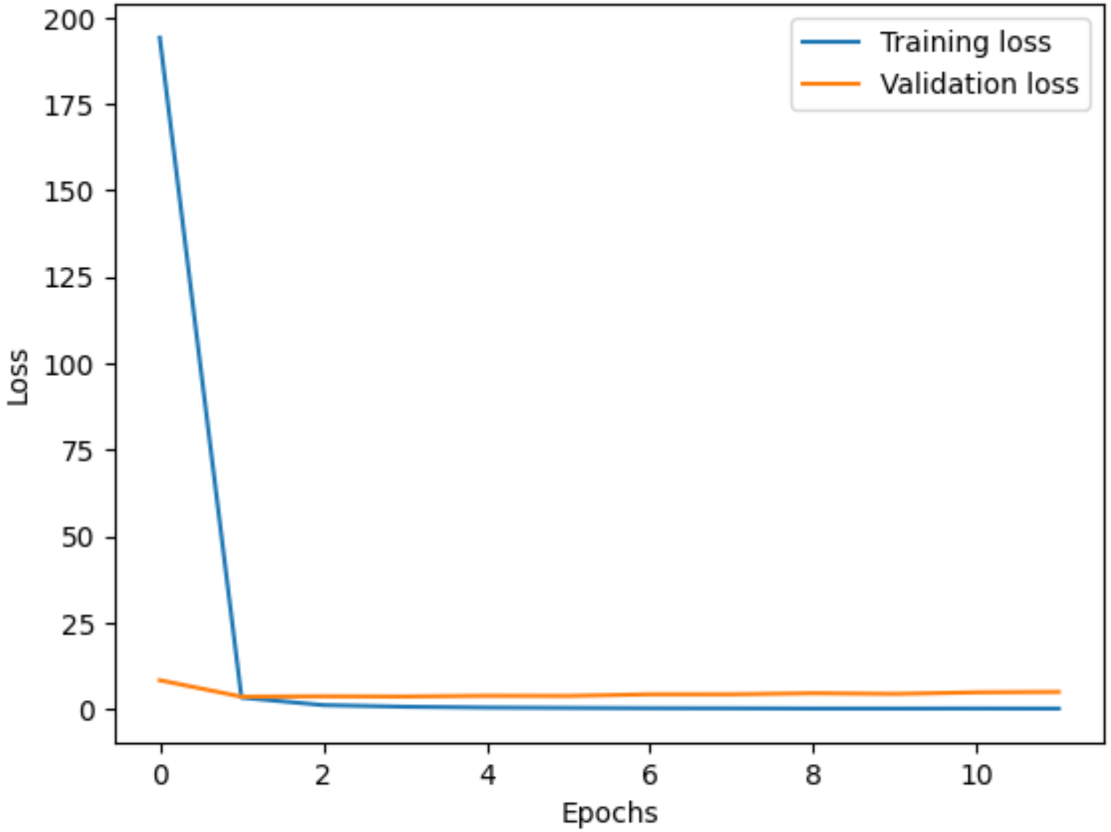


```
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step
```



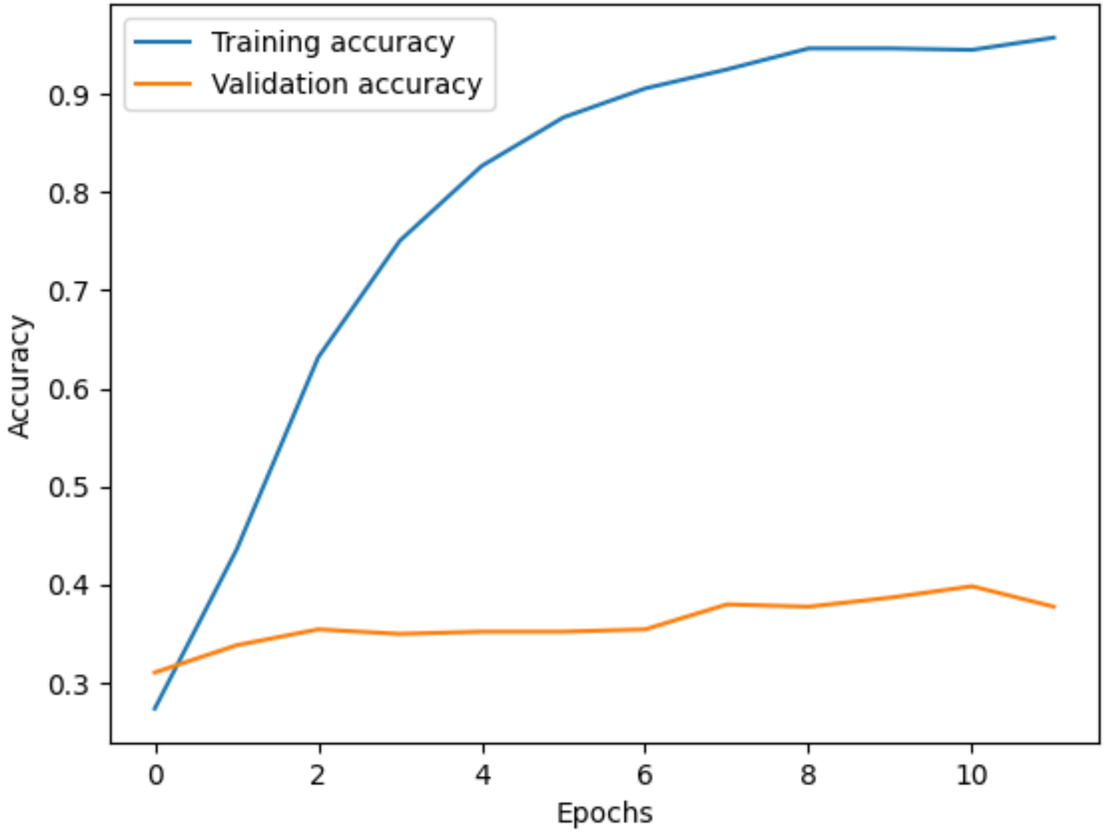
```
Model: "sequential_2"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                        ┃ Output Shape               ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_2 (Conv2D)                   │ (None, 78, 78, 16)         │             160 │
├─────────────────────────────────────┼────────────────────────────┼─────────────────┤
│ max_pooling2d_2 (MaxPooling2D)      │ (None, 39, 39, 16)         │               0 │
├─────────────────────────────────────┼────────────────────────────┼─────────────────┤
│ dropout_2 (Dropout)                 │ (None, 39, 39, 16)         │               0 │
├─────────────────────────────────────┼────────────────────────────┼─────────────────┤
│ flatten_2 (Flatten)                 │ (None, 24336)              │               0 │
├─────────────────────────────────────┼────────────────────────────┼─────────────────┤
│ dense_2 (Dense)                     │ (None, 5)                  │         121,685 │
└─────────────────────────────────────┴────────────────────────────┴─────────────────┘
 Total params: 121,845 (475.96 KB)
 Trainable params: 121,845 (475.96 KB)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 107ms/step - accuracy: 0.2521 - f1_score: 0.2503 - loss: 492.9043 - val_accuracy: 0.3102 - val_
f1_score: 0.2516 - val_loss: 8.3644
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 90ms/step - accuracy: 0.4321 - f1_score: 0.4323 - loss: 4.2141 - val_accuracy: 0.3380 - val_f1_
score: 0.3099 - val_loss: 3.6129
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 104ms/step - accuracy: 0.6363 - f1_score: 0.6363 - loss: 1.1693 - val_accuracy: 0.3542 - val_f1
_score: 0.3352 - val_loss: 3.7134
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 95ms/step - accuracy: 0.7514 - f1_score: 0.7510 - loss: 0.6698 - val_accuracy: 0.3495 - val_f1_
score: 0.3391 - val_loss: 3.6550
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 94ms/step - accuracy: 0.8293 - f1_score: 0.8293 - loss: 0.4588 - val_accuracy: 0.3519 - val_f1_
score: 0.3455 - val_loss: 3.8674
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 22s 105ms/step - accuracy: 0.8783 - f1_score: 0.8784 - loss: 0.3393 - val_accuracy: 0.3519 - val_f1
_score: 0.3518 - val_loss: 3.8306
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 90ms/step - accuracy: 0.9092 - f1_score: 0.9094 - loss: 0.2698 - val_accuracy: 0.3542 - val_f1_
score: 0.3388 - val_loss: 4.2922
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 11s 100ms/step - accuracy: 0.9270 - f1_score: 0.9271 - loss: 0.2313 - val_accuracy: 0.3796 - val_f1
_score: 0.3774 - val_loss: 4.2985
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 109ms/step - accuracy: 0.9416 - f1_score: 0.9417 - loss: 0.1929 - val_accuracy: 0.3773 - val_f1
_score: 0.3758 - val_loss: 4.6168
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 93ms/step - accuracy: 0.9514 - f1_score: 0.9515 - loss: 0.1693 - val_accuracy: 0.3866 - val_f1_
score: 0.3813 - val_loss: 4.4255
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 94ms/step - accuracy: 0.9465 - f1_score: 0.9466 - loss: 0.1899 - val_accuracy: 0.3981 - val_f1_
score: 0.3915 - val_loss: 4.8634
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 22s 105ms/step - accuracy: 0.9627 - f1_score: 0.9627 - loss: 0.1619 - val_accuracy: 0.3773 - val_f1
_score: 0.3745 - val_loss: 4.9914
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 29ms/step - accuracy: 0.3556 - f1_score: 0.3423 - loss: 3.7078
Test Loss: 3.545902729034424, Test Accuracy: 0.3541666567325592, Test F1 Score: 0.33932924270629883
Time required to train the model is 187.31955242156982 seconds
```

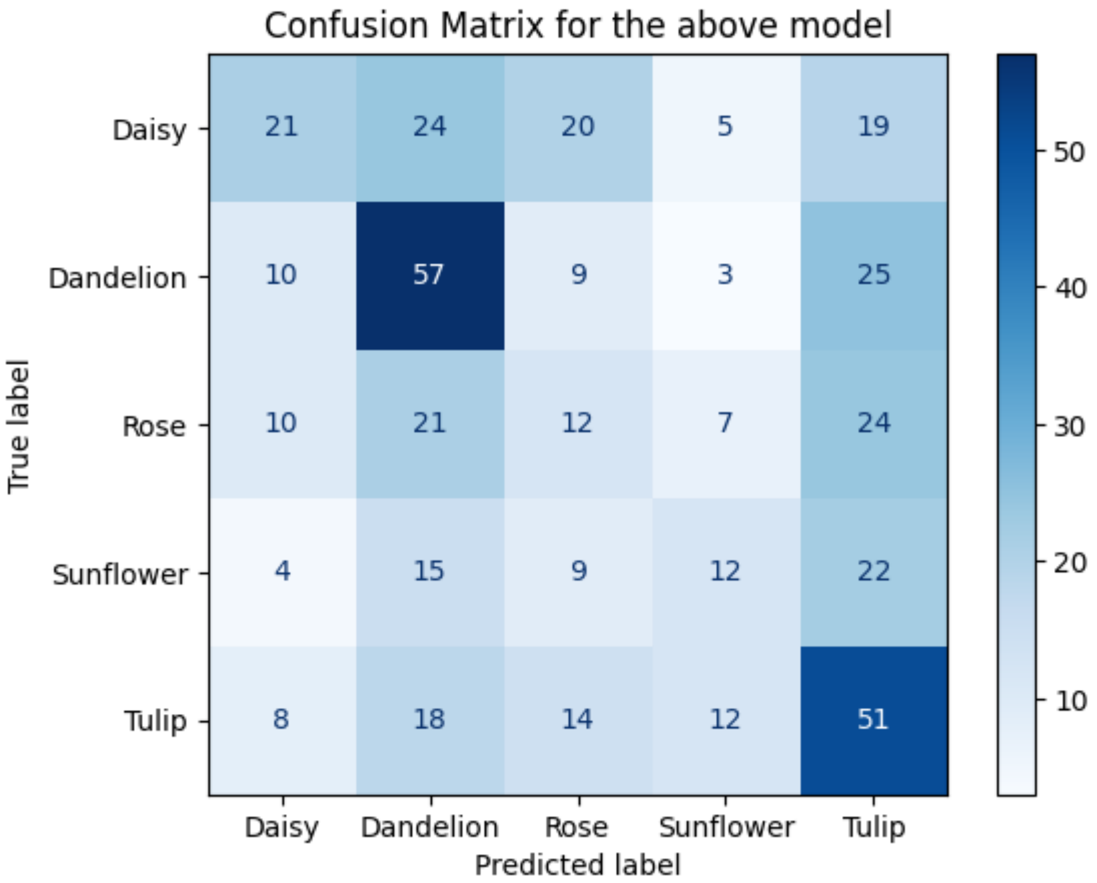


Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 0

Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 0

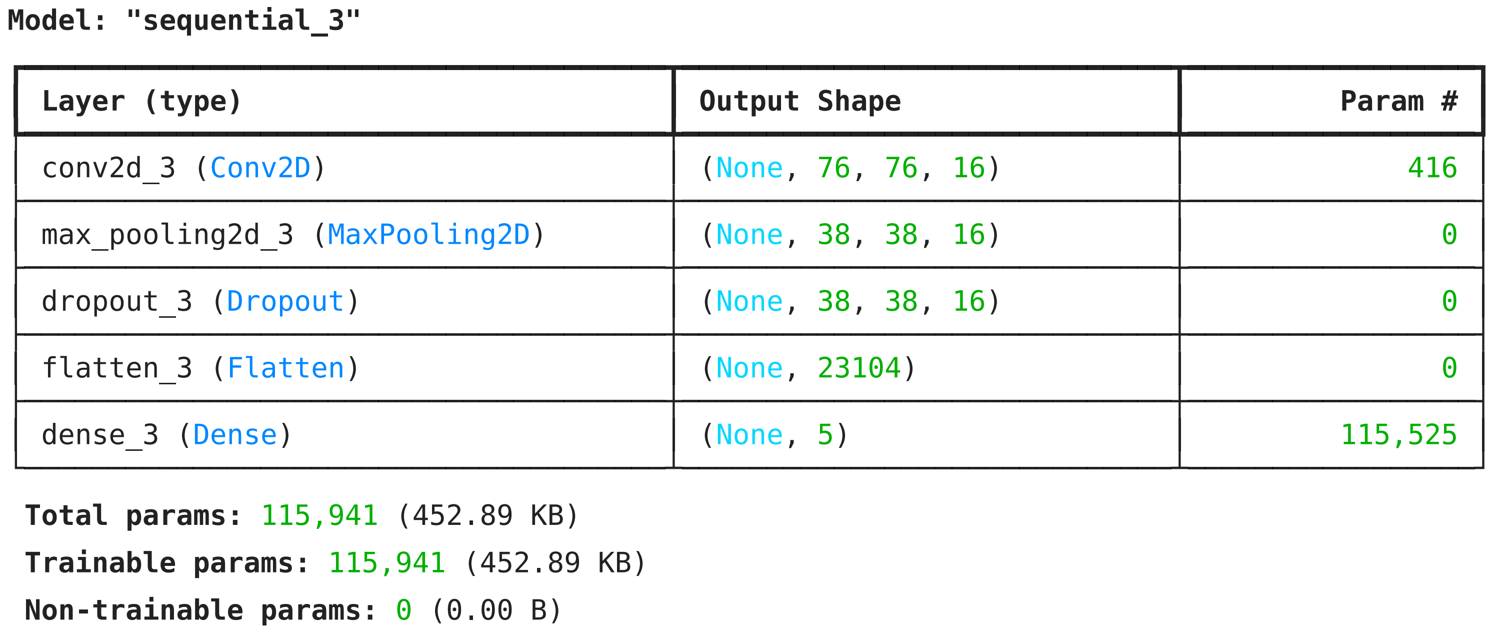


```
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 28ms/step
```



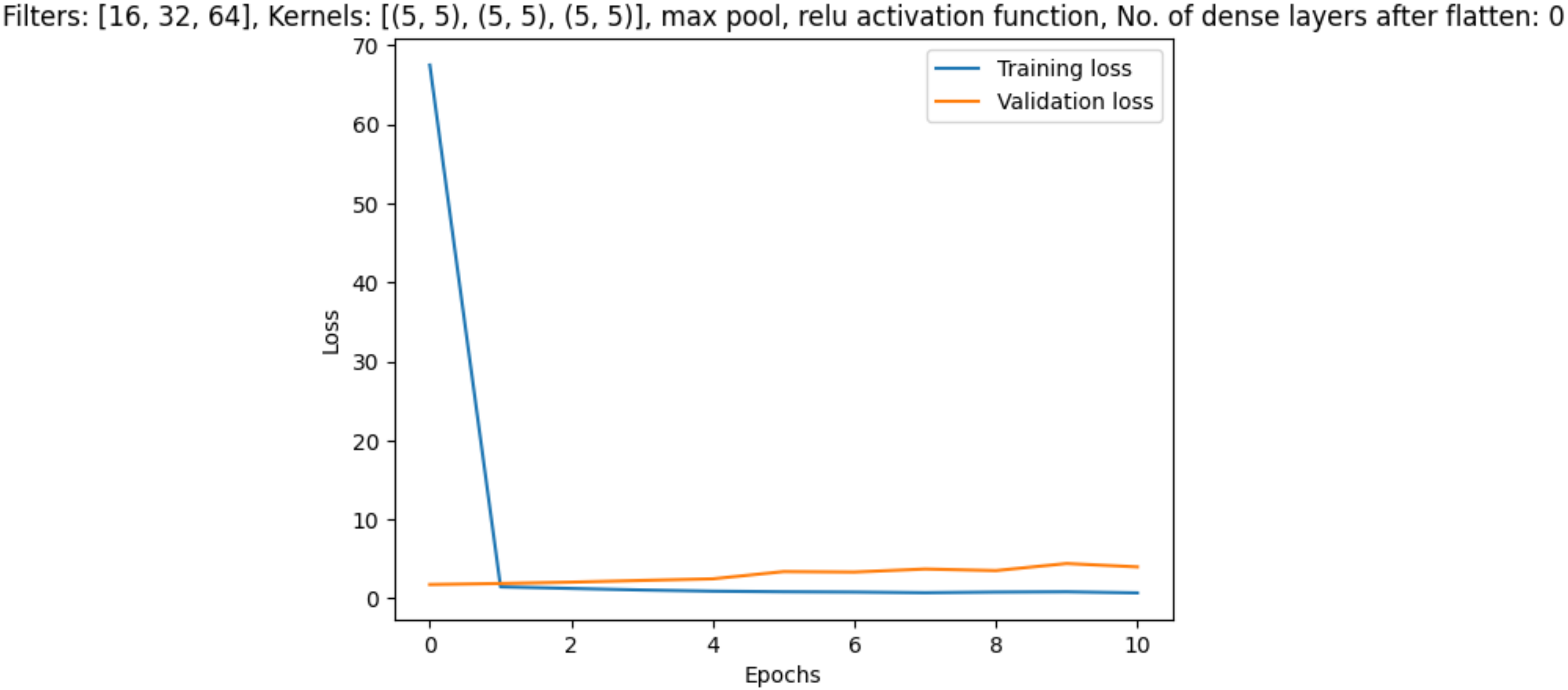
Confusion Matrix for the above model

True label \ Predicted label	Daisy	Dandelion	Rose	Sunflower	Tulip
Daisy	21	24	20	5	19
Dandelion	10	57	9	3	25
Rose	10	21	12	7	24
Sunflower	4	15	9	12	22
Tulip	8	18	14	12	51

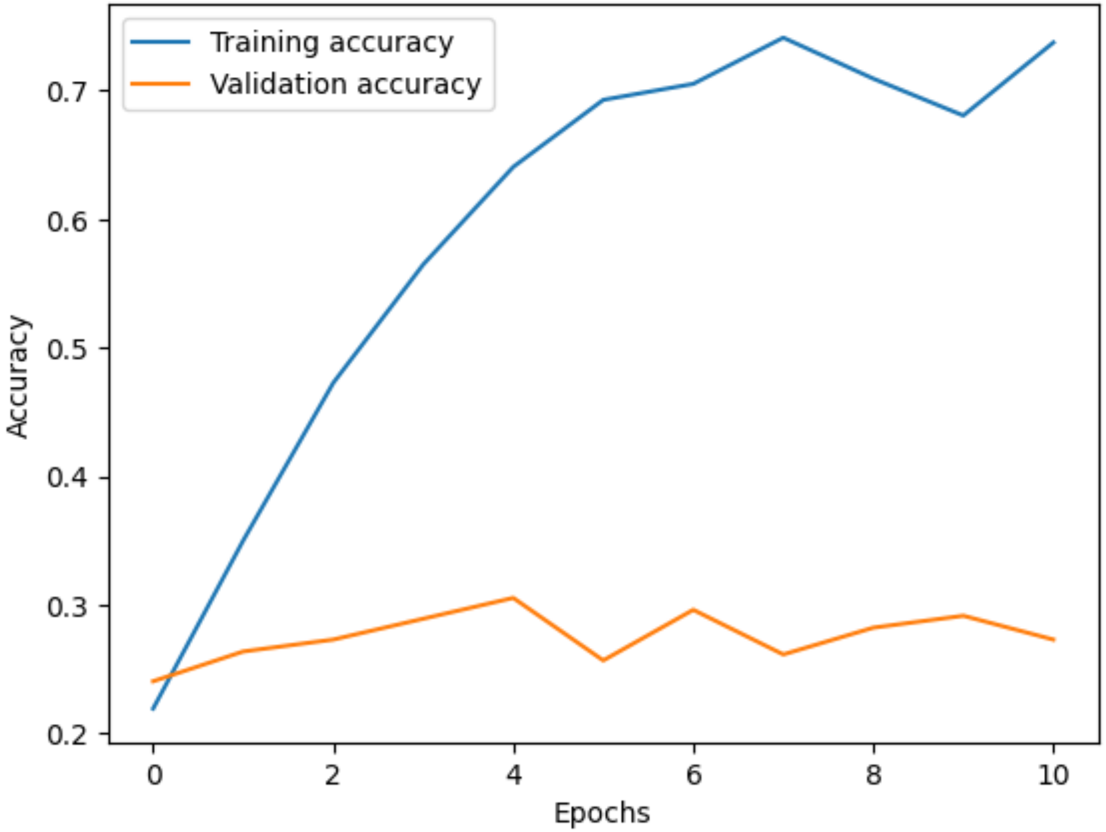


```
Model: "sequential_3"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_3 (Conv2D)                    │ (None, 76, 76, 16)          │             416 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_3 (MaxPooling2D)       │ (None, 38, 38, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_3 (Dropout)                  │ (None, 38, 38, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_3 (Flatten)                  │ (None, 23104)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_3 (Dense)                      │ (None, 5)                   │         115,525 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 115,941 (452.89 KB)
 Trainable params: 115,941 (452.89 KB)
 Non-trainable params: 0 (0.00 B)
```

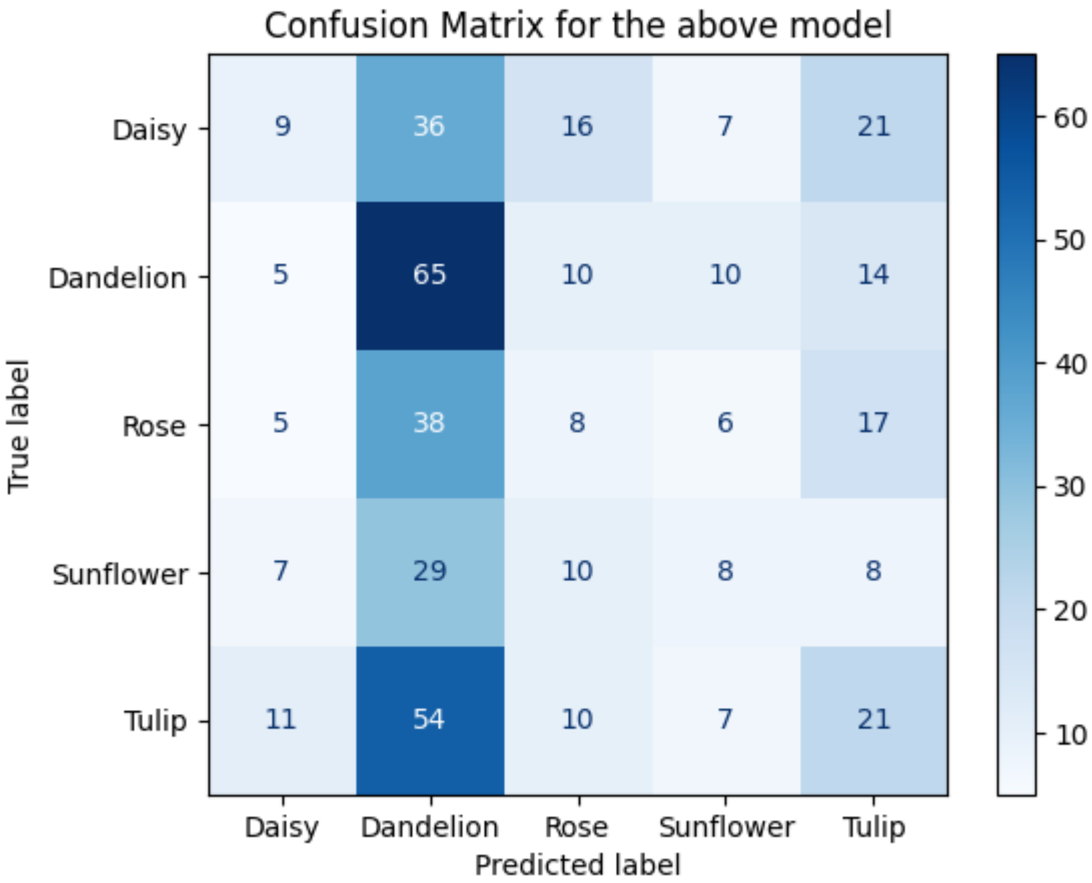
```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 132ms/step - accuracy: 0.2181 - f1_score: 0.2116 - loss: 204.3684 - val_accuracy: 0.2407 - val_
f1_score: 0.2167 - val_loss: 1.7584
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 126ms/step - accuracy: 0.3308 - f1_score: 0.3152 - loss: 1.4987 - val_accuracy: 0.2639 - val_f1
_score: 0.2283 - val_loss: 1.8946
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 129ms/step - accuracy: 0.4827 - f1_score: 0.4761 - loss: 1.2595 - val_accuracy: 0.2731 - val_f1
_score: 0.2455 - val_loss: 2.0592
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 130ms/step - accuracy: 0.5538 - f1_score: 0.5586 - loss: 1.0850 - val_accuracy: 0.2894 - val_f1
_score: 0.2590 - val_loss: 2.2781
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 128ms/step - accuracy: 0.6392 - f1_score: 0.6459 - loss: 0.9273 - val_accuracy: 0.3056 - val_f1
_score: 0.2865 - val_loss: 2.4814
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 132ms/step - accuracy: 0.7011 - f1_score: 0.7072 - loss: 0.8249 - val_accuracy: 0.2569 - val_f1
_score: 0.2450 - val_loss: 3.3964
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 131ms/step - accuracy: 0.7224 - f1_score: 0.7279 - loss: 0.7498 - val_accuracy: 0.2963 - val_f1
_score: 0.2802 - val_loss: 3.3382
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 135ms/step - accuracy: 0.7481 - f1_score: 0.7538 - loss: 0.7140 - val_accuracy: 0.2616 - val_f1
_score: 0.2496 - val_loss: 3.7218
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 128ms/step - accuracy: 0.7450 - f1_score: 0.7521 - loss: 0.7188 - val_accuracy: 0.2824 - val_f1
_score: 0.2427 - val_loss: 3.5226
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 135ms/step - accuracy: 0.6787 - f1_score: 0.6840 - loss: 0.8627 - val_accuracy: 0.2917 - val_f1
_score: 0.2582 - val_loss: 4.4186
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 140ms/step - accuracy: 0.7338 - f1_score: 0.7402 - loss: 0.6956 - val_accuracy: 0.2731 - val_f1
_score: 0.2418 - val_loss: 3.9892
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 59ms/step - accuracy: 0.2363 - f1_score: 0.2113 - loss: 1.6868
Test Loss: 1.7128006219863892, Test Accuracy: 0.2569444477558136, Test F1 Score: 0.22423039376735687
Time required to train the model is 189.06018662452698 seconds
```


Filters: [16, 32, 64], Kernels: [(5, 5), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 0
Training loss
Validation loss
Loss
70
60
50
40
30
20
10
0
0
2
4
6
8
10
Epochs

Filters: [16, 32, 64], Kernels: [(5, 5), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 0



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 45ms/step
```

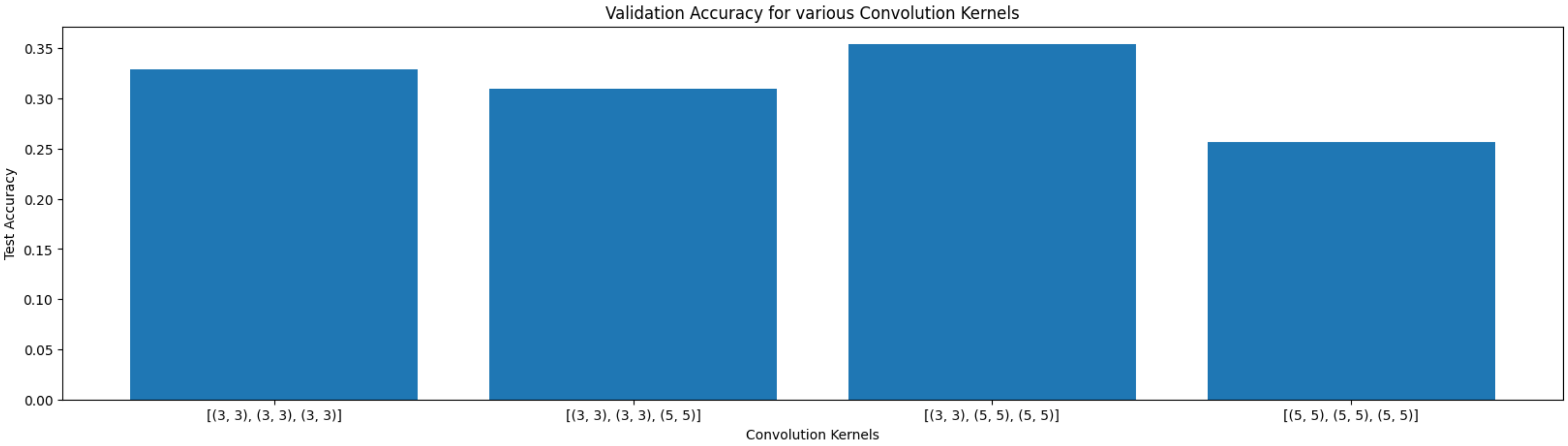


In [ ]:
```
result_df_1
```

Out[ ]:

	Conv Kernel Size	Conv Filter Size	Pooling Layers	Activation Function	No. of Dense Layers after Flatten	Dropout Rate	Test Loss	Test Accuracy	Test F1 Score	Training Time(in seconds)
0	[(3, 3), (3, 3), (3, 3)]	[16, 32, 64]	max	relu	0	0.1	3.092764	0.328704	0.333751	197.246979
1	[(3, 3), (3, 3), (5, 5)]	[16, 32, 64]	max	relu	0	0.1	2.864557	0.310185	0.307554	198.438426
2	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	0	0.1	3.545903	0.354167	0.339329	187.319552
3	[(5, 5), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	0	0.1	1.712801	0.256944	0.224230	189.060187

In [ ]:
```
plt.figure(figsize=(20,5))
plt.bar(
    [str(ker) for ker in result_df_1['Conv Kernel Size']],
    result_df_1['Test Accuracy']
)

plt.ylabel('Test Accuracy')
plt.xlabel('Convolution Kernels')
plt.title('Validation Accuracy for various Convolution Kernels')
plt.show()
```



```
In [ ]: best_kernel = result_df_1.sort_values(
            by=['Test Accuracy','Test F1 Score'],
            ascending=[False,False]
        )['Conv Kernel Size'].iloc[0]

        best_kernel
```

```
Out[ ]: [(3, 3), (5, 5), (5, 5)]
```

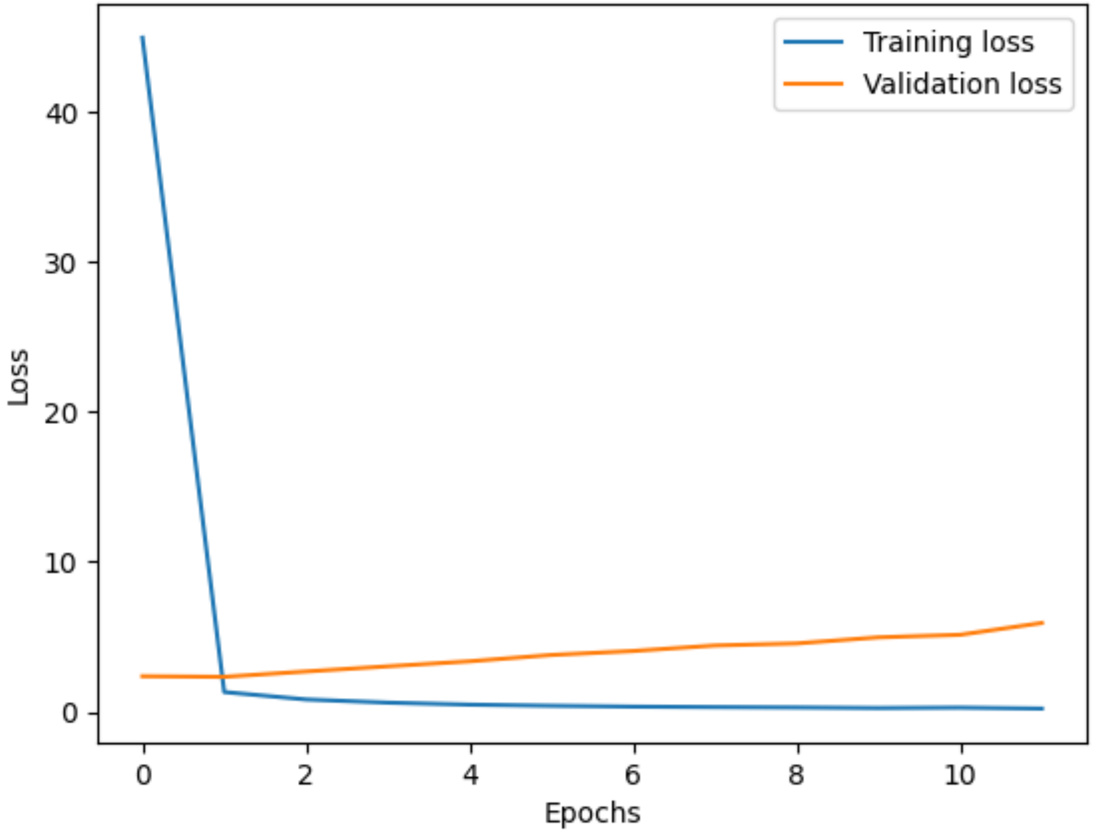
```
In [ ]: ## Subtask 2

        result_df_2 = pd.DataFrame(
            columns=[
                'Conv Kernel Size',
                'Conv Filter Size',
                'Pooling Layers',
                'Activation Function',
                'No. of Dense Layers after Flatten',
                'Dropout Rate',
                'Test Loss',
                'Test Accuracy',
                'Test F1 Score',
                'Training Time(in seconds)'
            ]
        )

        filters = [16,32,64]
        activation='relu'
        dropout_rate = 0.1
        pool='max'
        epochs = 20
        num_dense_layers = [1,2,3]

        for layer in num_dense_layers:
          test_loss,test_accuracy,test_f1,train_time,_ = train_model(
              kernels=best_kernel,
              filters=filters,
              activation_func=activation,
              pool=pool,
              dropout_rate=dropout_rate,
              num_dense_layers=layer,
              X_train=X_train,
              y_train=y_train,
              X_test=X_test,
              y_test=y_test,
              num_epochs=epochs
              )

          result_df_2.loc[len(result_df_2.index)]=[
              best_kernel,
              filters,
              pool,
              activation,
              layer,
              dropout_rate,
              test_loss,
              test_accuracy,
              test_f1,
              train_time
          ]
```

```
Model: "sequential_4"
```

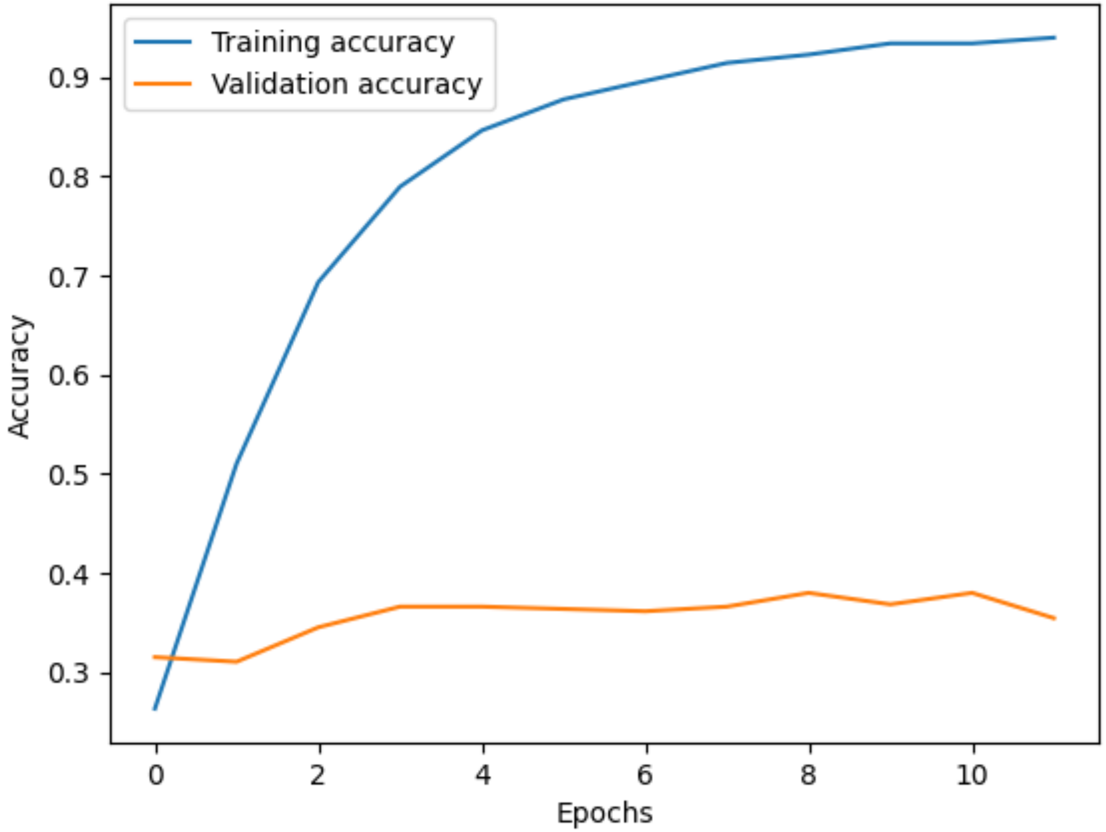
```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_4 (Conv2D)                    │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_4 (MaxPooling2D)       │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_4 (Dropout)                  │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_4 (Flatten)                  │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_4 (Dense)                      │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_5 (Dense)                      │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,558,053 (5.94 MB)
 Trainable params: 1,558,053 (5.94 MB)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 17s 139ms/step - accuracy: 0.2455 - f1_score: 0.2424 - loss: 128.6618 - val_accuracy: 0.3148 - val_
f1_score: 0.3127 - val_loss: 2.3806
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 18s 119ms/step - accuracy: 0.5185 - f1_score: 0.5174 - loss: 1.2598 - val_accuracy: 0.3102 - val_f1
_score: 0.3035 - val_loss: 2.3428
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 12s 114ms/step - accuracy: 0.7168 - f1_score: 0.7161 - loss: 0.8011 - val_accuracy: 0.3449 - val_f1
_score: 0.3353 - val_loss: 2.6991
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 12s 115ms/step - accuracy: 0.8022 - f1_score: 0.8019 - loss: 0.6054 - val_accuracy: 0.3657 - val_f1
_score: 0.3575 - val_loss: 3.0422
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 109ms/step - accuracy: 0.8647 - f1_score: 0.8642 - loss: 0.4511 - val_accuracy: 0.3657 - val_f1
_score: 0.3642 - val_loss: 3.3770
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 22s 123ms/step - accuracy: 0.8922 - f1_score: 0.8918 - loss: 0.3890 - val_accuracy: 0.3634 - val_f1
_score: 0.3528 - val_loss: 3.7982
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 122ms/step - accuracy: 0.9092 - f1_score: 0.9089 - loss: 0.3430 - val_accuracy: 0.3611 - val_f1
_score: 0.3421 - val_loss: 4.0634
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 115ms/step - accuracy: 0.9246 - f1_score: 0.9246 - loss: 0.2810 - val_accuracy: 0.3657 - val_f1
_score: 0.3604 - val_loss: 4.4306
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 12s 115ms/step - accuracy: 0.9293 - f1_score: 0.9290 - loss: 0.2849 - val_accuracy: 0.3796 - val_f1
_score: 0.3662 - val_loss: 4.5676
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 12s 113ms/step - accuracy: 0.9436 - f1_score: 0.9435 - loss: 0.2320 - val_accuracy: 0.3681 - val_f1
_score: 0.3609 - val_loss: 4.9733
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 97ms/step - accuracy: 0.9429 - f1_score: 0.9426 - loss: 0.2837 - val_accuracy: 0.3796 - val_f1_
score: 0.3762 - val_loss: 5.1438
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 22s 114ms/step - accuracy: 0.9469 - f1_score: 0.9467 - loss: 0.2289 - val_accuracy: 0.3542 - val_f1
_score: 0.3451 - val_loss: 5.9310
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.2672 - f1_score: 0.2628 - loss: 2.1882
Test Loss: 2.231379985809326, Test Accuracy: 0.28703704476356506, Test F1 Score: 0.2833707928657532
Time required to train the model is 208.50289726257324 seconds
```

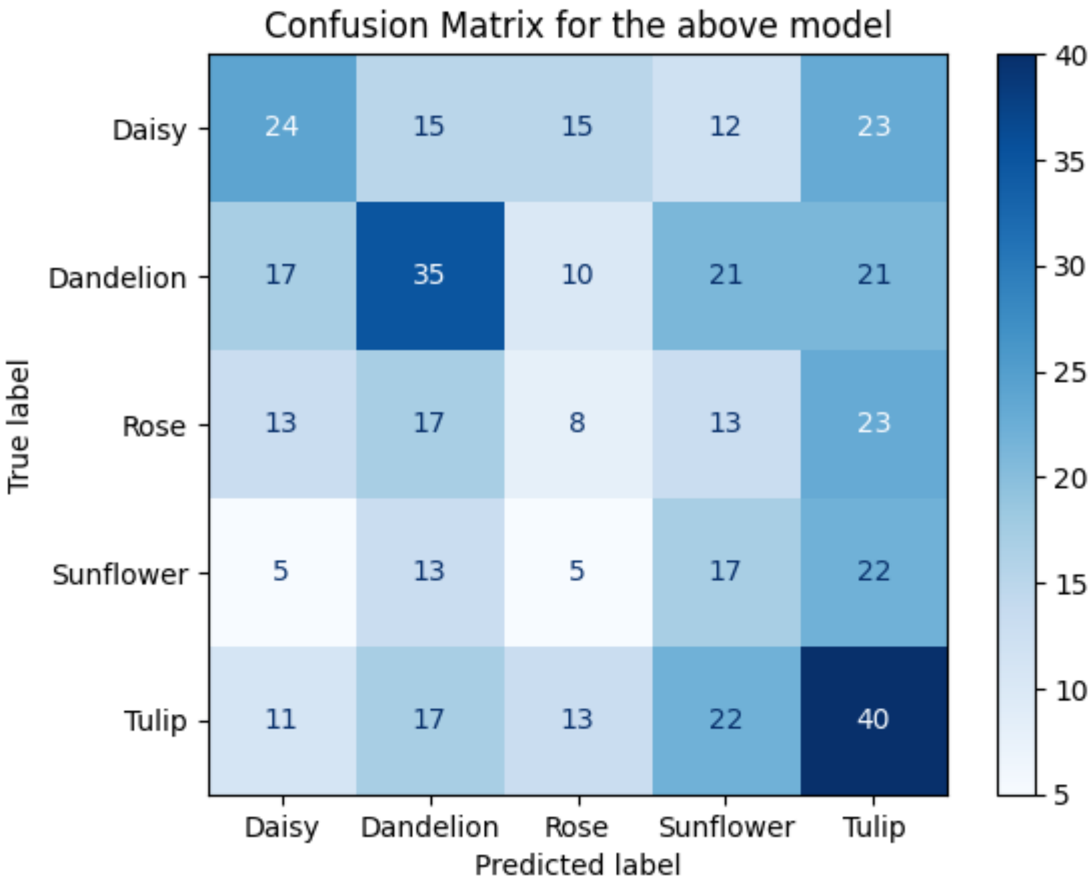
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 1



Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 1



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 33ms/step
```

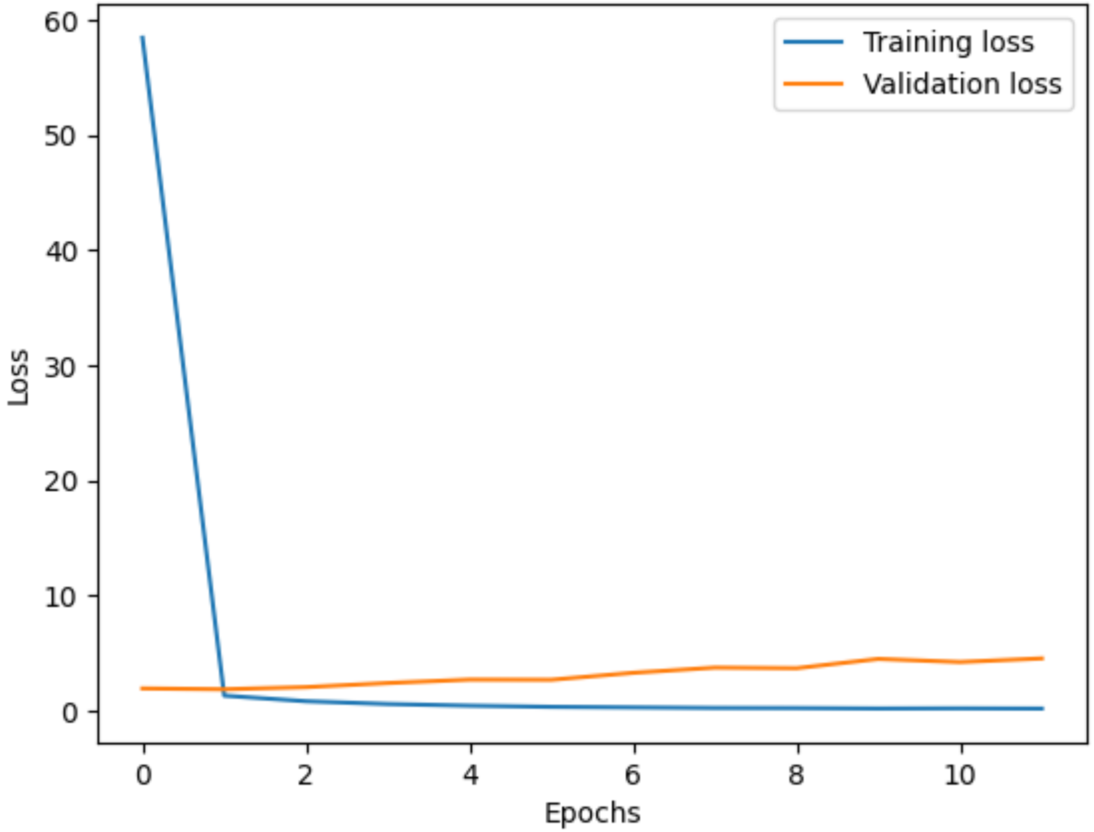


	Daisy	Dandelion	Rose	Sunflower	Tulip
Daisy	24	15	15	12	23
Dandelion	17	35	10	21	21
Rose	13	17	8	13	23
Sunflower	5	13	5	17	22
Tulip	11	17	13	22	40

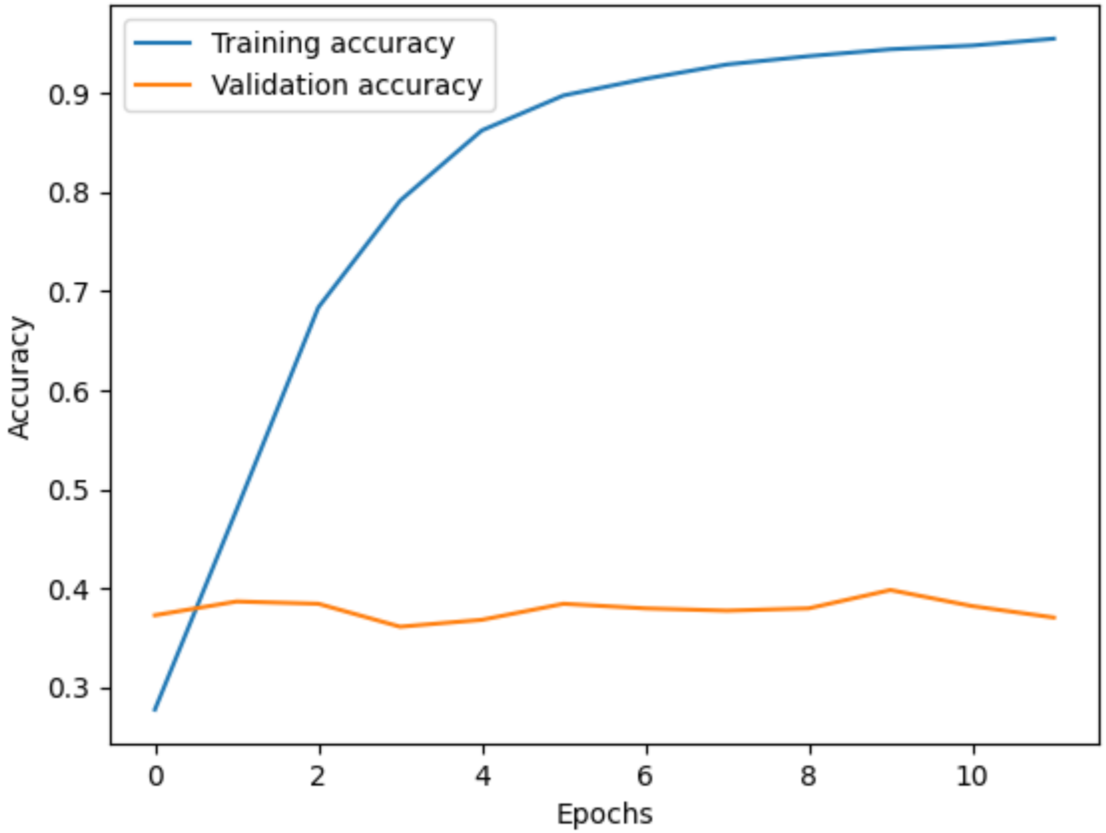
```
Model: "sequential_5"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_5 (Conv2D)                    │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_5 (MaxPooling2D)       │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_5 (Dropout)                  │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_5 (Flatten)                  │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_6 (Dense)                      │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_7 (Dense)                      │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_8 (Dense)                      │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,562,213 (5.96 MB)
```

```
Trainable params: 1,562,213 (5.96 MB)

Non-trainable params: 0 (0.00 B)

Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 117ms/step - accuracy: 0.2392 - f1_score: 0.2377 - loss: 159.1355 - val_accuracy: 0.3727 - val_
f1_score: 0.3513 - val_loss: 1.9389
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 103ms/step - accuracy: 0.4622 - f1_score: 0.4577 - loss: 1.3670 - val_accuracy: 0.3866 - val_f1
_score: 0.3790 - val_loss: 1.8688
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 22s 117ms/step - accuracy: 0.6879 - f1_score: 0.6870 - loss: 0.8206 - val_accuracy: 0.3843 - val_f1
_score: 0.3855 - val_loss: 2.0543
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 118ms/step - accuracy: 0.7927 - f1_score: 0.7936 - loss: 0.5902 - val_accuracy: 0.3611 - val_f1
_score: 0.3582 - val_loss: 2.4087
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 123ms/step - accuracy: 0.8671 - f1_score: 0.8675 - loss: 0.4360 - val_accuracy: 0.3681 - val_f1
_score: 0.3527 - val_loss: 2.7063
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 12s 114ms/step - accuracy: 0.9006 - f1_score: 0.9011 - loss: 0.3367 - val_accuracy: 0.3843 - val_f1
_score: 0.3803 - val_loss: 2.6917
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 116ms/step - accuracy: 0.9243 - f1_score: 0.9245 - loss: 0.2840 - val_accuracy: 0.3796 - val_f1
_score: 0.3780 - val_loss: 3.2956
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 121ms/step - accuracy: 0.9312 - f1_score: 0.9311 - loss: 0.2383 - val_accuracy: 0.3773 - val_f1
_score: 0.3839 - val_loss: 3.7464
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 114ms/step - accuracy: 0.9438 - f1_score: 0.9439 - loss: 0.2240 - val_accuracy: 0.3796 - val_f1
_score: 0.3733 - val_loss: 3.6956
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 121ms/step - accuracy: 0.9513 - f1_score: 0.9514 - loss: 0.1860 - val_accuracy: 0.3981 - val_f1
_score: 0.3870 - val_loss: 4.5019
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 121ms/step - accuracy: 0.9579 - f1_score: 0.9578 - loss: 0.1986 - val_accuracy: 0.3819 - val_f1
_score: 0.3613 - val_loss: 4.2326
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 113ms/step - accuracy: 0.9680 - f1_score: 0.9681 - loss: 0.1501 - val_accuracy: 0.3704 - val_f1
_score: 0.3652 - val_loss: 4.5444
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 31ms/step - accuracy: 0.3901 - f1_score: 0.3797 - loss: 1.7396
Test Loss: 1.8127901554107666, Test Accuracy: 0.38425925374031067, Test F1 Score: 0.3741406202316284
Time required to train the model is 217.4804346561432 seconds
```

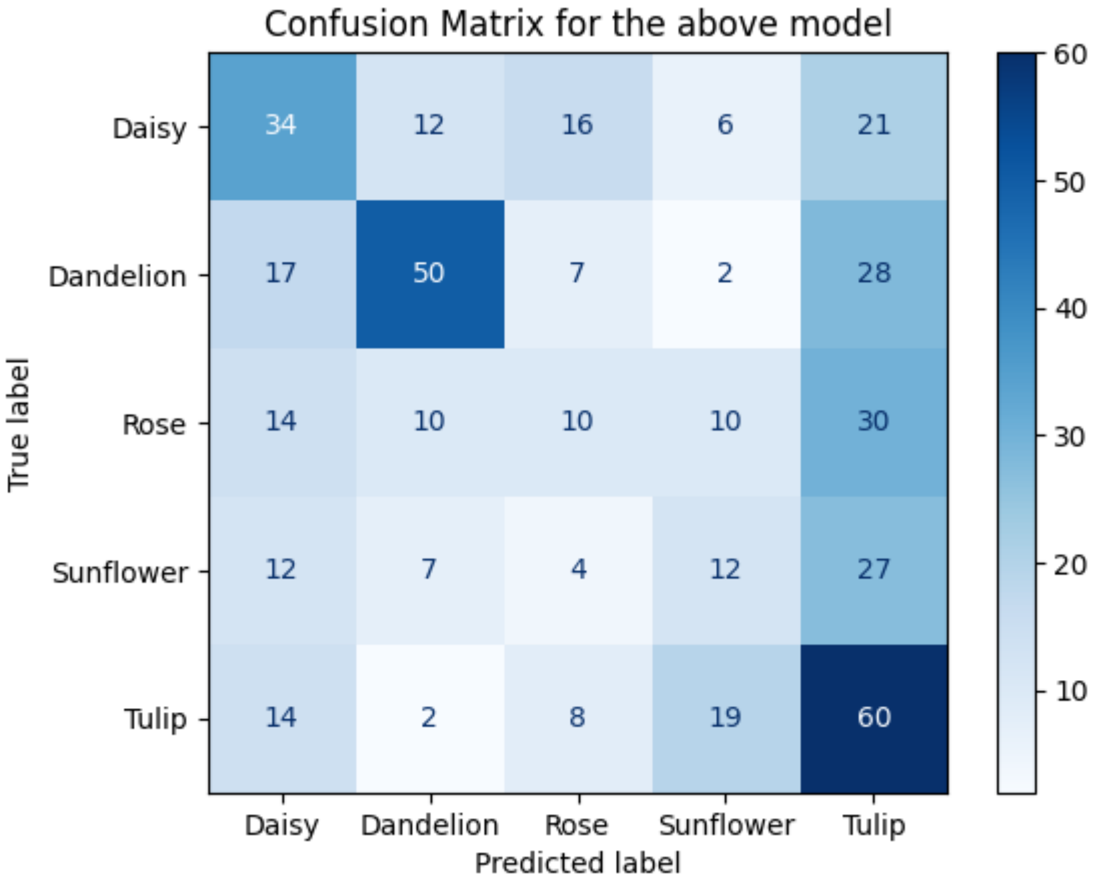
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 36ms/step
```

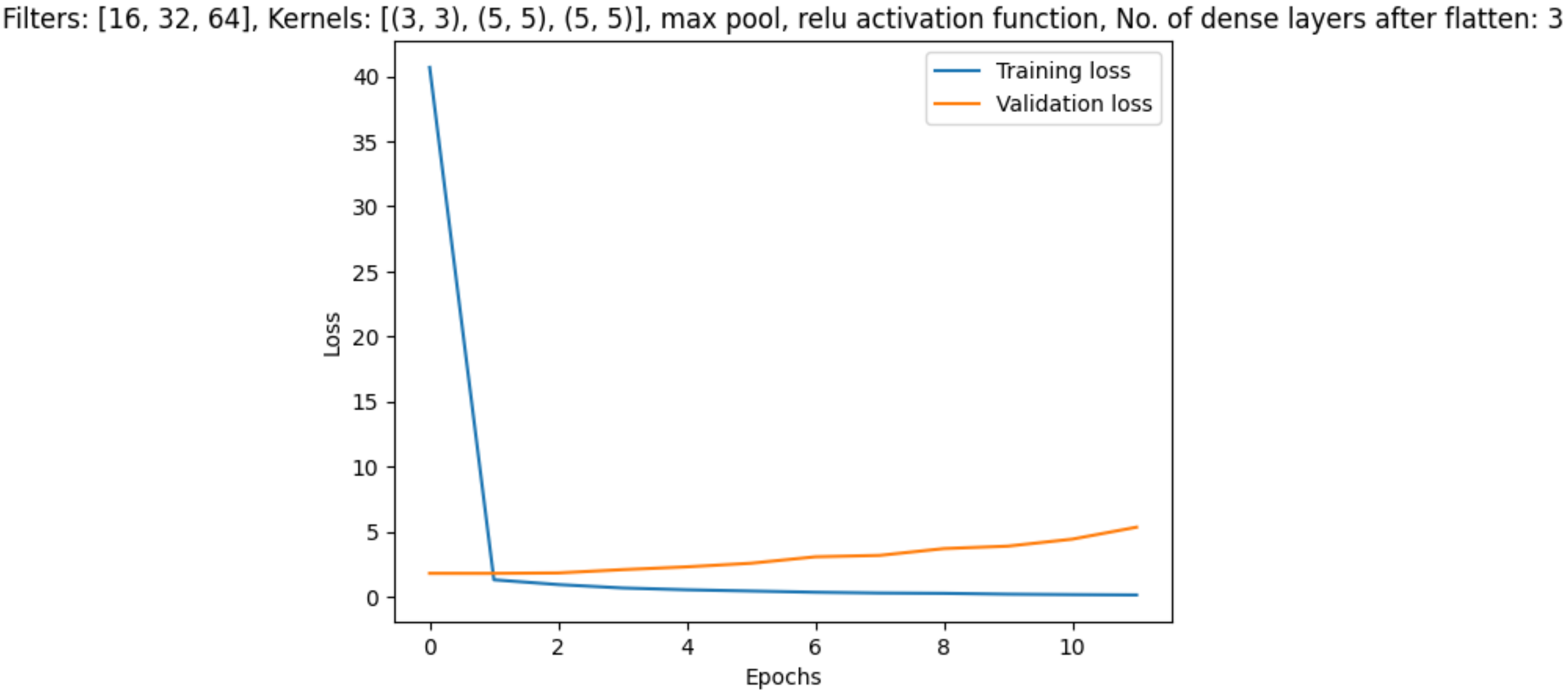


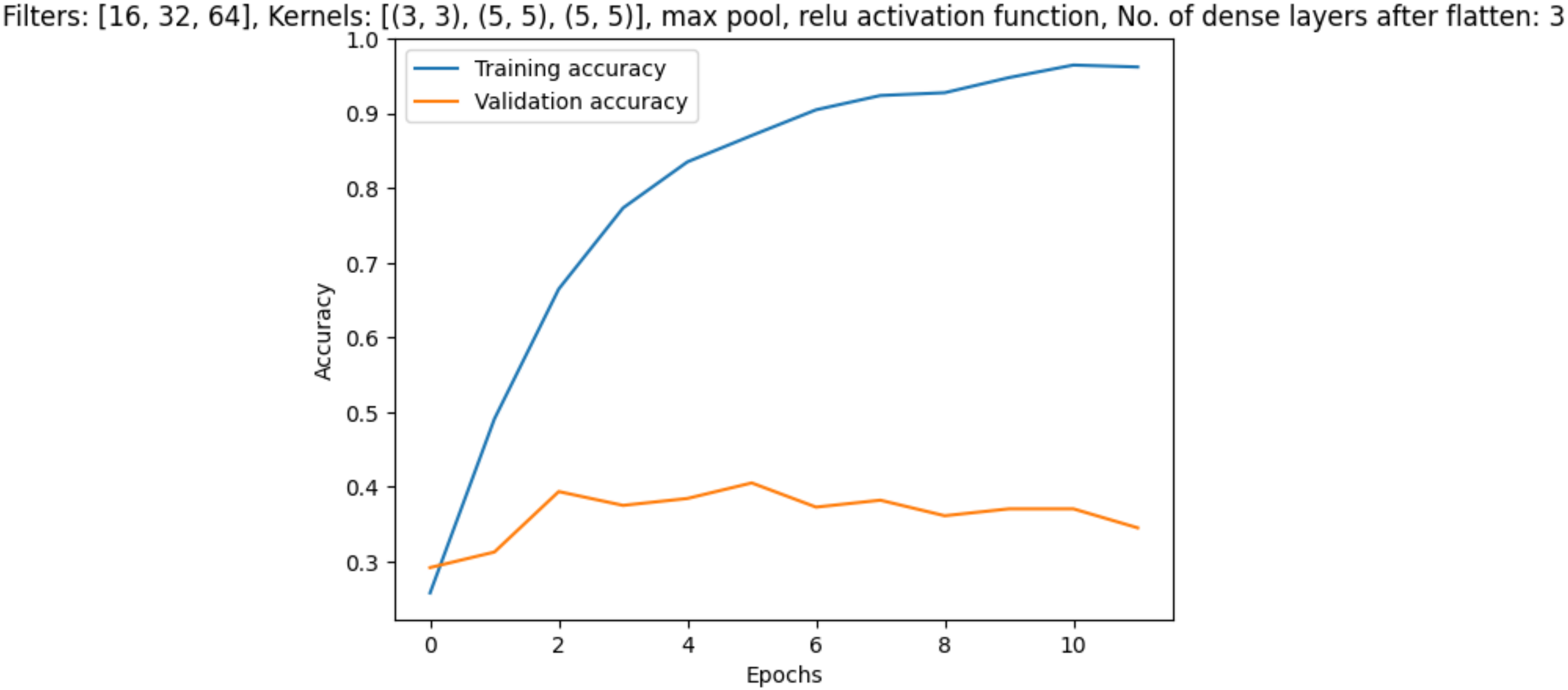
True label \ Predicted label	Daisy	Dandelion	Rose	Sunflower	Tulip
Daisy	34	12	16	6	21
Dandelion	17	50	7	2	28
Rose	14	10	10	10	30
Sunflower	12	7	4	12	27
Tulip	14	2	8	19	60

```
Model: "sequential_6"
```

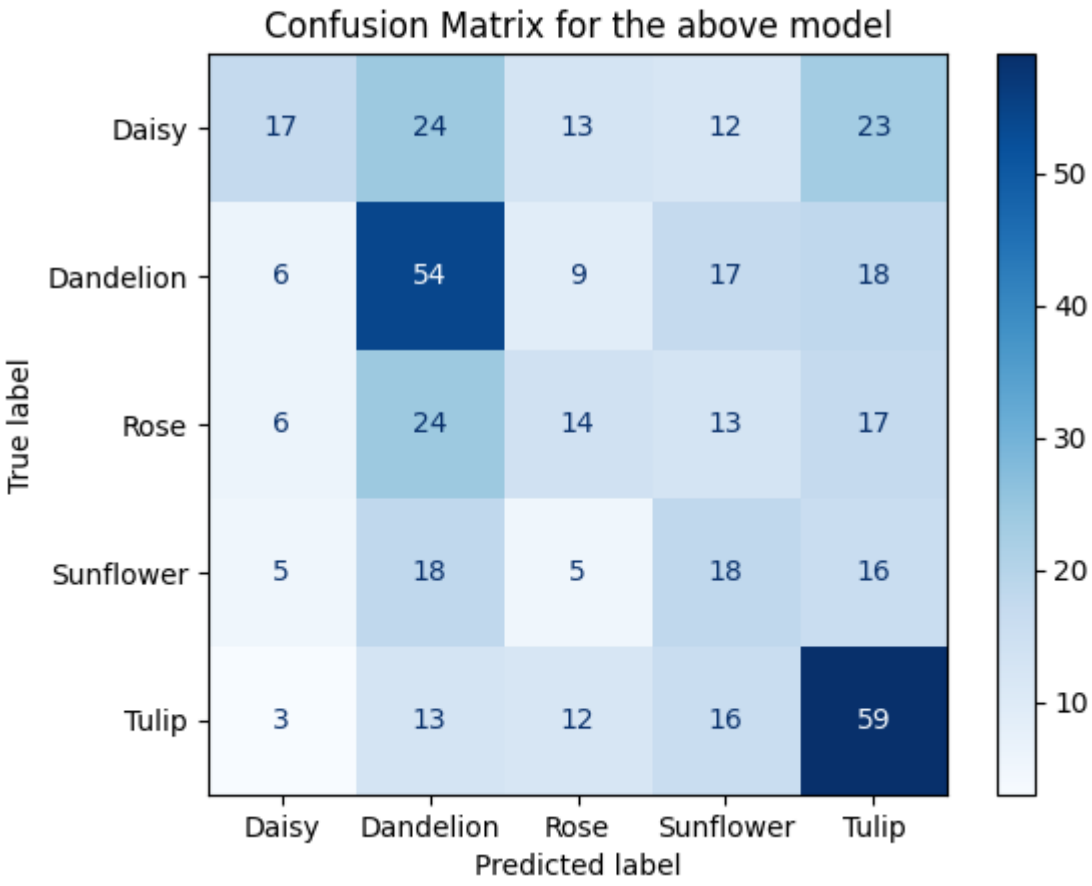
```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_6 (Conv2D)                    │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_6 (MaxPooling2D)       │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_6 (Dropout)                  │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_6 (Flatten)                  │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_9 (Dense)                      │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_10 (Dense)                     │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_11 (Dense)                     │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_12 (Dense)                     │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,566,373 (5.98 MB)
 Trainable params: 1,566,373 (5.98 MB)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 16s 124ms/step - accuracy: 0.2292 - f1_score: 0.2270 - loss: 110.7956 - val_accuracy: 0.2917 - val_
f1_score: 0.2805 - val_loss: 1.8010
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 126ms/step - accuracy: 0.4593 - f1_score: 0.4495 - loss: 1.3546 - val_accuracy: 0.3125 - val_f1
_score: 0.2987 - val_loss: 1.7974
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 124ms/step - accuracy: 0.6648 - f1_score: 0.6635 - loss: 0.9455 - val_accuracy: 0.3935 - val_f1
_score: 0.3877 - val_loss: 1.8300
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 127ms/step - accuracy: 0.7984 - f1_score: 0.8000 - loss: 0.6543 - val_accuracy: 0.3750 - val_f1
_score: 0.3600 - val_loss: 2.0824
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 114ms/step - accuracy: 0.8577 - f1_score: 0.8576 - loss: 0.4979 - val_accuracy: 0.3843 - val_f1
_score: 0.3739 - val_loss: 2.2979
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 12s 113ms/step - accuracy: 0.8861 - f1_score: 0.8868 - loss: 0.4069 - val_accuracy: 0.4051 - val_f1
_score: 0.3954 - val_loss: 2.5747
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 114ms/step - accuracy: 0.9052 - f1_score: 0.9056 - loss: 0.3497 - val_accuracy: 0.3727 - val_f1
_score: 0.3661 - val_loss: 3.0689
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 108ms/step - accuracy: 0.9304 - f1_score: 0.9306 - loss: 0.2558 - val_accuracy: 0.3819 - val_f1
_score: 0.3723 - val_loss: 3.1783
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 117ms/step - accuracy: 0.9318 - f1_score: 0.9319 - loss: 0.2608 - val_accuracy: 0.3611 - val_f1
_score: 0.3570 - val_loss: 3.6998
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 125ms/step - accuracy: 0.9557 - f1_score: 0.9558 - loss: 0.1828 - val_accuracy: 0.3704 - val_f1
_score: 0.3655 - val_loss: 3.8902
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 118ms/step - accuracy: 0.9671 - f1_score: 0.9671 - loss: 0.1501 - val_accuracy: 0.3704 - val_f1
_score: 0.3670 - val_loss: 4.4280
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 126ms/step - accuracy: 0.9656 - f1_score: 0.9656 - loss: 0.1274 - val_accuracy: 0.3449 - val_f1
_score: 0.3397 - val_loss: 5.3462
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 34ms/step - accuracy: 0.3728 - f1_score: 0.3530 - loss: 1.7272
Test Loss: 1.7116447687149048, Test Accuracy: 0.375, Test F1 Score: 0.3597155809402466
Time required to train the model is 219.30019235610962 seconds
```


Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 3
Training loss
Validation loss
Loss
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
Epochs



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 50ms/step
```



	Daisy	Dandelion	Rose	Sunflower	Tulip
Daisy	17	24	13	12	23
Dandelion	6	54	9	17	18
Rose	6	24	14	13	17
Sunflower	5	18	5	18	16
Tulip	3	13	12	16	59

In [ ]:

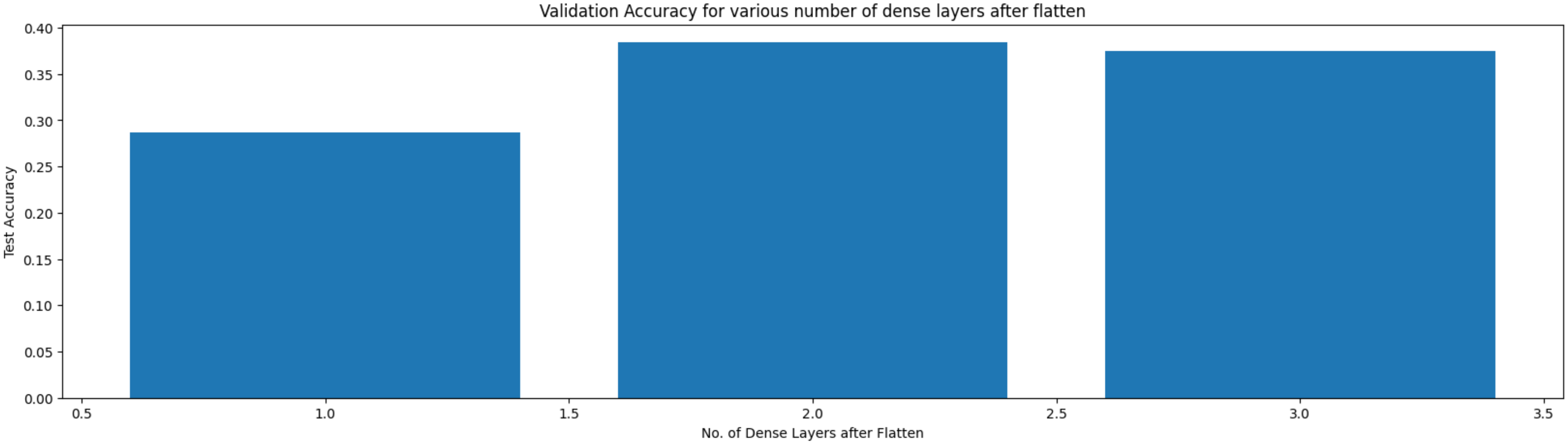
```
result_df_2
```

Out[ ]:

	Conv Kernel Size	Conv Filter Size	Pooling Layers	Activation Function	No. of Dense Layers after Flatten	Dropout Rate	Test Loss	Test Accuracy	Test F1 Score	Training Time(in seconds)
0	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	1	0.1	2.231380	0.287037	0.283371	208.502897
1	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.1	1.812790	0.384259	0.374141	217.480435
2	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	3	0.1	1.711645	0.375000	0.359716	219.300192

In [ ]:

```
plt.figure(figsize=(20,5))
plt.bar(
    result_df_2['No. of Dense Layers after Flatten'],
    result_df_2['Test Accuracy']
)

plt.ylabel('Test Accuracy')
plt.xlabel('No. of Dense Layers after Flatten')
plt.title('Validation Accuracy for various number of dense layers after flatten')
plt.show()
```



In [ ]:
```
best_num_dense = result_df_2.sort_values(
    by=['Test Accuracy','Test F1 Score'],
    ascending=[False,False]
)['No. of Dense Layers after Flatten'].iloc[0]

best_num_dense
```

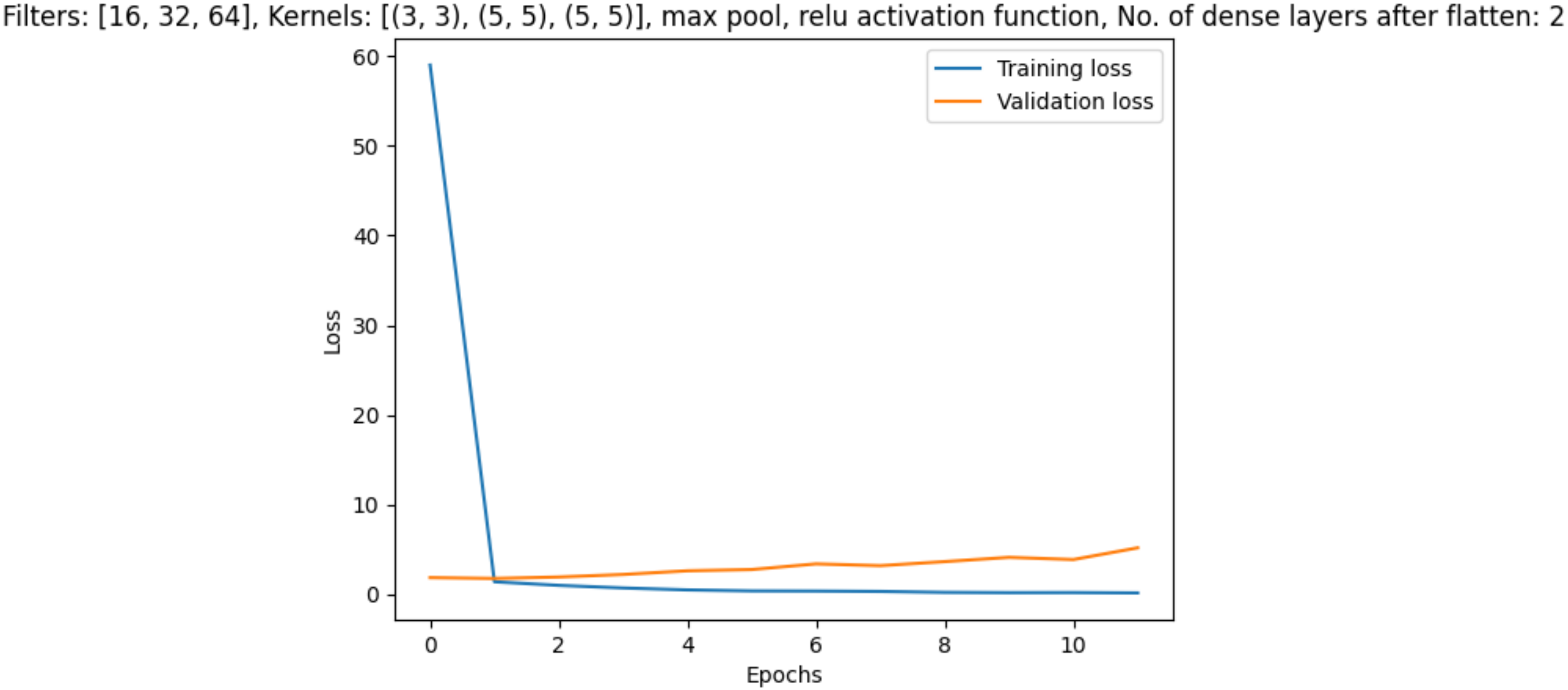
Out[ ]:
```
2
```

In [ ]:
```
## Subtask 3

result_df_3 = pd.DataFrame(
    columns=[
        'Conv Kernel Size',
        'Conv Filter Size',
        'Pooling Layers',
        'Activation Function',
        'No. of Dense Layers after Flatten',
        'Dropout Rate',
        'Test Loss',
        'Test Accuracy',
        'Test F1 Score',
        'Training Time(in seconds)'
    ]
)

filters = [16,32,64]
activation='relu'
dropout_rate = 0.1
pool=['max','avg']
epochs = 20

for p in pool:
  test_loss,test_accuracy,test_f1,train_time,_ = train_model(
      kernels=best_kernel,
      filters=filters,
      activation_func=activation,
      pool=p,
      dropout_rate=dropout_rate,
      num_dense_layers=best_num_dense,
      X_train=X_train,
      y_train=y_train,
      X_test=X_test,
      y_test=y_test,
      num_epochs=epochs
      )

  result_df_3.loc[len(result_df_3.index)]=[
      best_kernel,
      filters,
      p,
      activation,
      best_num_dense,
      dropout_rate,
      test_loss,
      test_accuracy,
      test_f1,
      train_time
  ]
```

```
Model: "sequential_7"
```

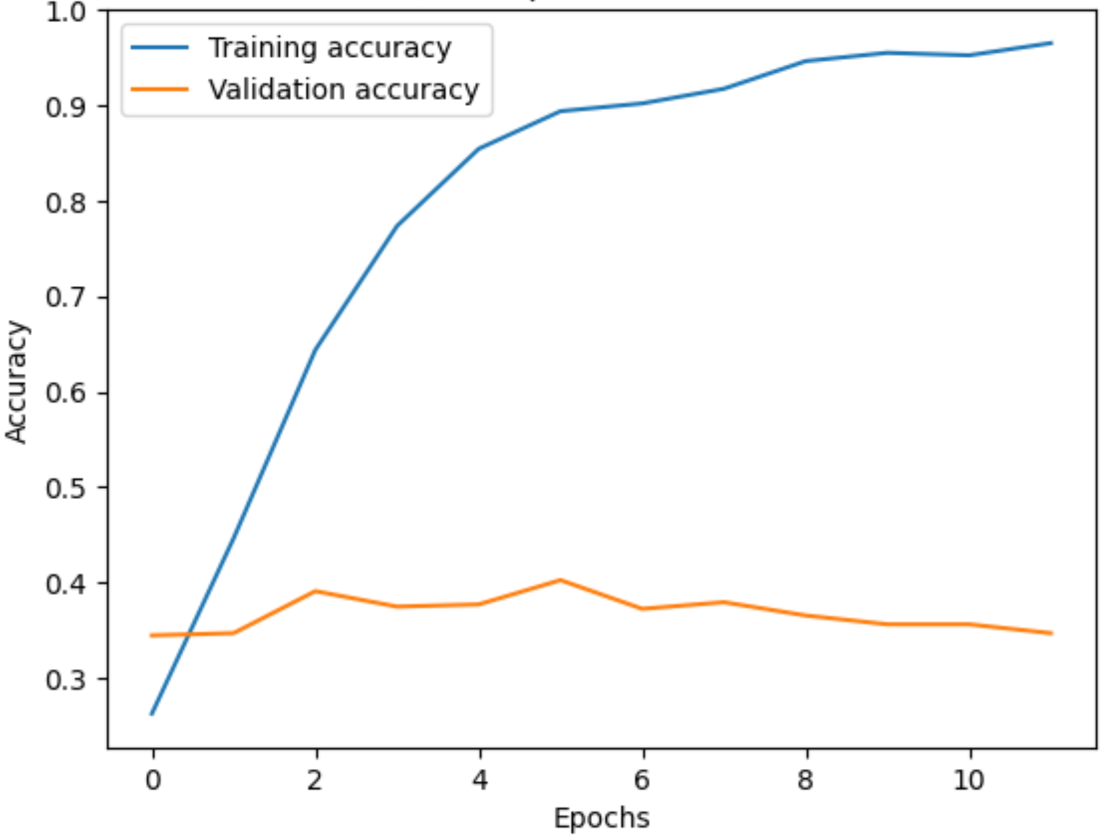
```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                          ┃ Output Shape                 ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_7 (Conv2D)                     │ (None, 78, 78, 16)           │             160 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ max_pooling2d_7 (MaxPooling2D)        │ (None, 39, 39, 16)           │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dropout_7 (Dropout)                   │ (None, 39, 39, 16)           │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ flatten_7 (Flatten)                   │ (None, 24336)                │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_13 (Dense)                      │ (None, 64)                   │       1,557,568 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_14 (Dense)                      │ (None, 64)                   │           4,160 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_15 (Dense)                      │ (None, 5)                    │             325 │
└───────────────────────────────────────┴──────────────────────────────┴─────────────────┘
 Total params: 1,562,213 (5.96 MB)
 Trainable params: 1,562,213 (5.96 MB)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 16s 121ms/step - accuracy: 0.2427 - f1_score: 0.2378 - loss: 160.6646 - val_accuracy: 0.3449 - val_
f1_score: 0.3434 - val_loss: 1.8507
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 123ms/step - accuracy: 0.4452 - f1_score: 0.4431 - loss: 1.4091 - val_accuracy: 0.3472 - val_f1
_score: 0.3418 - val_loss: 1.7605
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 17s 153ms/step - accuracy: 0.6456 - f1_score: 0.6436 - loss: 1.0002 - val_accuracy: 0.3912 - val_f1
_score: 0.3755 - val_loss: 1.9199
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 16s 109ms/step - accuracy: 0.7856 - f1_score: 0.7845 - loss: 0.6875 - val_accuracy: 0.3750 - val_f1
_score: 0.3702 - val_loss: 2.2030
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 118ms/step - accuracy: 0.8581 - f1_score: 0.8585 - loss: 0.4827 - val_accuracy: 0.3773 - val_f1
_score: 0.3655 - val_loss: 2.6122
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 104ms/step - accuracy: 0.9084 - f1_score: 0.9088 - loss: 0.3535 - val_accuracy: 0.4028 - val_f1
_score: 0.4009 - val_loss: 2.7527
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 22s 121ms/step - accuracy: 0.9149 - f1_score: 0.9149 - loss: 0.3241 - val_accuracy: 0.3727 - val_f1
_score: 0.3615 - val_loss: 3.3847
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 122ms/step - accuracy: 0.9254 - f1_score: 0.9254 - loss: 0.2878 - val_accuracy: 0.3796 - val_f1
_score: 0.3774 - val_loss: 3.1862
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 121ms/step - accuracy: 0.9517 - f1_score: 0.9520 - loss: 0.1843 - val_accuracy: 0.3657 - val_f1
_score: 0.3578 - val_loss: 3.6371
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 126ms/step - accuracy: 0.9589 - f1_score: 0.9590 - loss: 0.1612 - val_accuracy: 0.3565 - val_f1
_score: 0.3495 - val_loss: 4.1129
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 125ms/step - accuracy: 0.9620 - f1_score: 0.9620 - loss: 0.1529 - val_accuracy: 0.3565 - val_f1
_score: 0.3491 - val_loss: 3.8684
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 111ms/step - accuracy: 0.9588 - f1_score: 0.9589 - loss: 0.1641 - val_accuracy: 0.3472 - val_f1
_score: 0.3284 - val_loss: 5.1755
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.3671 - f1_score: 0.3718 - loss: 1.8074
Test Loss: 1.7586485147476196, Test Accuracy: 0.375, Test F1 Score: 0.36847788095474243
Time required to train the model is 227.50457501411438 seconds
```

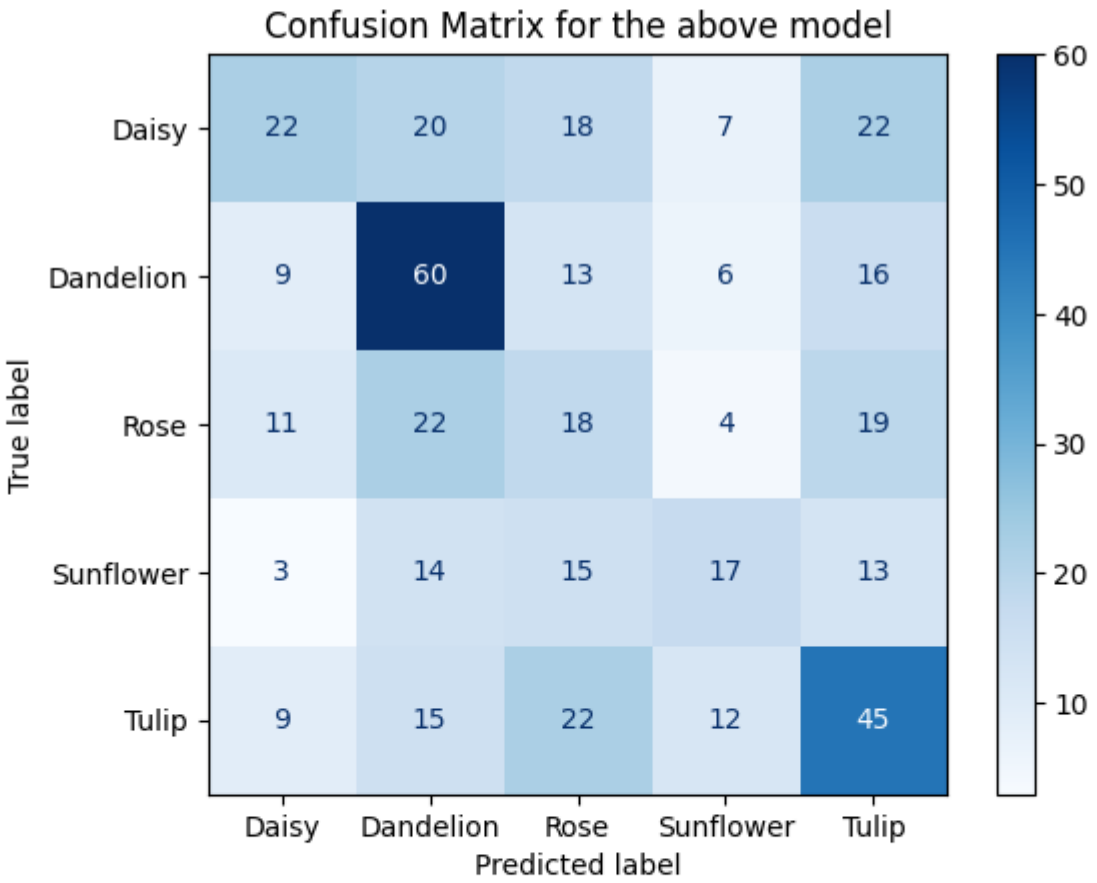


Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

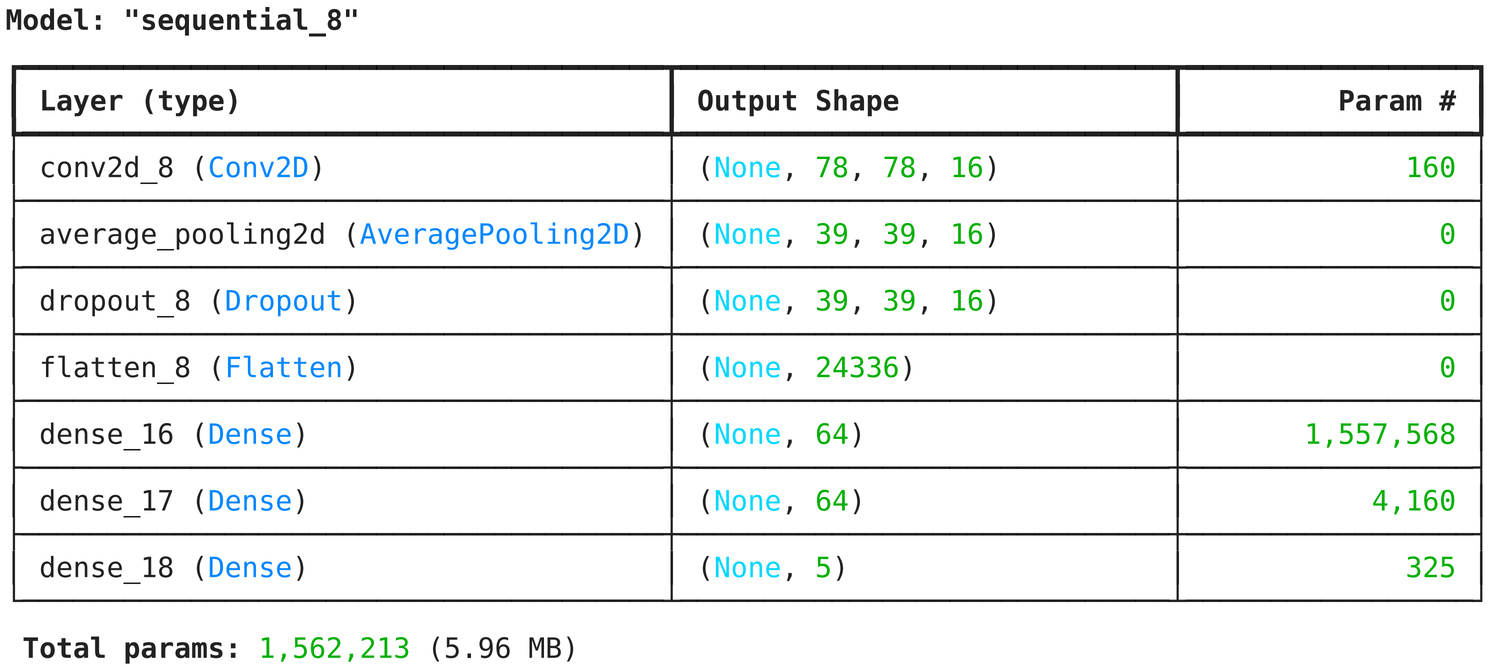


```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 33ms/step
```



Confusion Matrix for the above model

True label \ Predicted label	Daisy	Dandelion	Rose	Sunflower	Tulip
Daisy	22	20	18	7	22
Dandelion	9	60	13	6	16
Rose	11	22	18	4	19
Sunflower	3	14	15	17	13
Tulip	9	15	22	12	45

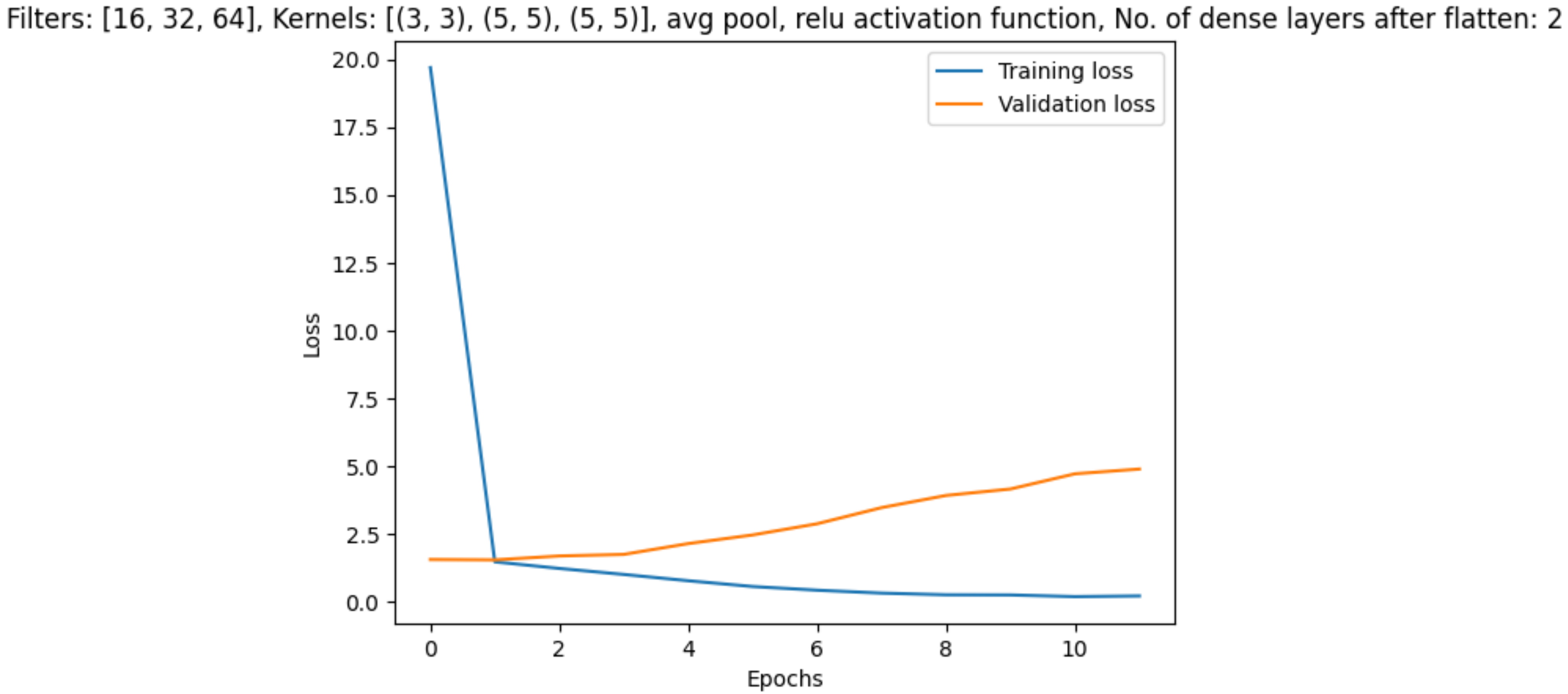


```
Model: "sequential_8"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_8 (Conv2D)                    │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ average_pooling2d (AveragePooling2D) │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_8 (Dropout)                  │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_8 (Flatten)                  │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_16 (Dense)                     │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_17 (Dense)                     │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_18 (Dense)                     │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,562,213 (5.96 MB)
```

Trainable params: 1,562,213 (5.96 MB)

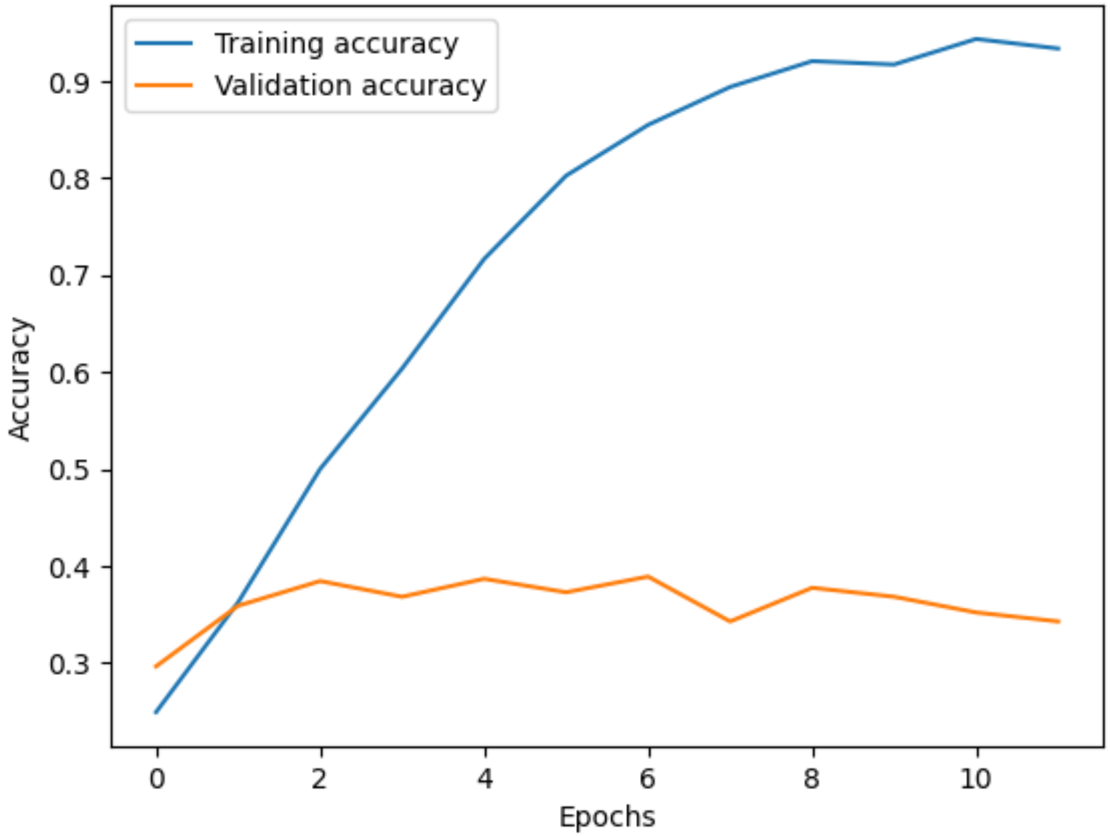
Non-trainable params: 0 (0.00 B)

```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 116ms/step - accuracy: 0.2262 - f1_score: 0.2208 - loss: 61.0823 - val_accuracy: 0.2963 - val_f
1_score: 0.2594 - val_loss: 1.5667
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 116ms/step - accuracy: 0.3516 - f1_score: 0.3497 - loss: 1.4920 - val_accuracy: 0.3588 - val_f1
_score: 0.3571 - val_loss: 1.5527
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 119ms/step - accuracy: 0.4960 - f1_score: 0.4950 - loss: 1.2497 - val_accuracy: 0.3843 - val_f1
_score: 0.3794 - val_loss: 1.6961
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 126ms/step - accuracy: 0.6142 - f1_score: 0.6156 - loss: 1.0053 - val_accuracy: 0.3681 - val_f1
_score: 0.3668 - val_loss: 1.7546
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 120ms/step - accuracy: 0.7288 - f1_score: 0.7291 - loss: 0.7755 - val_accuracy: 0.3866 - val_f1
_score: 0.3760 - val_loss: 2.1521
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 113ms/step - accuracy: 0.8187 - f1_score: 0.8197 - loss: 0.5467 - val_accuracy: 0.3727 - val_f1
_score: 0.3683 - val_loss: 2.4708
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 12s 111ms/step - accuracy: 0.8703 - f1_score: 0.8708 - loss: 0.4074 - val_accuracy: 0.3889 - val_f1
_score: 0.3676 - val_loss: 2.8826
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 119ms/step - accuracy: 0.9069 - f1_score: 0.9071 - loss: 0.2996 - val_accuracy: 0.3426 - val_f1
_score: 0.3429 - val_loss: 3.4772
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 118ms/step - accuracy: 0.9214 - f1_score: 0.9215 - loss: 0.2600 - val_accuracy: 0.3773 - val_f1
_score: 0.3615 - val_loss: 3.9255
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 116ms/step - accuracy: 0.9221 - f1_score: 0.9222 - loss: 0.2445 - val_accuracy: 0.3681 - val_f1
_score: 0.3384 - val_loss: 4.1631
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 119ms/step - accuracy: 0.9474 - f1_score: 0.9475 - loss: 0.1959 - val_accuracy: 0.3519 - val_f1
_score: 0.3384 - val_loss: 4.7231
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 110ms/step - accuracy: 0.9438 - f1_score: 0.9438 - loss: 0.1878 - val_accuracy: 0.3426 - val_f1
_score: 0.3288 - val_loss: 4.8987
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 38ms/step - accuracy: 0.3504 - f1_score: 0.3421 - loss: 1.5816
Test Loss: 1.5979018211364746, Test Accuracy: 0.32175925374031067, Test F1 Score: 0.3118511438369751
Time required to train the model is 208.19212317466736 seconds
```

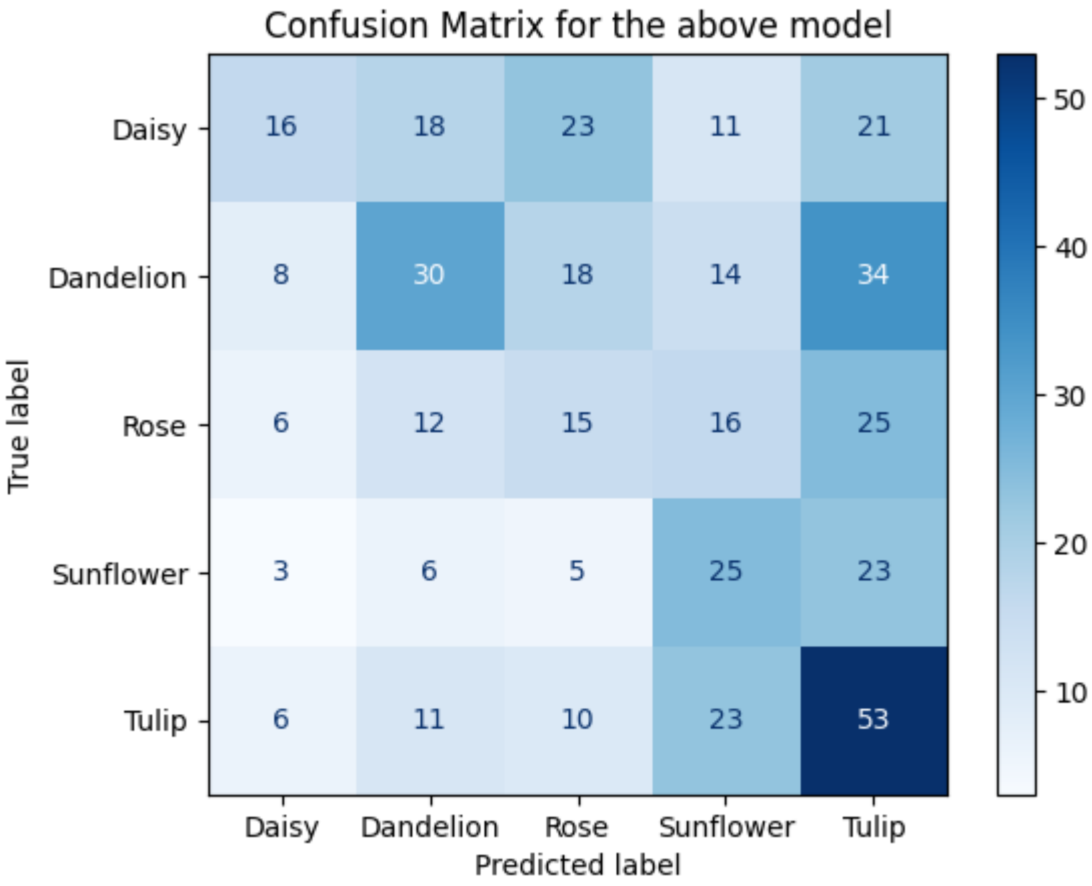


Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], avg pool, relu activation function, No. of dense layers after flatten: 2

Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], avg pool, relu activation function, No. of dense layers after flatten: 2



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 61ms/step
```

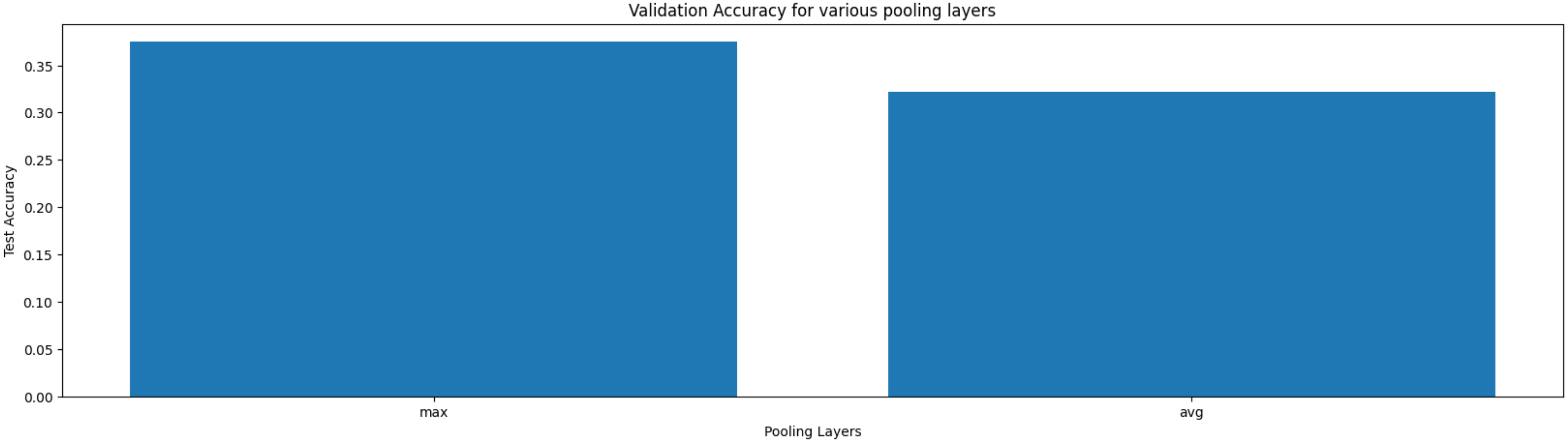


In [ ]:
```
result_df_3
```

Out[ ]:

	Conv Kernel Size	Conv Filter Size	Pooling Layers	Activation Function	No. of Dense Layers after Flatten	Dropout Rate	Test Loss	Test Accuracy	Test F1 Score	Training Time(in seconds)
0	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.1	1.758649	0.375000	0.368478	227.504575
1	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	avg	relu	2	0.1	1.597902	0.321759	0.311851	208.192123

In [ ]:
```
plt.figure(figsize=(20,5))
plt.bar(
    result_df_3['Pooling Layers'],
    result_df_3['Test Accuracy']
)

plt.ylabel('Test Accuracy')
plt.xlabel('Pooling Layers')
plt.title('Validation Accuracy for various pooling layers')
plt.show()
```

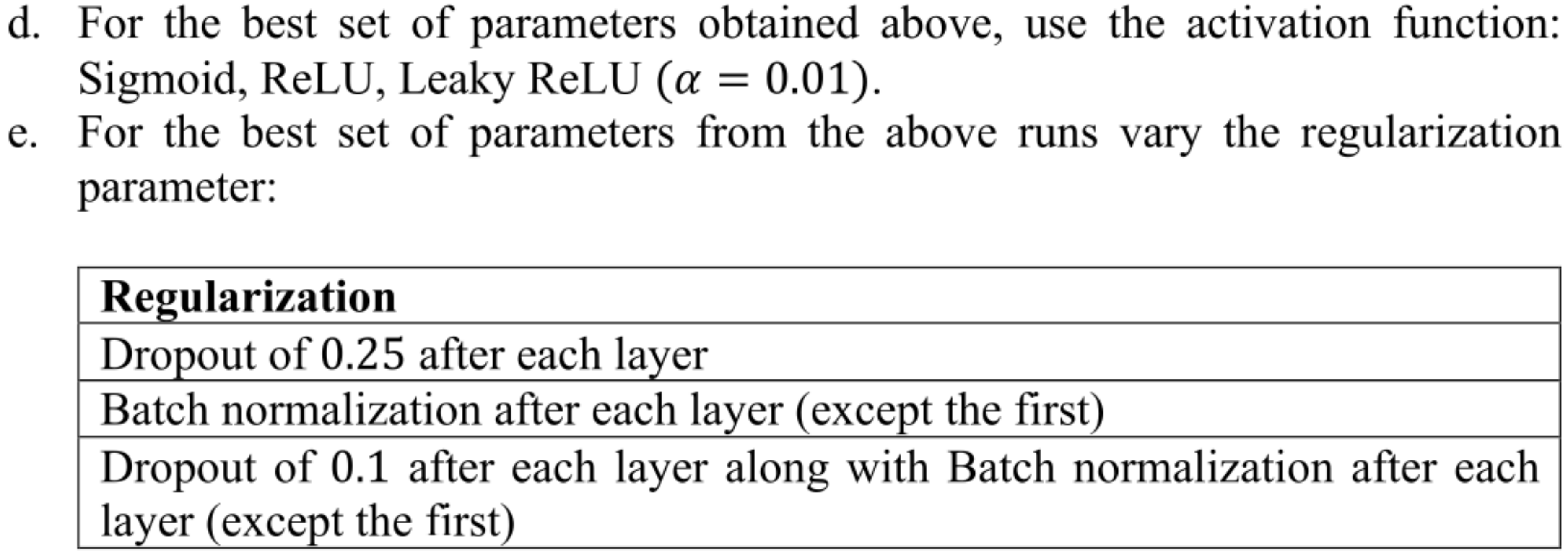


In [ ]:

```
best_pool = result_df_3.sort_values(
    by=['Test Accuracy','Test F1 Score'],
    ascending=[False,False]
)['Pooling Layers'].iloc[0]

best_pool
```

Out[ ]:

```
'max'
```



d. For the best set of parameters obtained above, use the activation function: Sigmoid, ReLU, Leaky ReLU ($\alpha = 0.01$).

e. For the best set of parameters from the above runs vary the regularization parameter:

Regularization
Dropout of 0.25 after each layer
Batch normalization after each layer (except the first)
Dropout of 0.1 after each layer along with Batch normalization after each layer (except the first)

In [ ]:

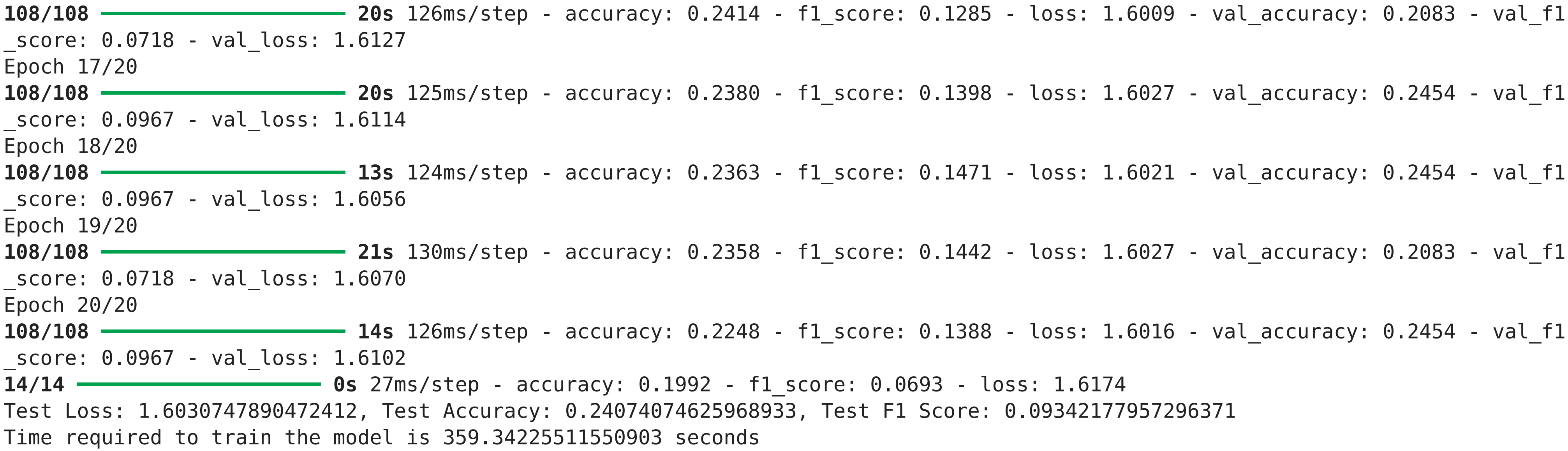
```
# Subtask 4

result_df_4 = pd.DataFrame(
    columns=[
        'Conv Kernel Size',
        'Conv Filter Size',
        'Pooling Layers',
        'Activation Function',
        'No. of Dense Layers after Flatten',
        'Dropout Rate',
        'Test Loss',
        'Test Accuracy',
        'Test F1 Score',
        'Training Time(in seconds)'
    ]
)

filters = [16,32,64]
activation_list=['sigmoid','relu','leaky_relu']
dropout_rate = 0.1
epochs = 20

for activation in activation_list:
```

```
test_loss,test_accuracy,test_f1,train_time,_ = train_model(
    kernels=best_kernel,
    filters=filters,
    activation_func=activation,
    pool=best_pool,
    dropout_rate=dropout_rate,
    num_dense_layers=best_num_dense,
    X_train=X_train,
    y_train=y_train,
    X_test=X_test,
    y_test=y_test,
    num_epochs=epochs
    )

result_df_4.loc[len(result_df_4.index)]=[
    best_kernel,
    filters,
    best_pool,
    activation,
    best_num_dense,
    dropout_rate,
    test_loss,
    test_accuracy,
    test_f1,
    train_time
]
```

```
Model: "sequential_9"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                          ┃ Output Shape                 ┃          Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━┩
│ conv2d_9 (Conv2D)                     │ (None, 78, 78, 16)           │              160 │
├───────────────────────────────────────┼──────────────────────────────┼──────────────────┤
│ max_pooling2d_8 (MaxPooling2D)        │ (None, 39, 39, 16)           │                0 │
├───────────────────────────────────────┼──────────────────────────────┼──────────────────┤
│ dropout_9 (Dropout)                   │ (None, 39, 39, 16)           │                0 │
├───────────────────────────────────────┼──────────────────────────────┼──────────────────┤
│ flatten_9 (Flatten)                   │ (None, 24336)                │                0 │
├───────────────────────────────────────┼──────────────────────────────┼──────────────────┤
│ dense_19 (Dense)                      │ (None, 64)                   │        1,557,568 │
├───────────────────────────────────────┼──────────────────────────────┼──────────────────┤
│ dense_20 (Dense)                      │ (None, 64)                   │            4,160 │
├───────────────────────────────────────┼──────────────────────────────┼──────────────────┤
│ dense_21 (Dense)                      │ (None, 5)                    │              325 │
└───────────────────────────────────────┴──────────────────────────────┴──────────────────┘
 Total params: 1,562,213 (5.96 MB)
```

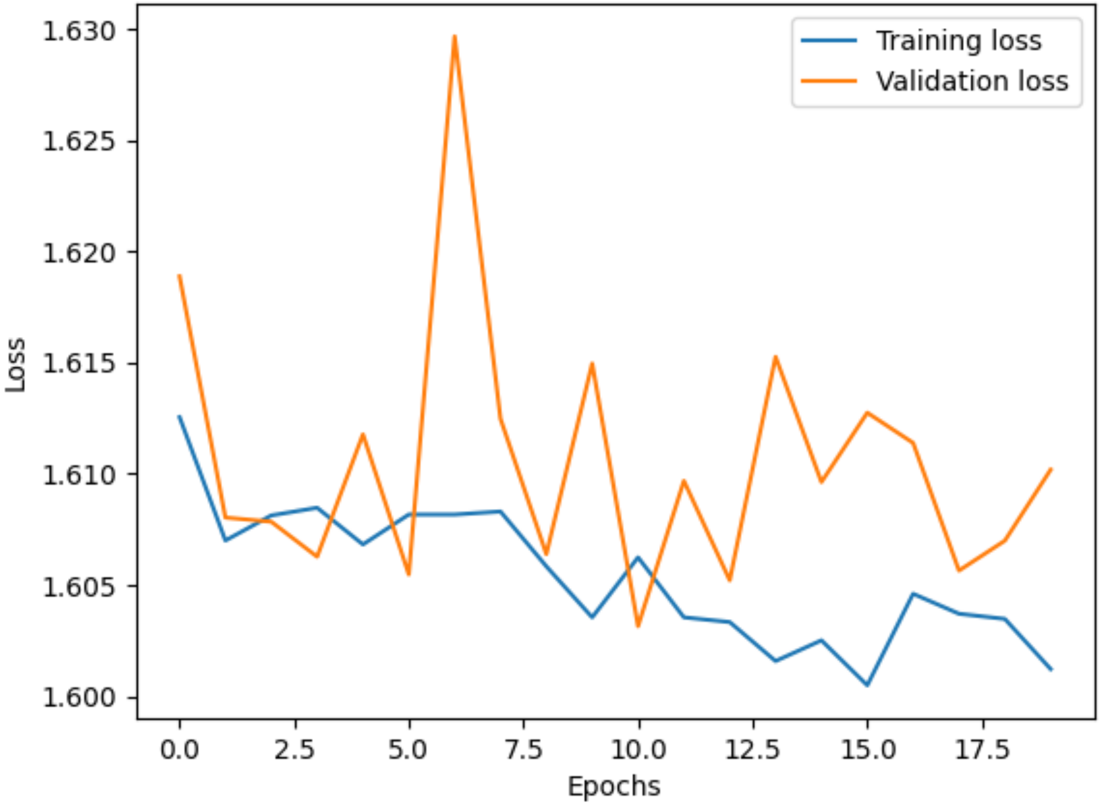
```
Trainable params: 1,562,213 (5.96 MB)
Non-trainable params: 0 (0.00 B)
```

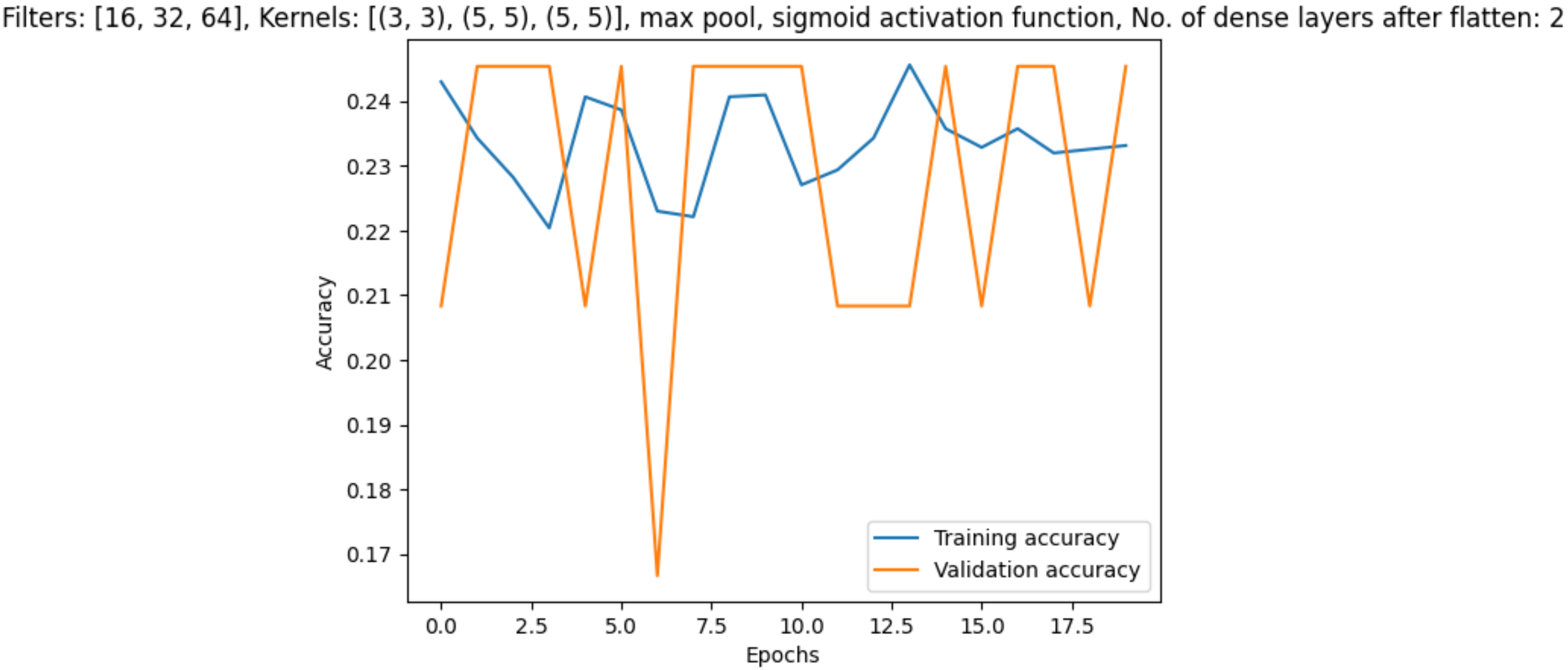
```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 16s 132ms/step - accuracy: 0.2421 - f1_score: 0.1551 - loss: 1.6267 - val_accuracy: 0.2083 - val_f1
_score: 0.0718 - val_loss: 1.6189
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 127ms/step - accuracy: 0.2324 - f1_score: 0.1425 - loss: 1.6046 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6080
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 127ms/step - accuracy: 0.2201 - f1_score: 0.1440 - loss: 1.6107 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6078
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 128ms/step - accuracy: 0.2356 - f1_score: 0.1390 - loss: 1.6060 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6063
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 124ms/step - accuracy: 0.2345 - f1_score: 0.1568 - loss: 1.6080 - val_accuracy: 0.2083 - val_f1
_score: 0.0718 - val_loss: 1.6118
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 131ms/step - accuracy: 0.2374 - f1_score: 0.1460 - loss: 1.6078 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6055
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 125ms/step - accuracy: 0.2348 - f1_score: 0.1685 - loss: 1.6052 - val_accuracy: 0.1667 - val_f1
_score: 0.0476 - val_loss: 1.6297
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 132ms/step - accuracy: 0.2182 - f1_score: 0.1514 - loss: 1.6066 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6125
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 135ms/step - accuracy: 0.2389 - f1_score: 0.1484 - loss: 1.6066 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6064
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 125ms/step - accuracy: 0.2362 - f1_score: 0.1282 - loss: 1.6092 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6150
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 131ms/step - accuracy: 0.2188 - f1_score: 0.1356 - loss: 1.6072 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6031
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 127ms/step - accuracy: 0.2338 - f1_score: 0.1268 - loss: 1.6042 - val_accuracy: 0.2083 - val_f1
_score: 0.0718 - val_loss: 1.6097
Epoch 13/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 134ms/step - accuracy: 0.2351 - f1_score: 0.1485 - loss: 1.6040 - val_accuracy: 0.2083 - val_f1
_score: 0.0718 - val_loss: 1.6052
Epoch 14/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 130ms/step - accuracy: 0.2425 - f1_score: 0.1369 - loss: 1.5992 - val_accuracy: 0.2083 - val_f1
_score: 0.0718 - val_loss: 1.6153
Epoch 15/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 131ms/step - accuracy: 0.2336 - f1_score: 0.1402 - loss: 1.6065 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6096
Epoch 16/20
```



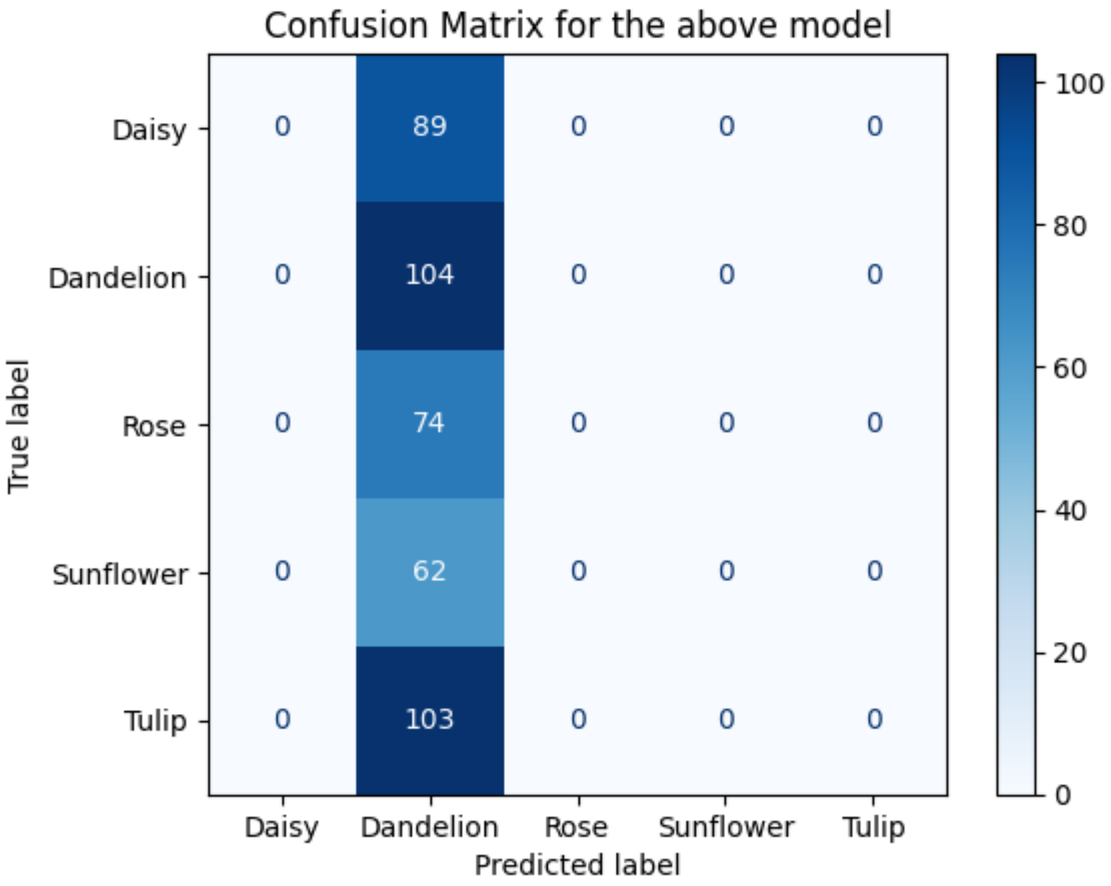
```
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 126ms/step - accuracy: 0.2414 - f1_score: 0.1285 - loss: 1.6009 - val_accuracy: 0.2083 - val_f1
_score: 0.0718 - val_loss: 1.6127
Epoch 17/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 125ms/step - accuracy: 0.2380 - f1_score: 0.1398 - loss: 1.6027 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6114
Epoch 18/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 124ms/step - accuracy: 0.2363 - f1_score: 0.1471 - loss: 1.6021 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6056
Epoch 19/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 130ms/step - accuracy: 0.2358 - f1_score: 0.1442 - loss: 1.6027 - val_accuracy: 0.2083 - val_f1
_score: 0.0718 - val_loss: 1.6070
Epoch 20/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 126ms/step - accuracy: 0.2248 - f1_score: 0.1388 - loss: 1.6016 - val_accuracy: 0.2454 - val_f1
_score: 0.0967 - val_loss: 1.6102
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.1992 - f1_score: 0.0693 - loss: 1.6174
Test Loss: 1.6030747890472412, Test Accuracy: 0.24074074625968933, Test F1 Score: 0.09342177957296371
Time required to train the model is 359.34225511550903 seconds
```

Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, sigmoid activation function, No. of dense layers after flatten: 2



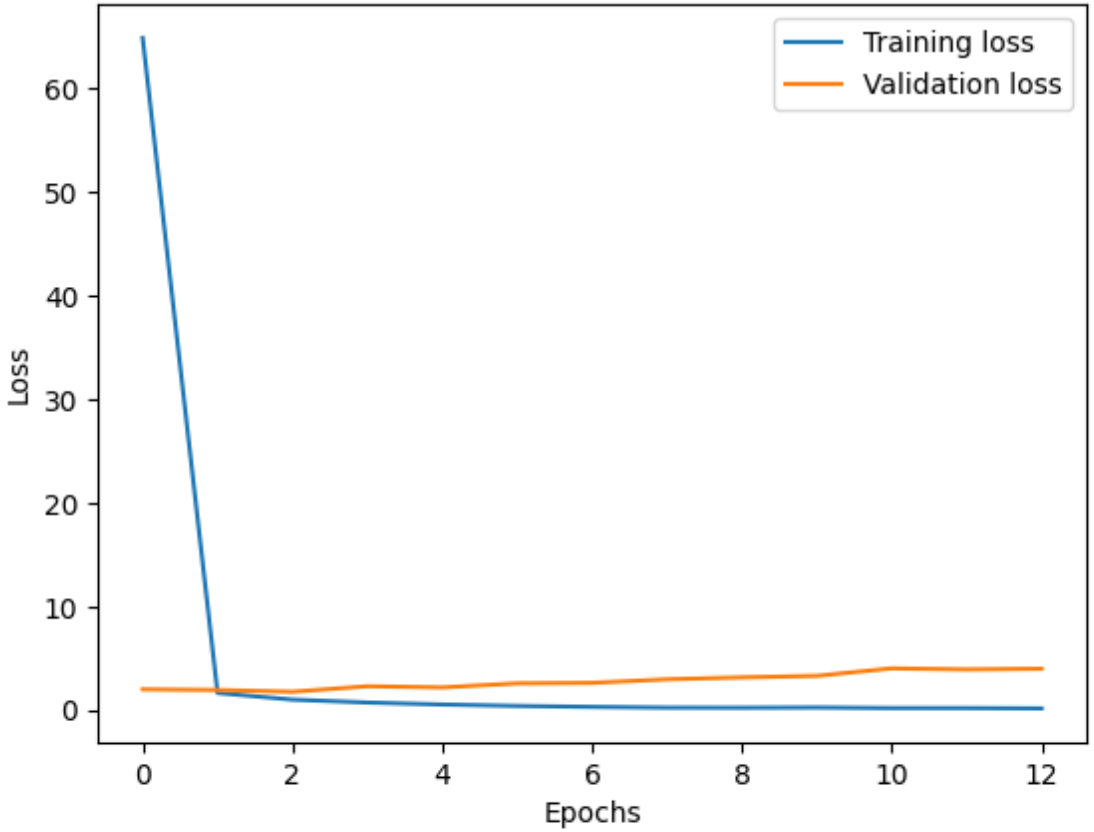


```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 35ms/step
```



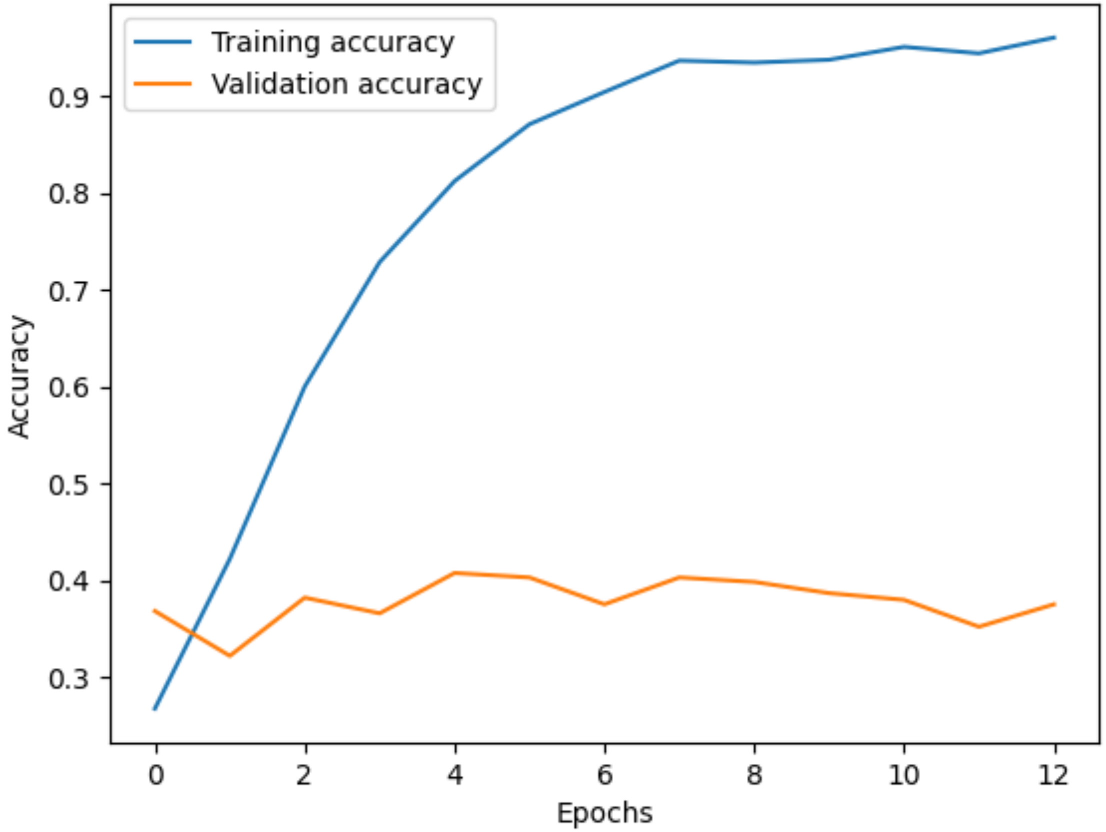
```
Model: "sequential_10"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_10 (Conv2D)                   │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_9 (MaxPooling2D)       │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_10 (Dropout)                 │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_10 (Flatten)                 │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_22 (Dense)                     │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_23 (Dense)                     │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_24 (Dense)                     │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,562,213 (5.96 MB)
```

```
Trainable params: 1,562,213 (5.96 MB)

Non-trainable params: 0 (0.00 B)

Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 126ms/step - accuracy: 0.2408 - f1_score: 0.2380 - loss: 189.2480 - val_accuracy: 0.3681 - val_
f1_score: 0.3521 - val_loss: 2.0062
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 121ms/step - accuracy: 0.4189 - f1_score: 0.4185 - loss: 1.7014 - val_accuracy: 0.3218 - val_f1
_score: 0.2767 - val_loss: 1.9406
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 121ms/step - accuracy: 0.6098 - f1_score: 0.6088 - loss: 0.9774 - val_accuracy: 0.3819 - val_f1
_score: 0.3697 - val_loss: 1.7696
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 125ms/step - accuracy: 0.7290 - f1_score: 0.7298 - loss: 0.7256 - val_accuracy: 0.3657 - val_f1
_score: 0.3478 - val_loss: 2.3024
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 134ms/step - accuracy: 0.8288 - f1_score: 0.8298 - loss: 0.5196 - val_accuracy: 0.4074 - val_f1
_score: 0.3933 - val_loss: 2.1891
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 128ms/step - accuracy: 0.8740 - f1_score: 0.8749 - loss: 0.4043 - val_accuracy: 0.4028 - val_f1
_score: 0.3738 - val_loss: 2.5812
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 128ms/step - accuracy: 0.9124 - f1_score: 0.9129 - loss: 0.3020 - val_accuracy: 0.3750 - val_f1
_score: 0.3651 - val_loss: 2.6319
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 127ms/step - accuracy: 0.9459 - f1_score: 0.9461 - loss: 0.2195 - val_accuracy: 0.4028 - val_f1
_score: 0.3863 - val_loss: 2.9725
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 23s 147ms/step - accuracy: 0.9454 - f1_score: 0.9455 - loss: 0.2061 - val_accuracy: 0.3981 - val_f1
_score: 0.3871 - val_loss: 3.1585
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 17s 118ms/step - accuracy: 0.9573 - f1_score: 0.9574 - loss: 0.2070 - val_accuracy: 0.3866 - val_f1
_score: 0.3782 - val_loss: 3.3044
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 120ms/step - accuracy: 0.9590 - f1_score: 0.9589 - loss: 0.1825 - val_accuracy: 0.3796 - val_f1
_score: 0.3555 - val_loss: 4.0280
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 128ms/step - accuracy: 0.9544 - f1_score: 0.9544 - loss: 0.1841 - val_accuracy: 0.3519 - val_f1
_score: 0.3349 - val_loss: 3.9221
Epoch 13/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 131ms/step - accuracy: 0.9625 - f1_score: 0.9625 - loss: 0.1585 - val_accuracy: 0.3750 - val_f1
_score: 0.3705 - val_loss: 3.9933
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.3617 - f1_score: 0.3417 - loss: 1.9335
Test Loss: 1.8960705995559692, Test Accuracy: 0.37731480598449707, Test F1 Score: 0.36335206031799316
Time required to train the model is 239.42326736450195 seconds
```

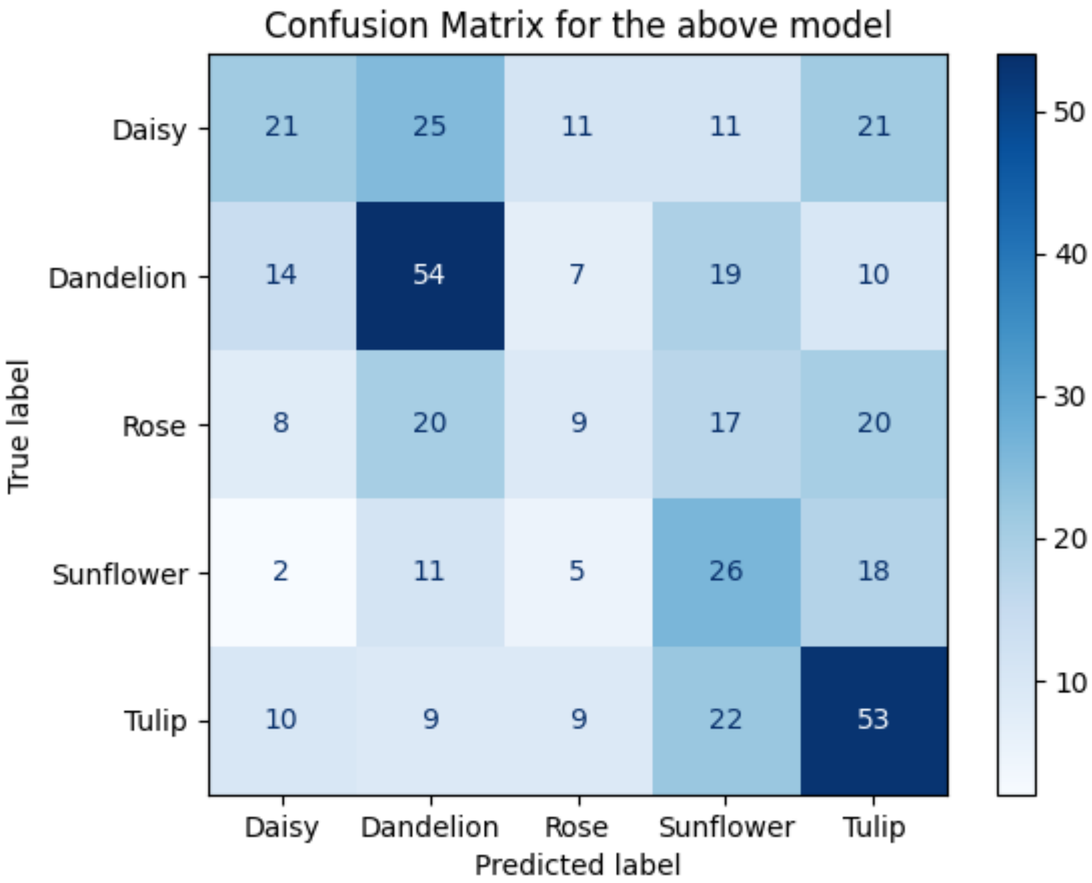


Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

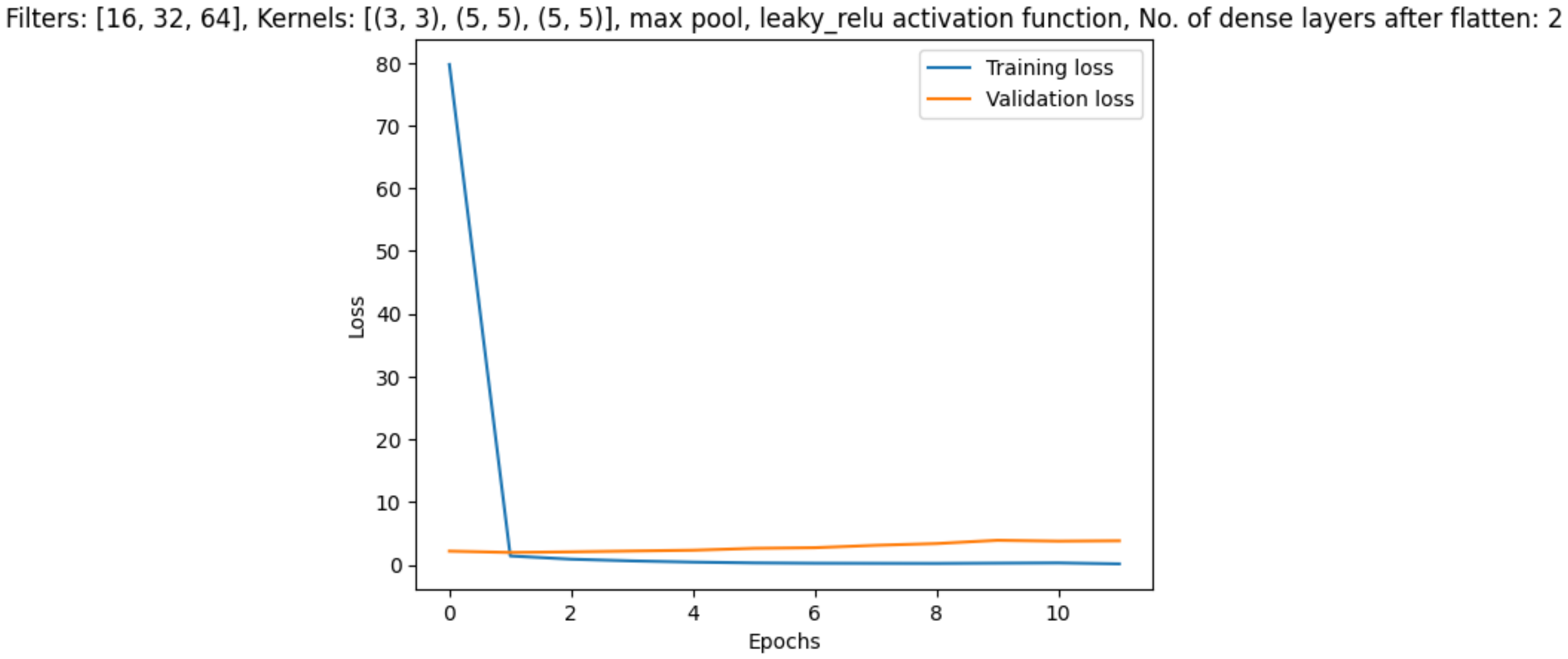


```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 31ms/step
```



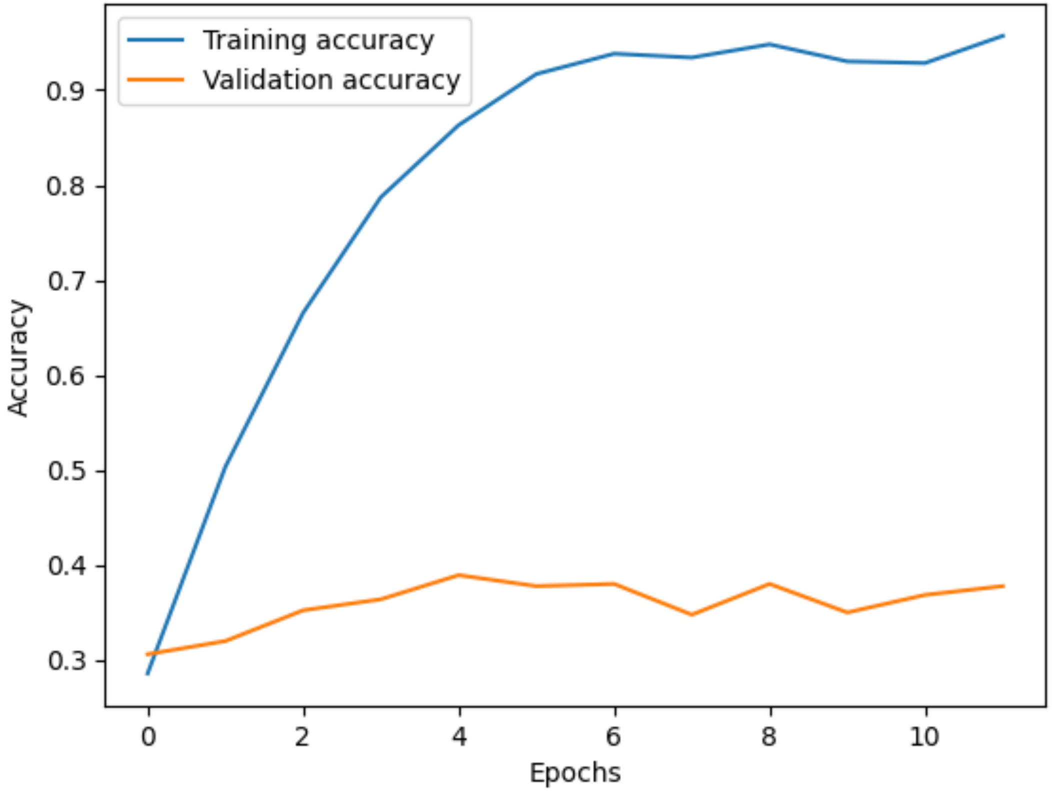
```
Model: "sequential_11"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_11 (Conv2D)                   │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_10 (MaxPooling2D)      │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_11 (Dropout)                 │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_11 (Flatten)                 │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_25 (Dense)                     │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_26 (Dense)                     │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_27 (Dense)                     │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,562,213 (5.96 MB)
```

```
Trainable params: 1,562,213 (5.96 MB)

Non-trainable params: 0 (0.00 B)

Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 17s 136ms/step - accuracy: 0.2487 - f1_score: 0.2430 - loss: 226.8415 - val_accuracy: 0.3056 - val_
f1_score: 0.3064 - val_loss: 2.1821
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 130ms/step - accuracy: 0.4977 - f1_score: 0.4959 - loss: 1.4525 - val_accuracy: 0.3194 - val_f1
_score: 0.3240 - val_loss: 1.9707
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 131ms/step - accuracy: 0.6741 - f1_score: 0.6716 - loss: 0.8715 - val_accuracy: 0.3519 - val_f1
_score: 0.3492 - val_loss: 2.0662
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 119ms/step - accuracy: 0.7846 - f1_score: 0.7818 - loss: 0.6272 - val_accuracy: 0.3634 - val_f1
_score: 0.3487 - val_loss: 2.2012
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 128ms/step - accuracy: 0.8648 - f1_score: 0.8637 - loss: 0.4250 - val_accuracy: 0.3889 - val_f1
_score: 0.3855 - val_loss: 2.3269
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 130ms/step - accuracy: 0.9251 - f1_score: 0.9250 - loss: 0.2935 - val_accuracy: 0.3773 - val_f1
_score: 0.3679 - val_loss: 2.6274
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 131ms/step - accuracy: 0.9488 - f1_score: 0.9487 - loss: 0.2368 - val_accuracy: 0.3796 - val_f1
_score: 0.3678 - val_loss: 2.7289
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 130ms/step - accuracy: 0.9492 - f1_score: 0.9491 - loss: 0.2063 - val_accuracy: 0.3472 - val_f1
_score: 0.3328 - val_loss: 3.1098
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 131ms/step - accuracy: 0.9533 - f1_score: 0.9532 - loss: 0.2129 - val_accuracy: 0.3796 - val_f1
_score: 0.3799 - val_loss: 3.3902
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 131ms/step - accuracy: 0.9430 - f1_score: 0.9430 - loss: 0.2216 - val_accuracy: 0.3495 - val_f1
_score: 0.3459 - val_loss: 3.9098
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 133ms/step - accuracy: 0.9228 - f1_score: 0.9228 - loss: 0.3893 - val_accuracy: 0.3681 - val_f1
_score: 0.3544 - val_loss: 3.7751
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 135ms/step - accuracy: 0.9641 - f1_score: 0.9640 - loss: 0.1480 - val_accuracy: 0.3773 - val_f1
_score: 0.3675 - val_loss: 3.8326
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 34ms/step - accuracy: 0.2961 - f1_score: 0.3012 - loss: 2.0987
Test Loss: 2.026577949523926, Test Accuracy: 0.31481480598449707, Test F1 Score: 0.32019156217575073
Time required to train the model is 210.24508500099182 seconds
```



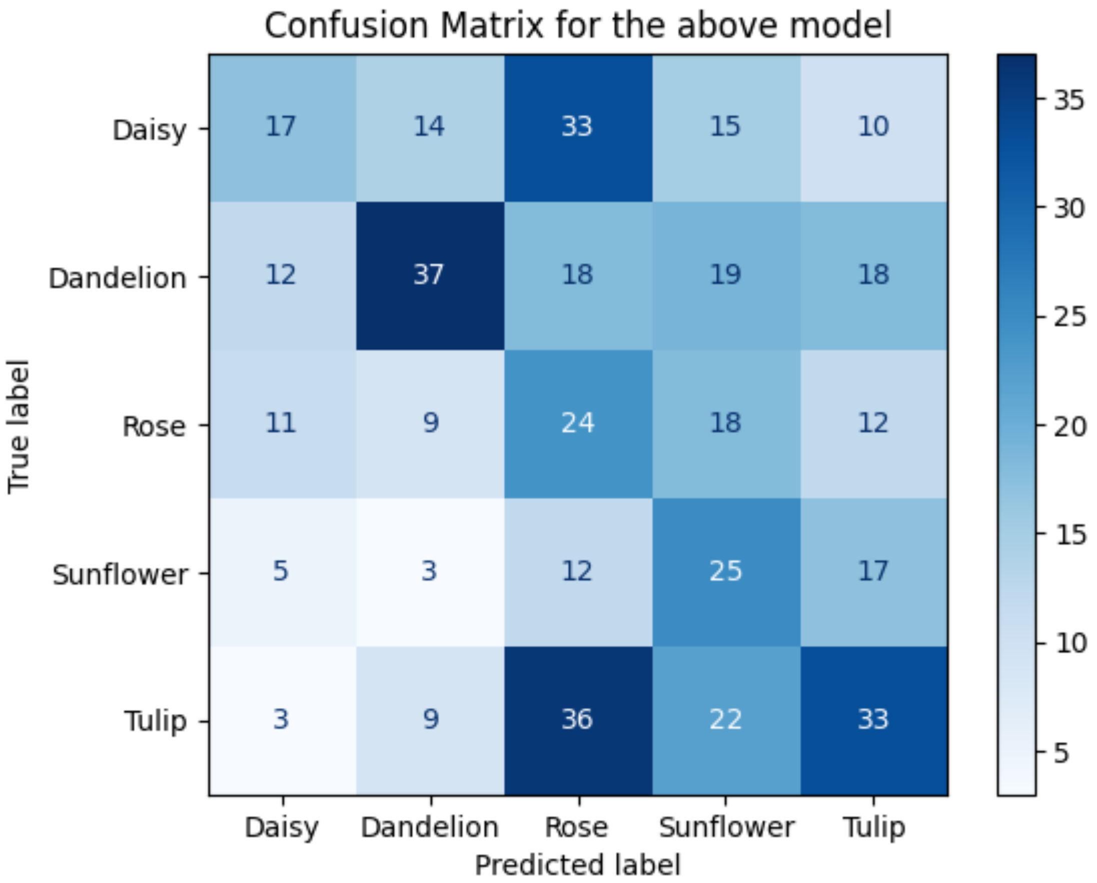
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, leaky_relu activation function, No. of dense layers after flatten: 2

Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, leaky_relu activation function, No. of dense layers after flatten: 2



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 57ms/step
```

Confusion Matrix for the above model

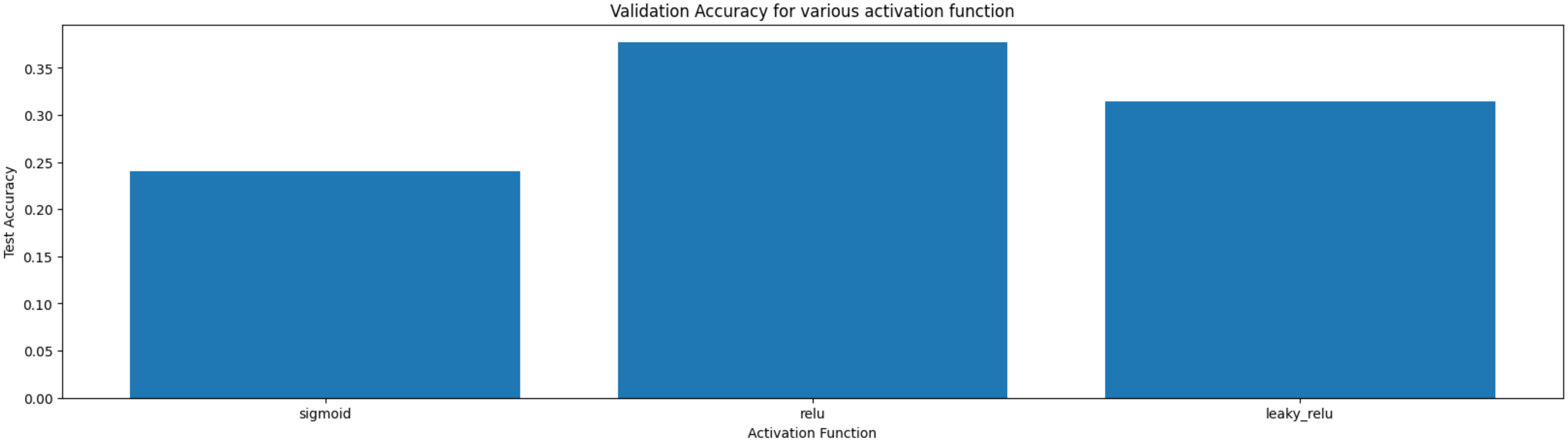


```
In [ ]: result_df_4
```

Out[ ]:

	Conv Kernel Size	Conv Filter Size	Pooling Layers	Activation Function	No. of Dense Layers after Flatten	Dropout Rate	Test Loss	Test Accuracy	Test F1 Score	Training Time(in seconds)
0	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	sigmoid	2	0.1	1.603075	0.240741	0.093422	359.342255
1	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.1	1.896071	0.377315	0.363352	239.423267
2	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	leaky_relu	2	0.1	2.026578	0.314815	0.320192	210.245085

```
In [ ]: plt.figure(figsize=(20,5))
        plt.bar(
            result_df_4['Activation Function'],
            result_df_4['Test Accuracy']
        )

        plt.ylabel('Test Accuracy')
        plt.xlabel('Activation Function')
        plt.title('Validation Accuracy for various activation function')
        plt.show()
```



In [ ]:

```
best_activation_function = result_df_4.sort_values(
    by=['Test Accuracy','Test F1 Score'],
    ascending=[False,False]
)['Activation Function'].iloc[0]

best_activation_function
```

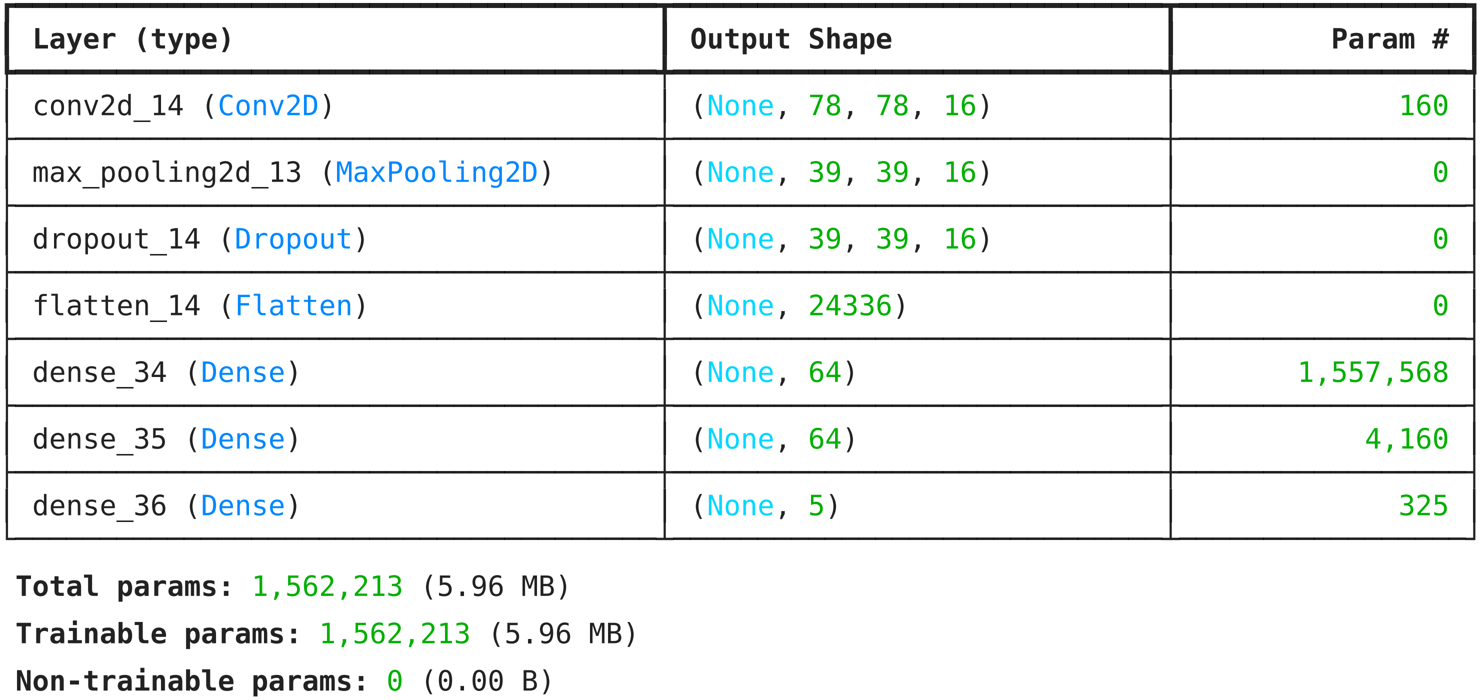
Out[ ]:

```
'relu'
```

In [ ]:

```
# Subtask 5

result_df_5 = pd.DataFrame(
    columns=[
        'Conv Kernel Size',
        'Conv Filter Size',
        'Pooling Layers',
        'Activation Function',
        'No. of Dense Layers after Flatten',
        'Dropout Rate',
        'Test Loss',
        'Test Accuracy',
        'Test F1 Score',
        'Batch Normalization Presence',
        'Training Time(in seconds)'
    ]
)

filters = [16,32,64]
dropout_rates = [0.1,0.25,0,0.1]
batch_norm=[False,False,True,True]
epochs = 20

for dropout_rate,add_batch in zip(dropout_rates,batch_norm):
  test_loss,test_accuracy,test_f1,train_time,_ = train_model(
      kernels=best_kernel,
      filters=filters,
      activation_func=best_activation_function,
      pool=best_pool,
      dropout_rate=dropout_rate,
      num_dense_layers=best_num_dense,
      X_train=X_train,
      y_train=y_train,
      X_test=X_test,
      y_test=y_test,
      num_epochs=epochs,
      add_batch_normalization=add_batch
      )

  result_df_5.loc[len(result_df_5.index)]=[
      best_kernel,
      filters,
      best_pool,
      best_activation_function,
      best_num_dense,
      dropout_rate,
      test_loss,
      test_accuracy,
      test_f1,
      add_batch,
      train_time
  ]
```

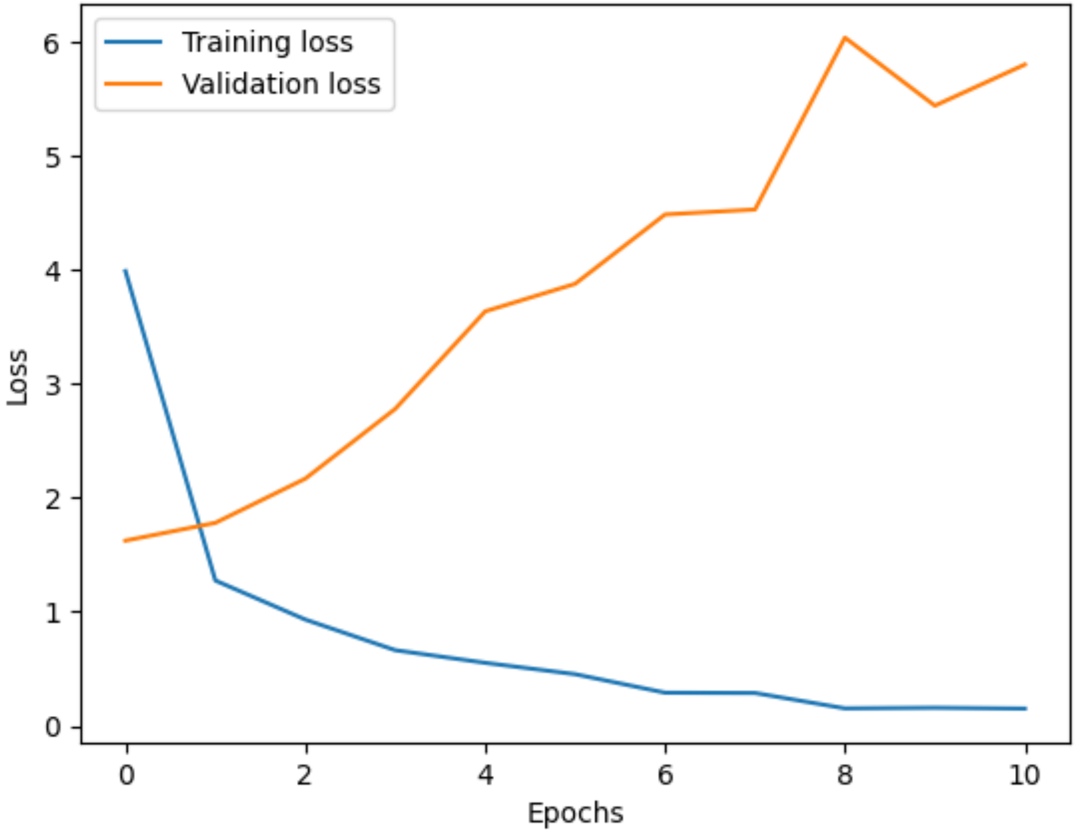
```
Model: "sequential_14"
```



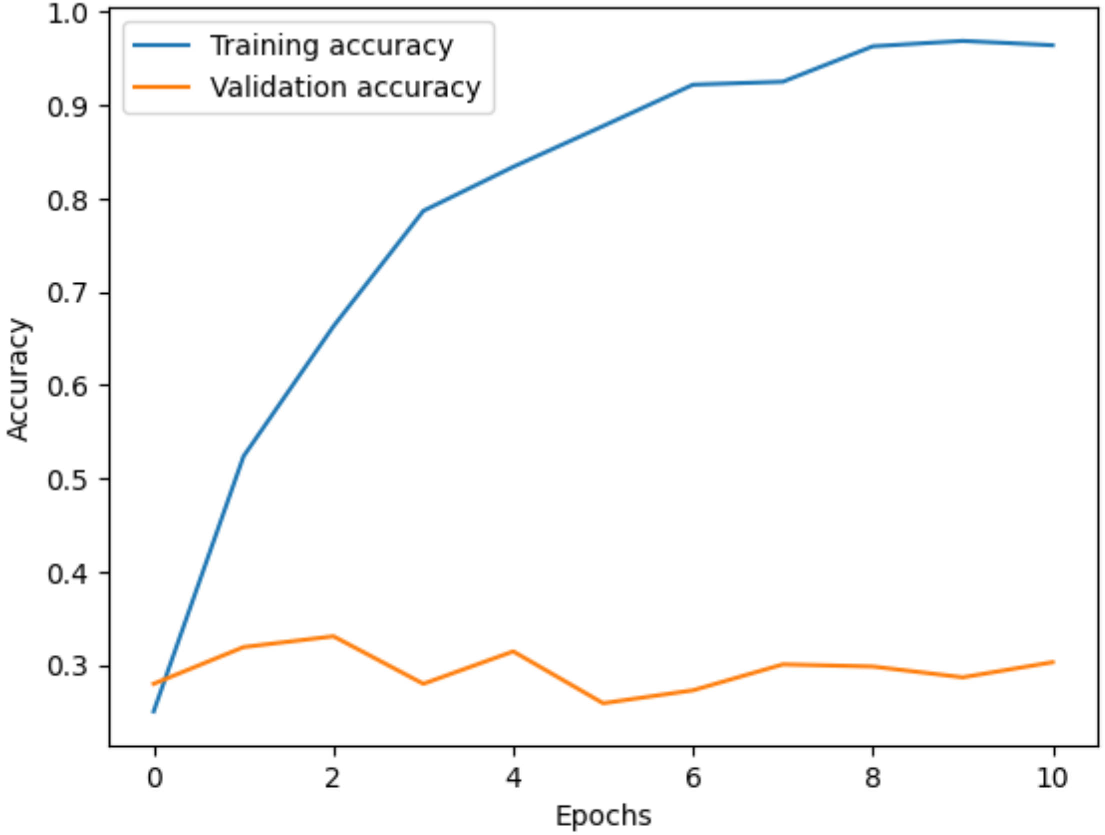
```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_14 (Conv2D)                   │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_13 (MaxPooling2D)      │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_14 (Dropout)                 │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_14 (Flatten)                 │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_34 (Dense)                     │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_35 (Dense)                     │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_36 (Dense)                     │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,562,213 (5.96 MB)
 Trainable params: 1,562,213 (5.96 MB)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 113ms/step - accuracy: 0.2102 - f1_score: 0.2049 - loss: 9.4014 - val_accuracy: 0.2801 - val_f1
_score: 0.2679 - val_loss: 1.6251
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 25s 155ms/step - accuracy: 0.5163 - f1_score: 0.5125 - loss: 1.3066 - val_accuracy: 0.3194 - val_f1
_score: 0.3024 - val_loss: 1.7811
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 180ms/step - accuracy: 0.6823 - f1_score: 0.6827 - loss: 0.9143 - val_accuracy: 0.3310 - val_f1
_score: 0.3181 - val_loss: 2.1691
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 18s 161ms/step - accuracy: 0.7920 - f1_score: 0.7919 - loss: 0.6391 - val_accuracy: 0.2801 - val_f1
_score: 0.2662 - val_loss: 2.7814
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 18s 167ms/step - accuracy: 0.8402 - f1_score: 0.8400 - loss: 0.5474 - val_accuracy: 0.3148 - val_f1
_score: 0.2975 - val_loss: 3.6367
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 18s 148ms/step - accuracy: 0.8896 - f1_score: 0.8899 - loss: 0.4420 - val_accuracy: 0.2593 - val_f1
_score: 0.2531 - val_loss: 3.8784
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 136ms/step - accuracy: 0.9285 - f1_score: 0.9286 - loss: 0.2619 - val_accuracy: 0.2731 - val_f1
_score: 0.2729 - val_loss: 4.4871
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 23s 160ms/step - accuracy: 0.9189 - f1_score: 0.9192 - loss: 0.3187 - val_accuracy: 0.3009 - val_f1
_score: 0.2960 - val_loss: 4.5305
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 18s 138ms/step - accuracy: 0.9606 - f1_score: 0.9605 - loss: 0.1577 - val_accuracy: 0.2986 - val_f1
_score: 0.2889 - val_loss: 6.0384
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 147ms/step - accuracy: 0.9742 - f1_score: 0.9742 - loss: 0.1252 - val_accuracy: 0.2870 - val_f1
_score: 0.2835 - val_loss: 5.4415
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 18s 121ms/step - accuracy: 0.9593 - f1_score: 0.9594 - loss: 0.1675 - val_accuracy: 0.3032 - val_f1
_score: 0.2980 - val_loss: 5.8022
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step - accuracy: 0.3144 - f1_score: 0.3004 - loss: 1.5944
Test Loss: 1.597295880317688, Test Accuracy: 0.3263888955116272, Test F1 Score: 0.30750915408134446
Time required to train the model is 221.19082760810852 seconds
```

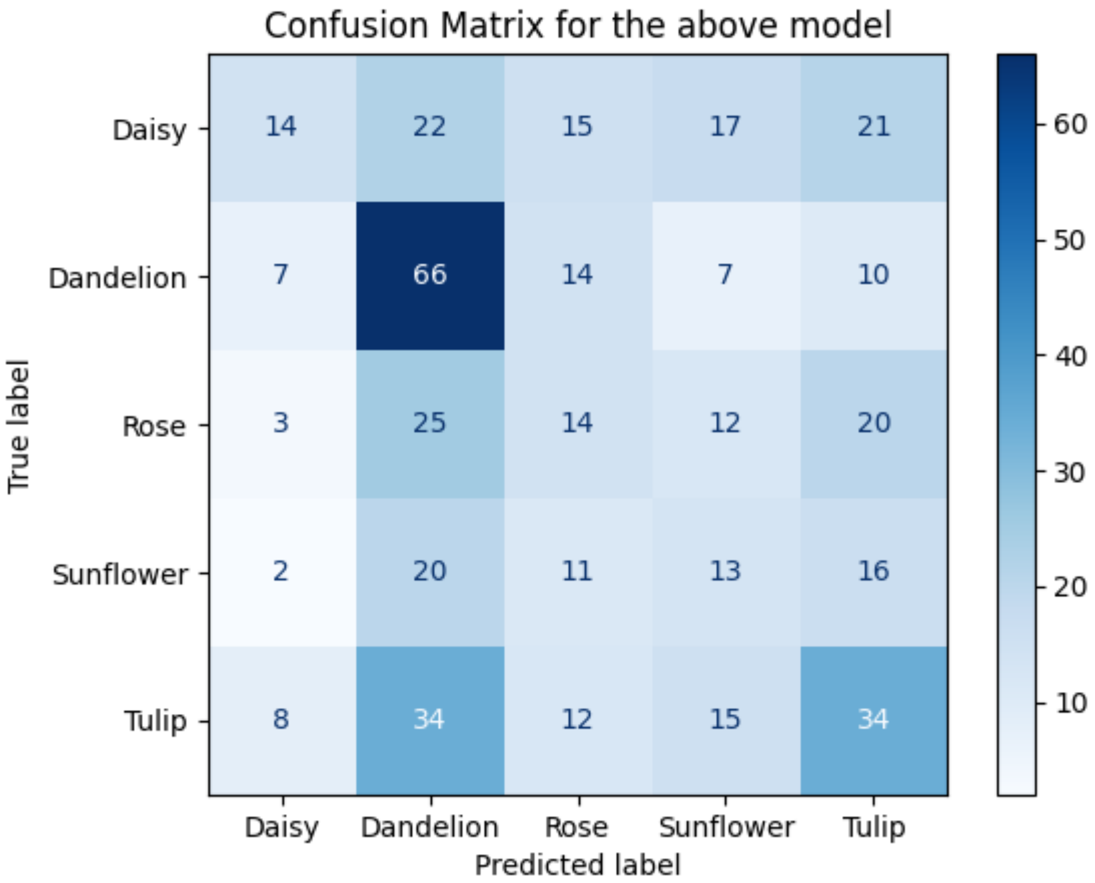
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

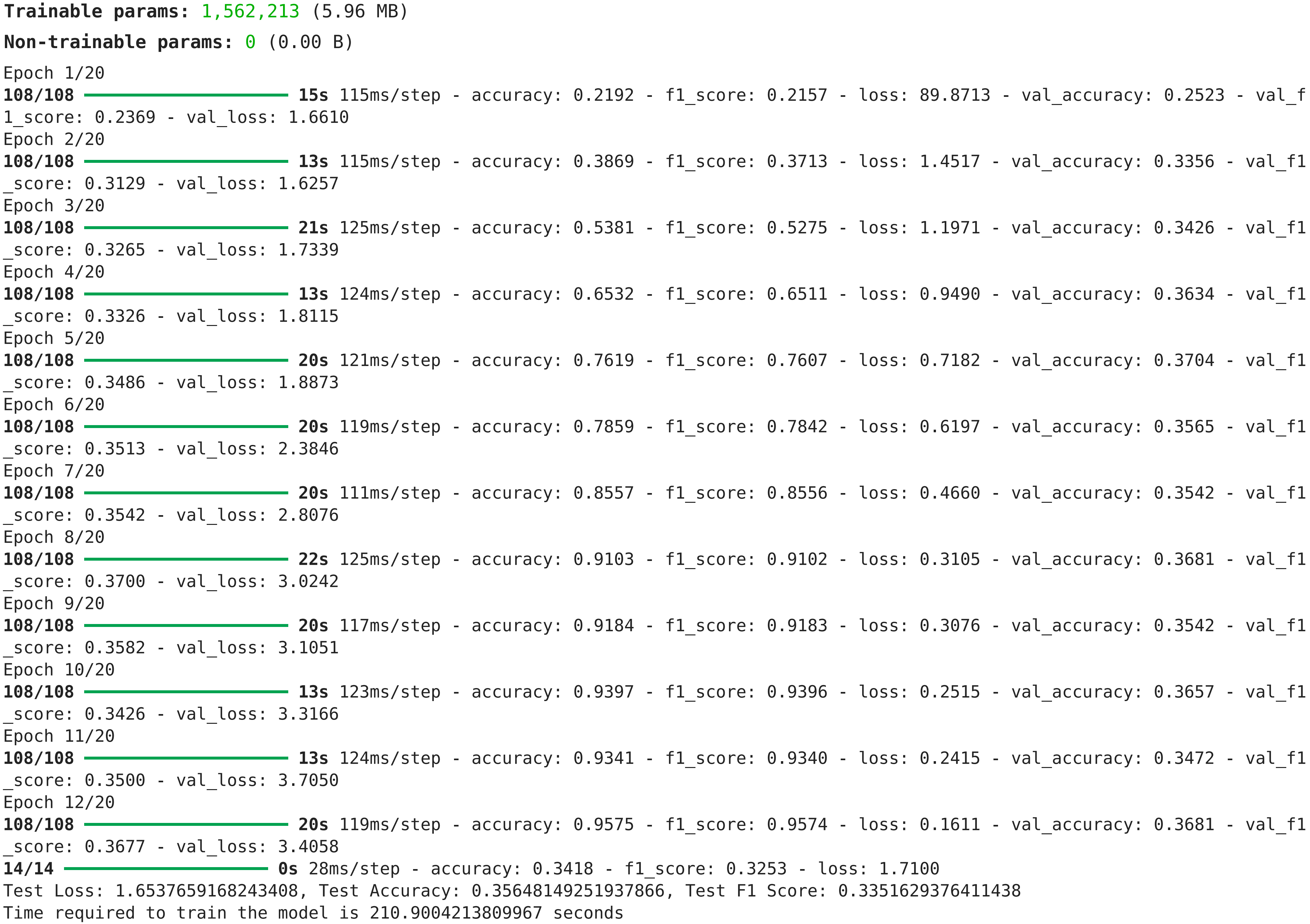


```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 32ms/step
```

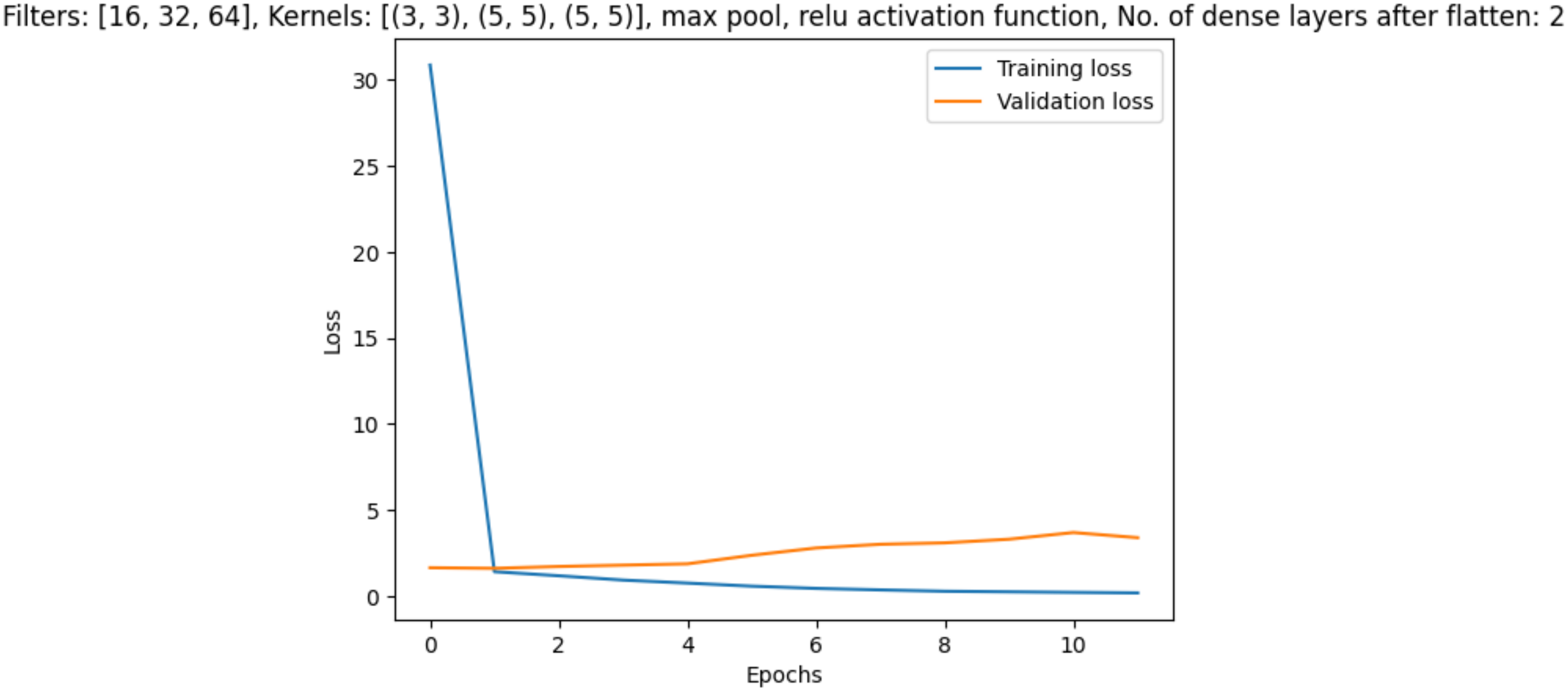


Confusion Matrix for the above model

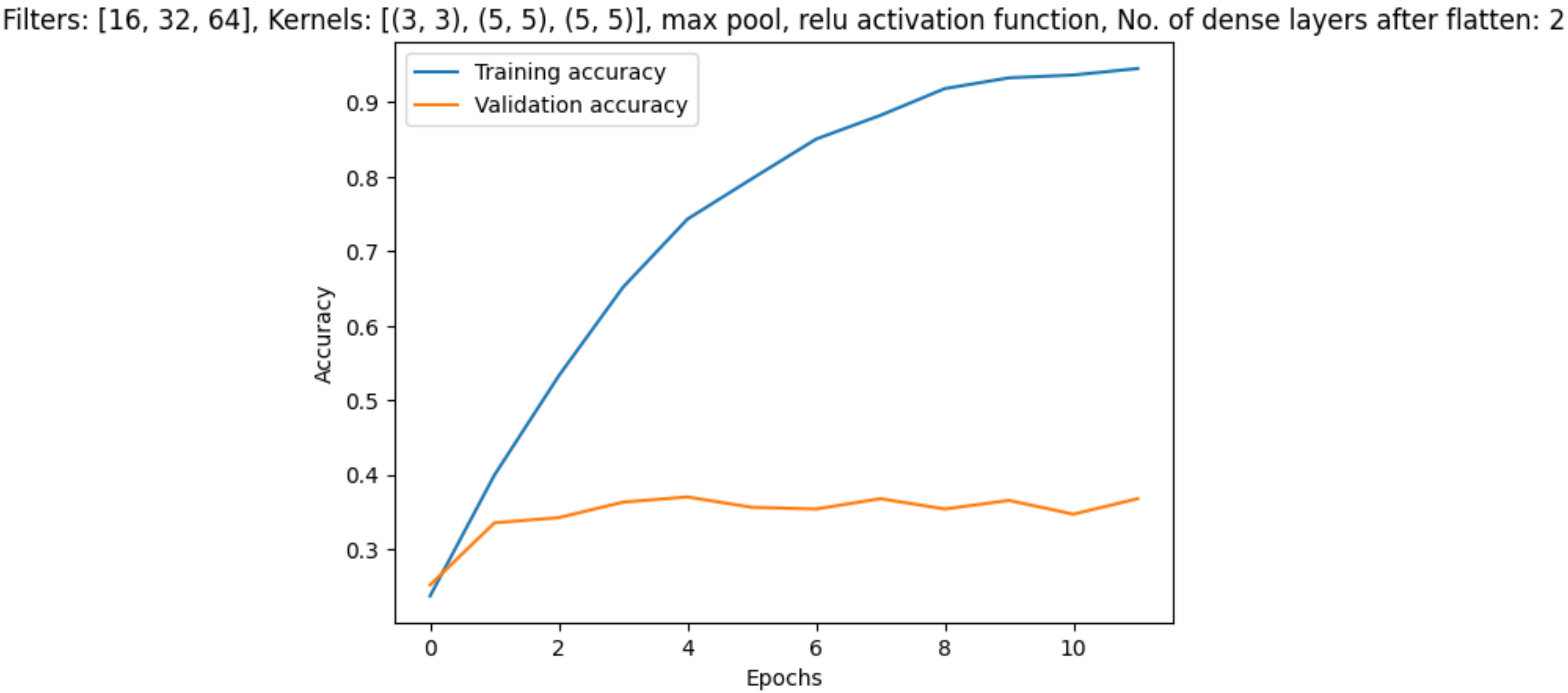
```
Model: "sequential_15"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_15 (Conv2D)                   │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_14 (MaxPooling2D)      │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dropout_15 (Dropout)                 │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_15 (Flatten)                 │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_37 (Dense)                     │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_38 (Dense)                     │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_39 (Dense)                     │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 1,562,213 (5.96 MB)
```



```
Trainable params: 1,562,213 (5.96 MB)

Non-trainable params: 0 (0.00 B)

Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 115ms/step - accuracy: 0.2192 - f1_score: 0.2157 - loss: 89.8713 - val_accuracy: 0.2523 - val_f
1_score: 0.2369 - val_loss: 1.6610
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 115ms/step - accuracy: 0.3869 - f1_score: 0.3713 - loss: 1.4517 - val_accuracy: 0.3356 - val_f1
_score: 0.3129 - val_loss: 1.6257
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 125ms/step - accuracy: 0.5381 - f1_score: 0.5275 - loss: 1.1971 - val_accuracy: 0.3426 - val_f1
_score: 0.3265 - val_loss: 1.7339
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 124ms/step - accuracy: 0.6532 - f1_score: 0.6511 - loss: 0.9490 - val_accuracy: 0.3634 - val_f1
_score: 0.3326 - val_loss: 1.8115
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 121ms/step - accuracy: 0.7619 - f1_score: 0.7607 - loss: 0.7182 - val_accuracy: 0.3704 - val_f1
_score: 0.3486 - val_loss: 1.8873
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 119ms/step - accuracy: 0.7859 - f1_score: 0.7842 - loss: 0.6197 - val_accuracy: 0.3565 - val_f1
_score: 0.3513 - val_loss: 2.3846
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 111ms/step - accuracy: 0.8557 - f1_score: 0.8556 - loss: 0.4660 - val_accuracy: 0.3542 - val_f1
_score: 0.3542 - val_loss: 2.8076
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 22s 125ms/step - accuracy: 0.9103 - f1_score: 0.9102 - loss: 0.3105 - val_accuracy: 0.3681 - val_f1
_score: 0.3700 - val_loss: 3.0242
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 117ms/step - accuracy: 0.9184 - f1_score: 0.9183 - loss: 0.3076 - val_accuracy: 0.3542 - val_f1
_score: 0.3582 - val_loss: 3.1051
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 123ms/step - accuracy: 0.9397 - f1_score: 0.9396 - loss: 0.2515 - val_accuracy: 0.3657 - val_f1
_score: 0.3426 - val_loss: 3.3166
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 124ms/step - accuracy: 0.9341 - f1_score: 0.9340 - loss: 0.2415 - val_accuracy: 0.3472 - val_f1
_score: 0.3500 - val_loss: 3.7050
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 119ms/step - accuracy: 0.9575 - f1_score: 0.9574 - loss: 0.1611 - val_accuracy: 0.3681 - val_f1
_score: 0.3677 - val_loss: 3.4058
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 28ms/step - accuracy: 0.3418 - f1_score: 0.3253 - loss: 1.7100
Test Loss: 1.6537659168243408, Test Accuracy: 0.35648149251937866, Test F1 Score: 0.3351629376411438
Time required to train the model is 210.9004213809967 seconds
```

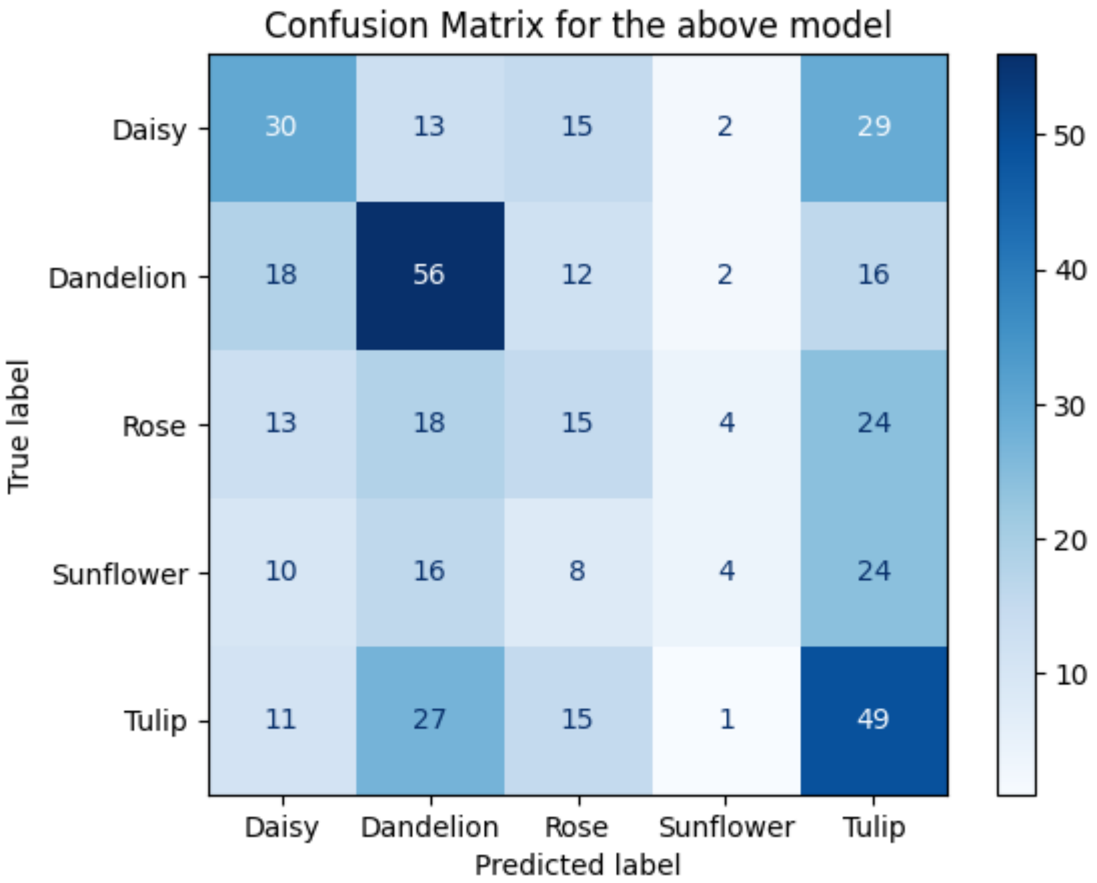


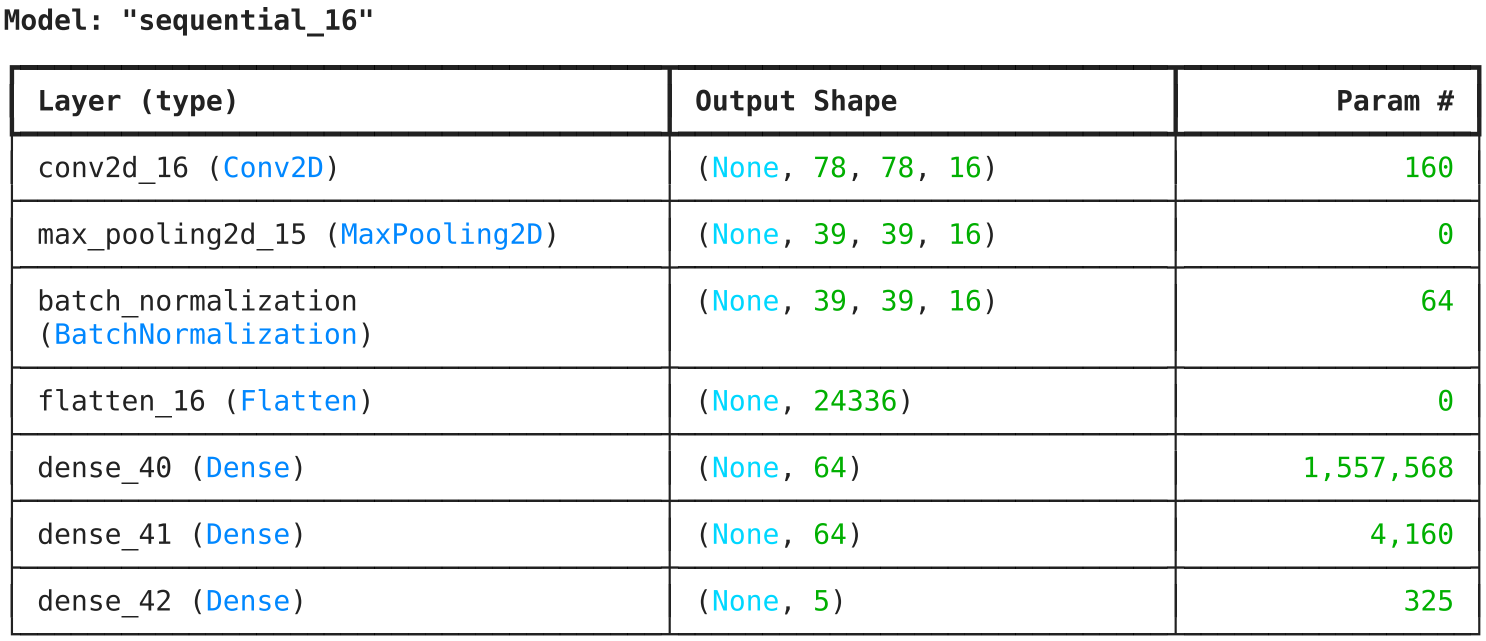
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



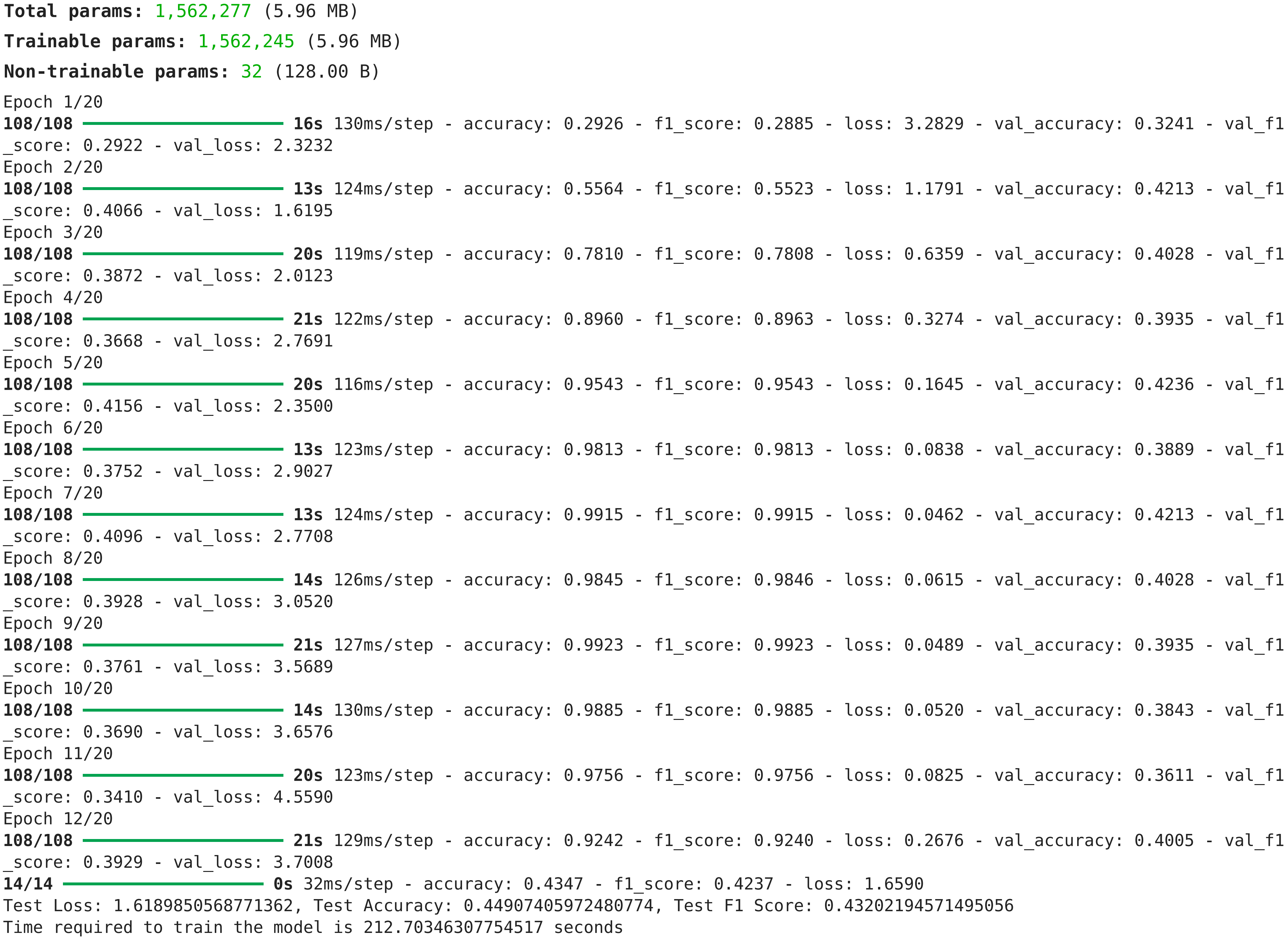
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 35ms/step
```

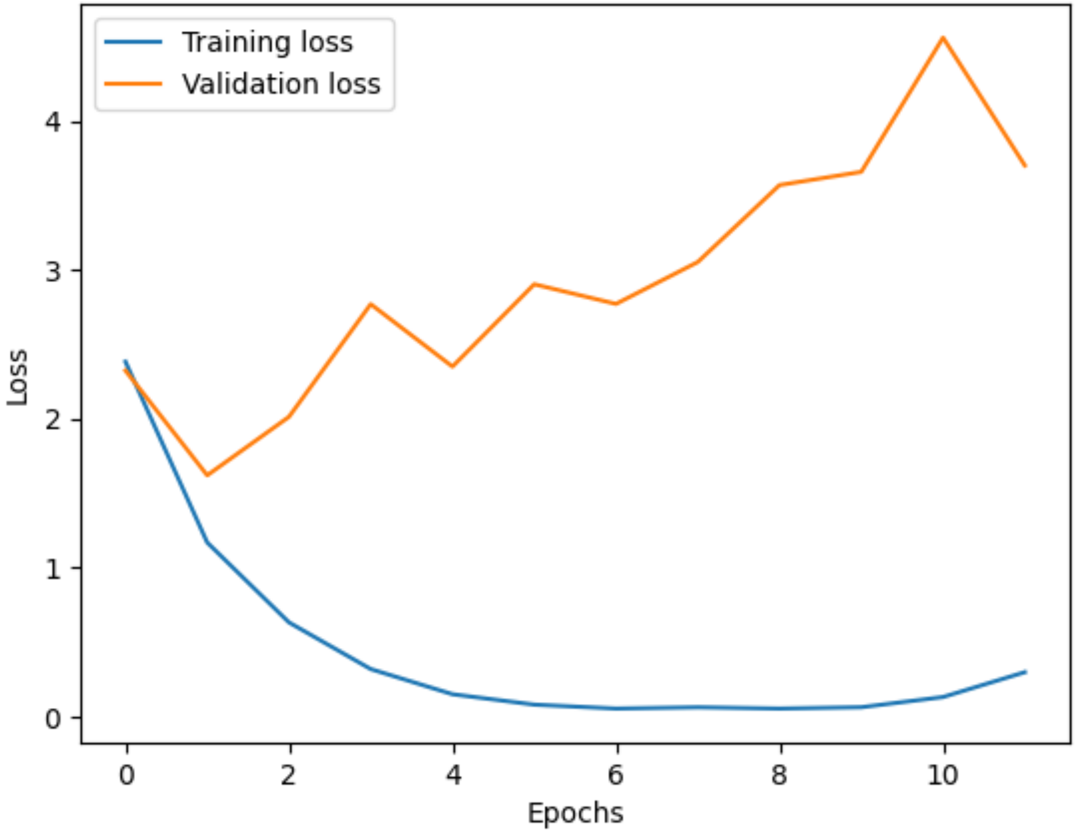




```
Model: "sequential_16"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_16 (Conv2D)                   │ (None, 78, 78, 16)          │             160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_15 (MaxPooling2D)      │ (None, 39, 39, 16)          │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ batch_normalization                  │ (None, 39, 39, 16)          │              64 │
│ (BatchNormalization)                 │                             │                 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_16 (Flatten)                 │ (None, 24336)               │               0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_40 (Dense)                     │ (None, 64)                  │       1,557,568 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_41 (Dense)                     │ (None, 64)                  │           4,160 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_42 (Dense)                     │ (None, 5)                   │             325 │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
```

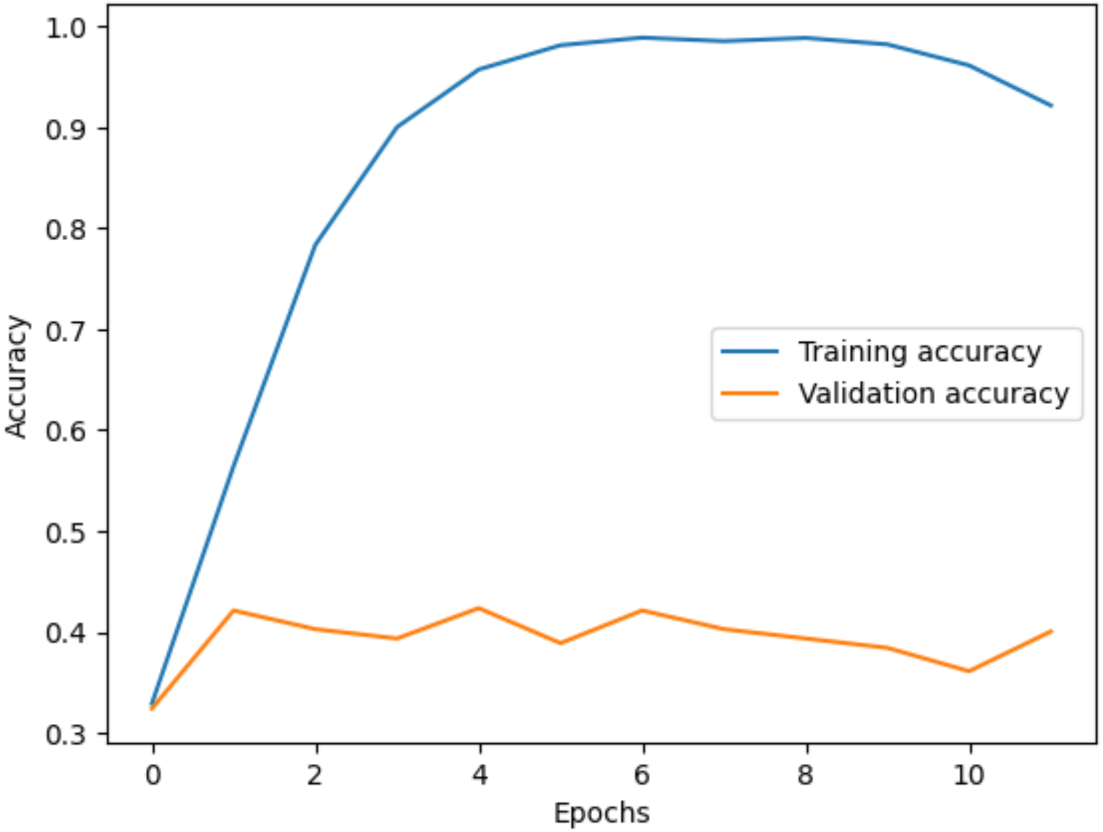


```
Total params: 1,562,277 (5.96 MB)
Trainable params: 1,562,245 (5.96 MB)
Non-trainable params: 32 (128.00 B)
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 16s 130ms/step - accuracy: 0.2926 - f1_score: 0.2885 - loss: 3.2829 - val_accuracy: 0.3241 - val_f1
_score: 0.2922 - val_loss: 2.3232
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 124ms/step - accuracy: 0.5564 - f1_score: 0.5523 - loss: 1.1791 - val_accuracy: 0.4213 - val_f1
_score: 0.4066 - val_loss: 1.6195
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 119ms/step - accuracy: 0.7810 - f1_score: 0.7808 - loss: 0.6359 - val_accuracy: 0.4028 - val_f1
_score: 0.3872 - val_loss: 2.0123
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 122ms/step - accuracy: 0.8960 - f1_score: 0.8963 - loss: 0.3274 - val_accuracy: 0.3935 - val_f1
_score: 0.3668 - val_loss: 2.7691
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 116ms/step - accuracy: 0.9543 - f1_score: 0.9543 - loss: 0.1645 - val_accuracy: 0.4236 - val_f1
_score: 0.4156 - val_loss: 2.3500
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 123ms/step - accuracy: 0.9813 - f1_score: 0.9813 - loss: 0.0838 - val_accuracy: 0.3889 - val_f1
_score: 0.3752 - val_loss: 2.9027
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 124ms/step - accuracy: 0.9915 - f1_score: 0.9915 - loss: 0.0462 - val_accuracy: 0.4213 - val_f1
_score: 0.4096 - val_loss: 2.7708
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 126ms/step - accuracy: 0.9845 - f1_score: 0.9846 - loss: 0.0615 - val_accuracy: 0.4028 - val_f1
_score: 0.3928 - val_loss: 3.0520
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 127ms/step - accuracy: 0.9923 - f1_score: 0.9923 - loss: 0.0489 - val_accuracy: 0.3935 - val_f1
_score: 0.3761 - val_loss: 3.5689
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 130ms/step - accuracy: 0.9885 - f1_score: 0.9885 - loss: 0.0520 - val_accuracy: 0.3843 - val_f1
_score: 0.3690 - val_loss: 3.6576
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 123ms/step - accuracy: 0.9756 - f1_score: 0.9756 - loss: 0.0825 - val_accuracy: 0.3611 - val_f1
_score: 0.3410 - val_loss: 4.5590
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 129ms/step - accuracy: 0.9242 - f1_score: 0.9240 - loss: 0.2676 - val_accuracy: 0.4005 - val_f1
_score: 0.3929 - val_loss: 3.7008
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 0.4347 - f1_score: 0.4237 - loss: 1.6590
Test Loss: 1.6189850568771362, Test Accuracy: 0.44907405972480774, Test F1 Score: 0.43202194571495056
Time required to train the model is 212.70346307754517 seconds
```

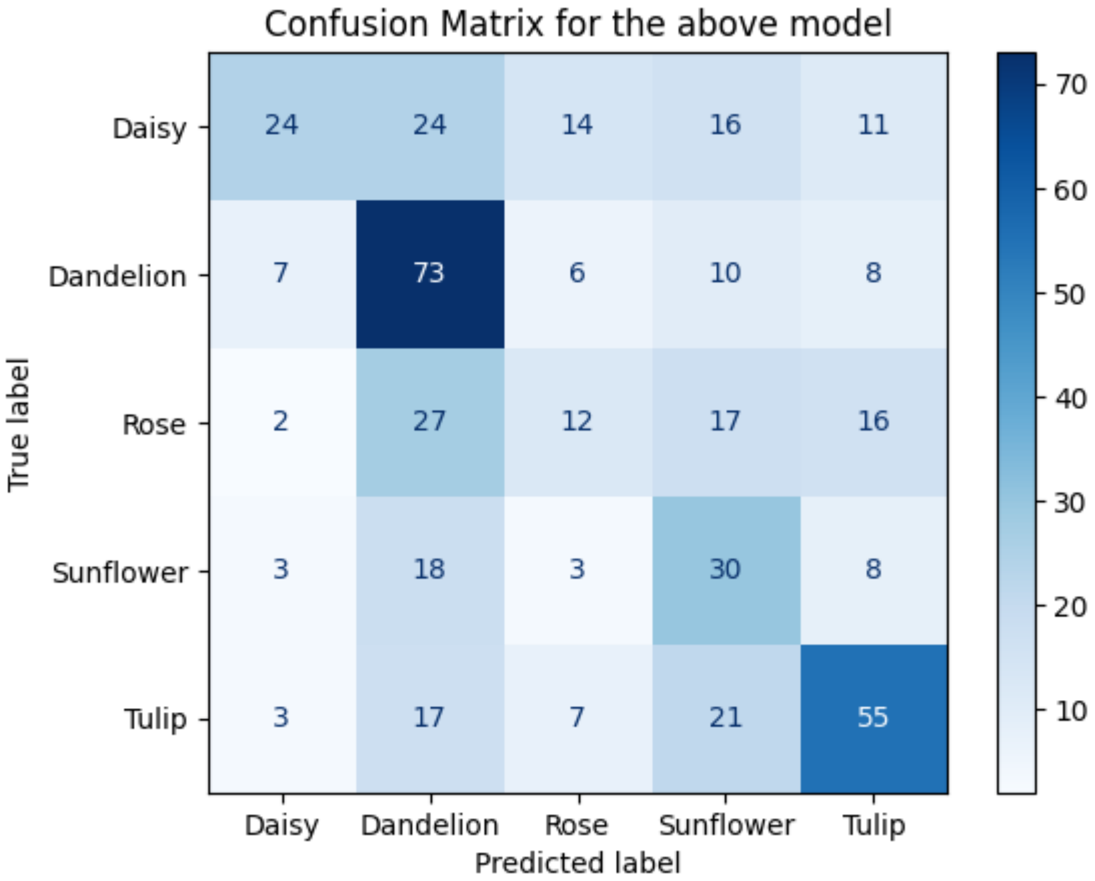


Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

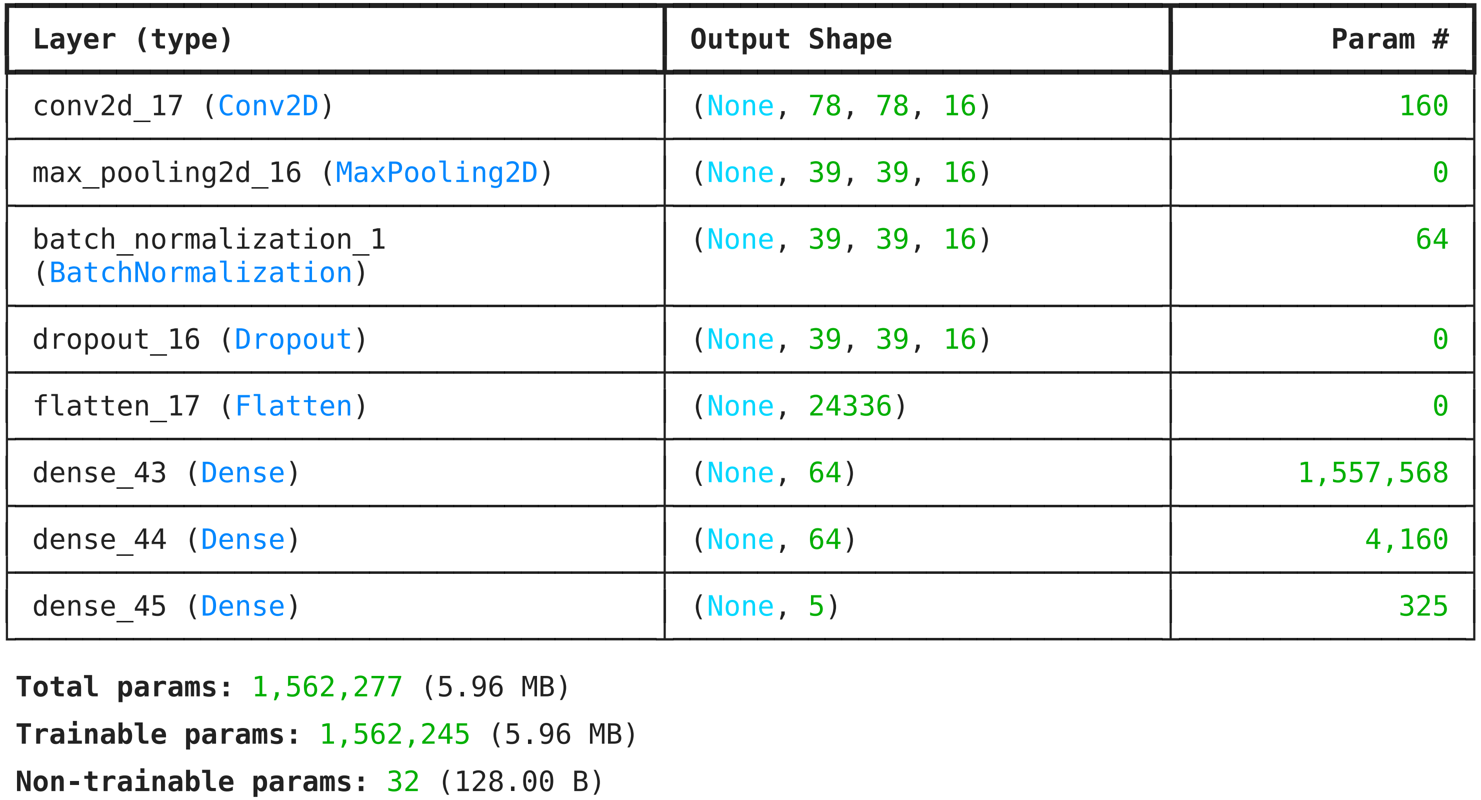
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 39ms/step
```

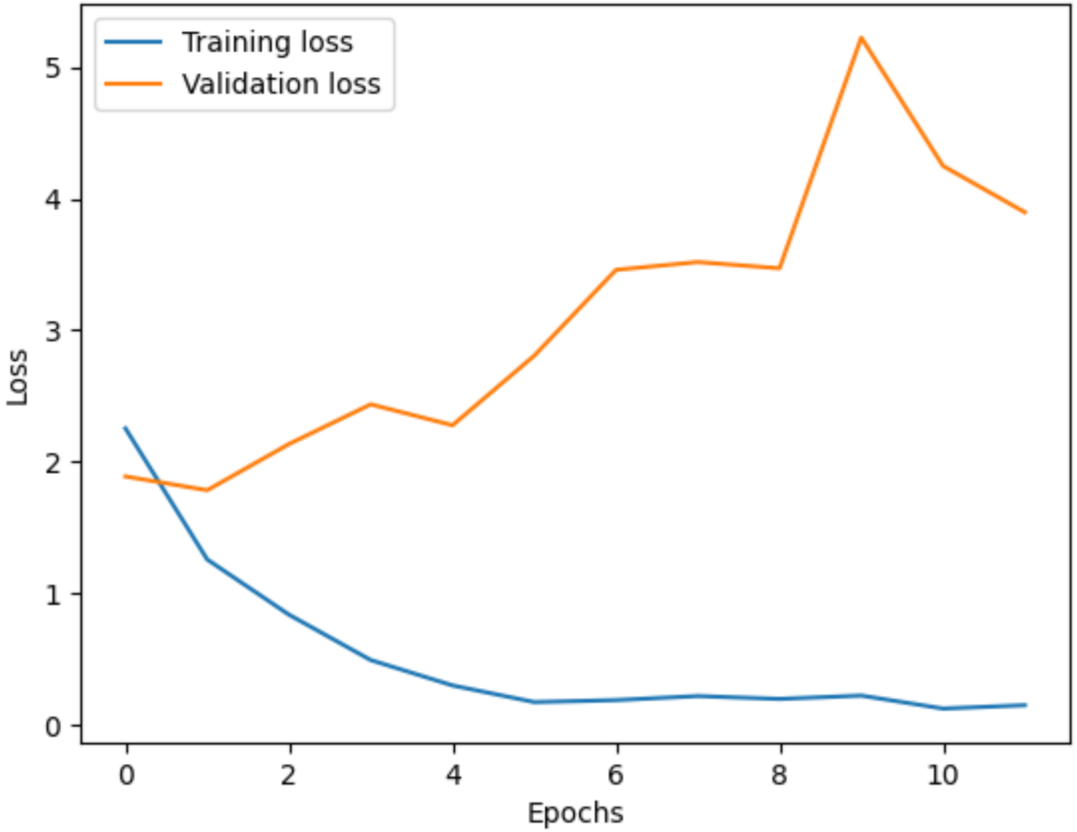


```
Model: "sequential_17"
```

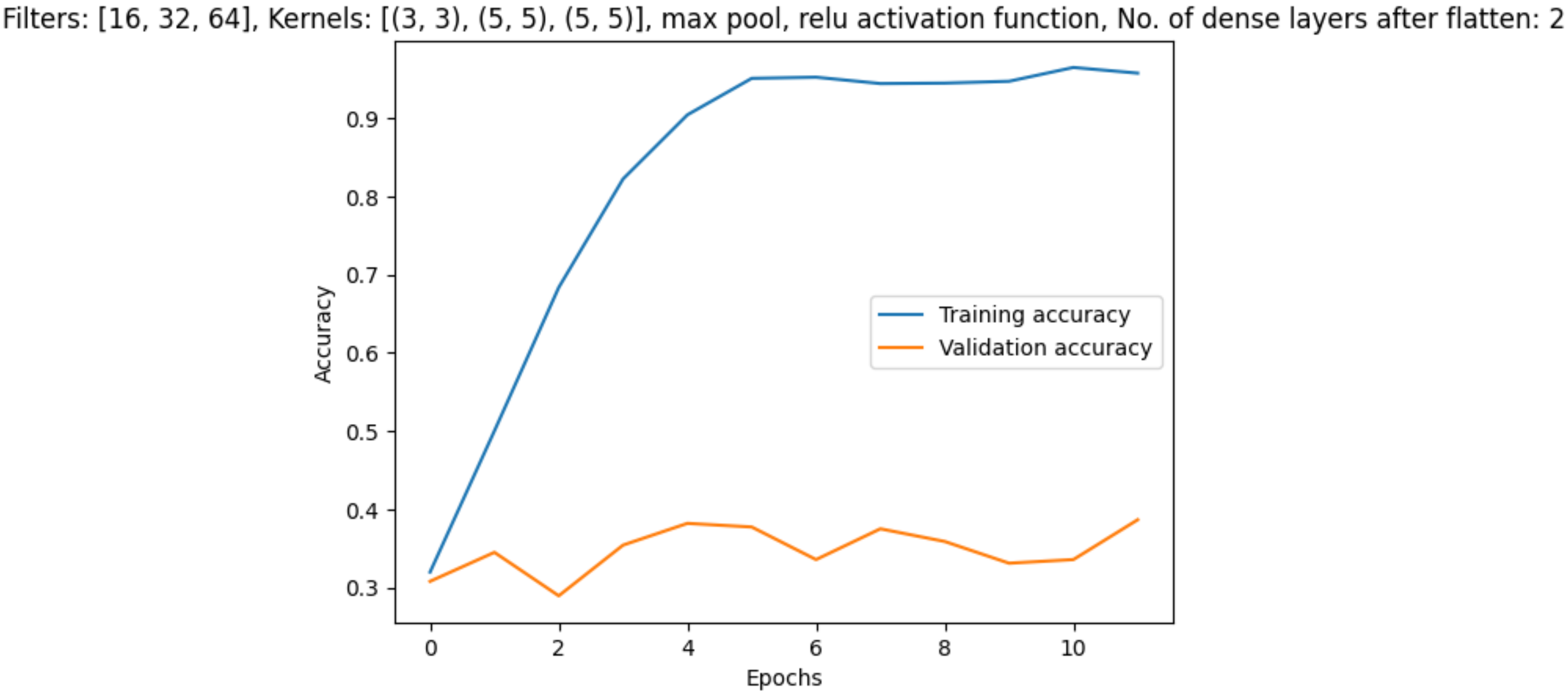


```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                          ┃ Output Shape                 ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_17 (Conv2D)                    │ (None, 78, 78, 16)           │             160 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ max_pooling2d_16 (MaxPooling2D)       │ (None, 39, 39, 16)           │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ batch_normalization_1                 │ (None, 39, 39, 16)           │              64 │
│ (BatchNormalization)                  │                              │                 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dropout_16 (Dropout)                  │ (None, 39, 39, 16)           │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ flatten_17 (Flatten)                  │ (None, 24336)                │               0 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_43 (Dense)                      │ (None, 64)                   │       1,557,568 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_44 (Dense)                      │ (None, 64)                   │           4,160 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_45 (Dense)                      │ (None, 5)                    │             325 │
└───────────────────────────────────────┴──────────────────────────────┴─────────────────┘
 Total params: 1,562,277 (5.96 MB)
 Trainable params: 1,562,245 (5.96 MB)
 Non-trainable params: 32 (128.00 B)
```

```
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 19s 147ms/step - accuracy: 0.3085 - f1_score: 0.3049 - loss: 2.8237 - val_accuracy: 0.3079 - val_f1
_score: 0.2847 - val_loss: 1.8885
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 136ms/step - accuracy: 0.4960 - f1_score: 0.4902 - loss: 1.2529 - val_accuracy: 0.3449 - val_f1
_score: 0.3296 - val_loss: 1.7837
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 140ms/step - accuracy: 0.6838 - f1_score: 0.6812 - loss: 0.8260 - val_accuracy: 0.2894 - val_f1
_score: 0.2437 - val_loss: 2.1348
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 138ms/step - accuracy: 0.8160 - f1_score: 0.8152 - loss: 0.5066 - val_accuracy: 0.3542 - val_f1
_score: 0.3437 - val_loss: 2.4368
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 135ms/step - accuracy: 0.9196 - f1_score: 0.9197 - loss: 0.2631 - val_accuracy: 0.3819 - val_f1
_score: 0.3694 - val_loss: 2.2777
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 140ms/step - accuracy: 0.9489 - f1_score: 0.9488 - loss: 0.1810 - val_accuracy: 0.3773 - val_f1
_score: 0.3709 - val_loss: 2.8069
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 137ms/step - accuracy: 0.9582 - f1_score: 0.9581 - loss: 0.1559 - val_accuracy: 0.3356 - val_f1
_score: 0.3361 - val_loss: 3.4593
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 133ms/step - accuracy: 0.9447 - f1_score: 0.9447 - loss: 0.2027 - val_accuracy: 0.3750 - val_f1
_score: 0.3591 - val_loss: 3.5186
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 140ms/step - accuracy: 0.9506 - f1_score: 0.9506 - loss: 0.1694 - val_accuracy: 0.3588 - val_f1
_score: 0.3484 - val_loss: 3.4710
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 135ms/step - accuracy: 0.9510 - f1_score: 0.9509 - loss: 0.1960 - val_accuracy: 0.3310 - val_f1
_score: 0.3114 - val_loss: 5.2249
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 135ms/step - accuracy: 0.9637 - f1_score: 0.9637 - loss: 0.1282 - val_accuracy: 0.3356 - val_f1
_score: 0.3180 - val_loss: 4.2496
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 134ms/step - accuracy: 0.9637 - f1_score: 0.9637 - loss: 0.1365 - val_accuracy: 0.3866 - val_f1
_score: 0.3737 - val_loss: 3.8974
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 30ms/step - accuracy: 0.3305 - f1_score: 0.3218 - loss: 1.8348
Test Loss: 1.7746429443359375, Test Accuracy: 0.35185185074806213, Test F1 Score: 0.33424222469329834
Time required to train the model is 222.4370560646057 seconds
```

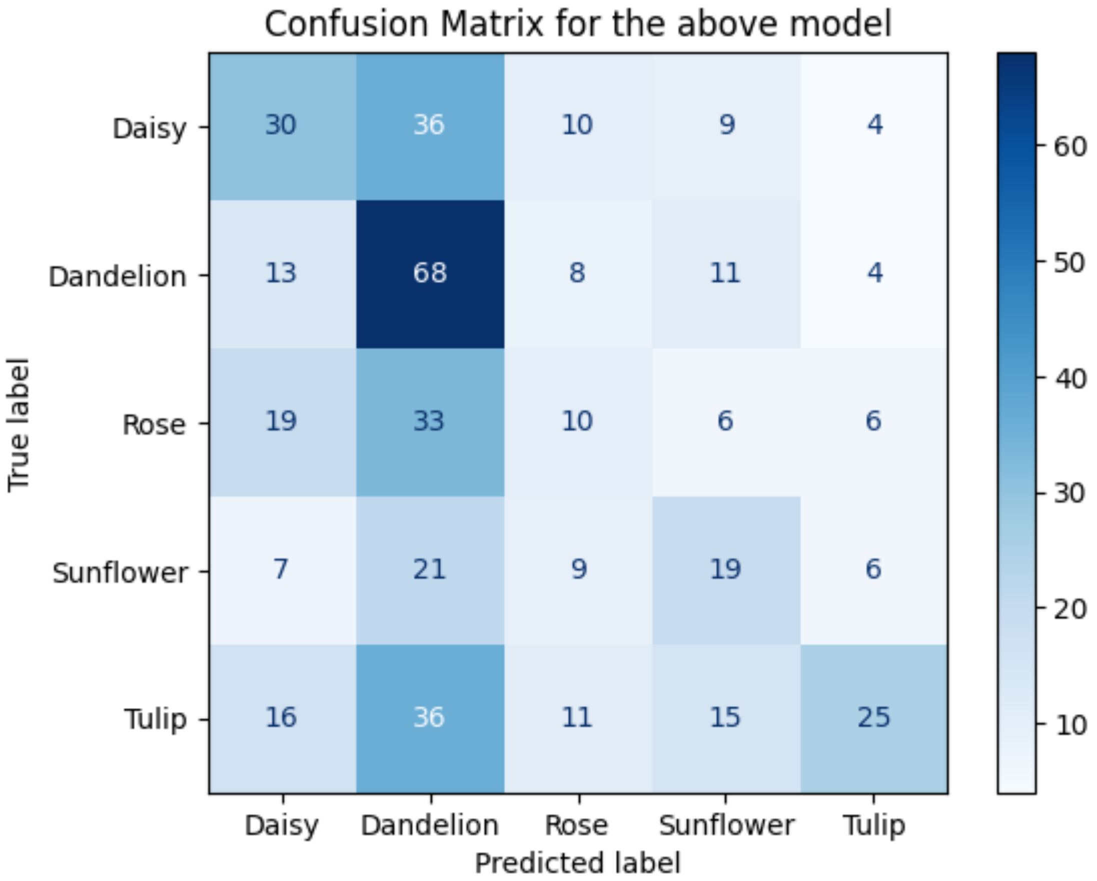


Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 37ms/step
```



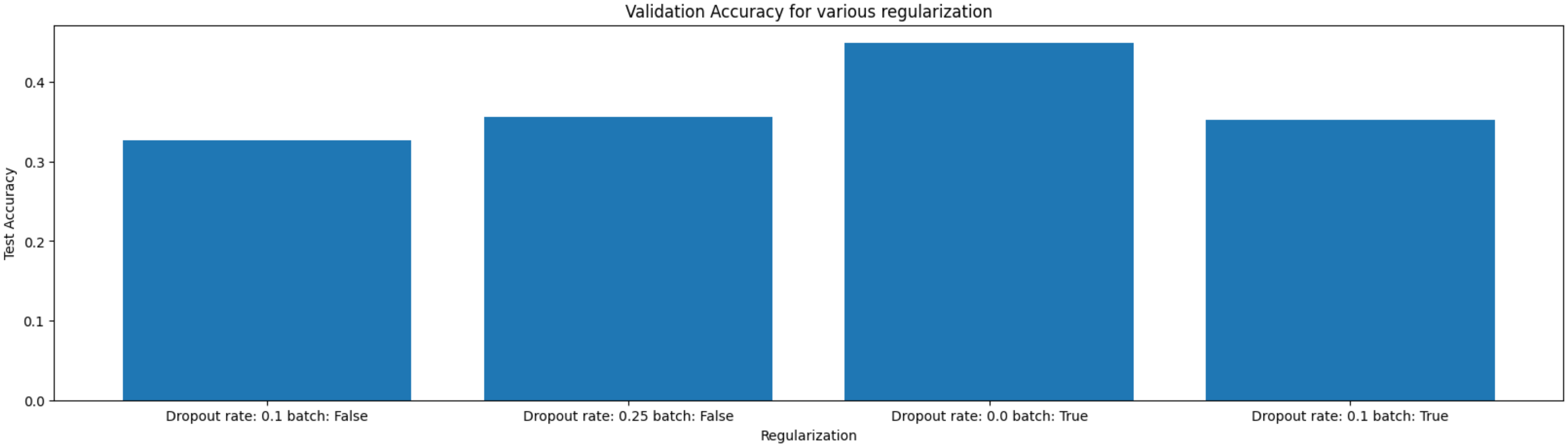
```
In [ ]: result_df_5
```

Out[ ]:

	Conv Kernel Size	Conv Filter Size	Pooling Layers	Activation Function	No. of Dense Layers after Flatten	Dropout Rate	Test Loss	Test Accuracy	Test F1 Score	Batch Normalization Presence	Training Time(in seconds)
0	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.10	1.597296	0.326389	0.307509	False	221.190828
1	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.25	1.653766	0.356481	0.335163	False	210.900421
2	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.00	1.618985	0.449074	0.432022	True	212.703463
3	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.10	1.774643	0.351852	0.334242	True	222.437056

In [ ]:

```
plt.figure(figsize=(20,5))
plt.bar(
    [f'Dropout rate: {drop} batch: {batch}' for drop,batch in zip(result_df_5['Dropout Rate'],result_df_5['Batch Normalization
    result_df_5['Test Accuracy']
)

plt.ylabel('Test Accuracy')
plt.xlabel('Regularization')
plt.title('Validation Accuracy for various regularization')
plt.show()
```



In [ ]:

```
best_dropout = result_df_5.sort_values(
    by=['Test Accuracy','Test F1 Score'],
    ascending=[False,False]
)['Dropout Rate'].iloc[0]

best_dropout
```

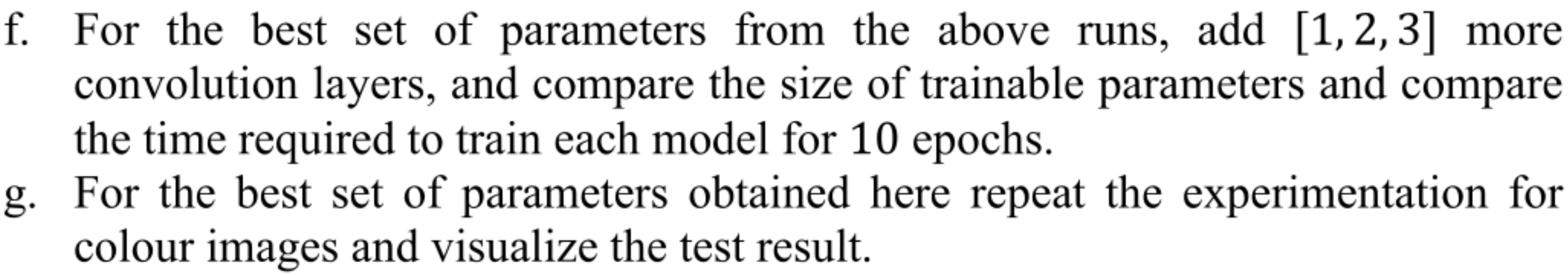
Out[ ]:

```
0.0
```

In [ ]:

```
best_do_batch = result_df_5.sort_values(
    by=['Test Accuracy','Test F1 Score'],
    ascending=[False,False]
)['Batch Normalization Presence'].iloc[0]

best_do_batch
```

```
Out[ ]:  True
```



f. For the best set of parameters from the above runs, add $[1,2,3]$ more convolution layers, and compare the size of trainable parameters and compare the time required to train each model for 10 epochs.

g. For the best set of parameters obtained here repeat the experimentation for colour images and visualize the test result.

In [ ]:

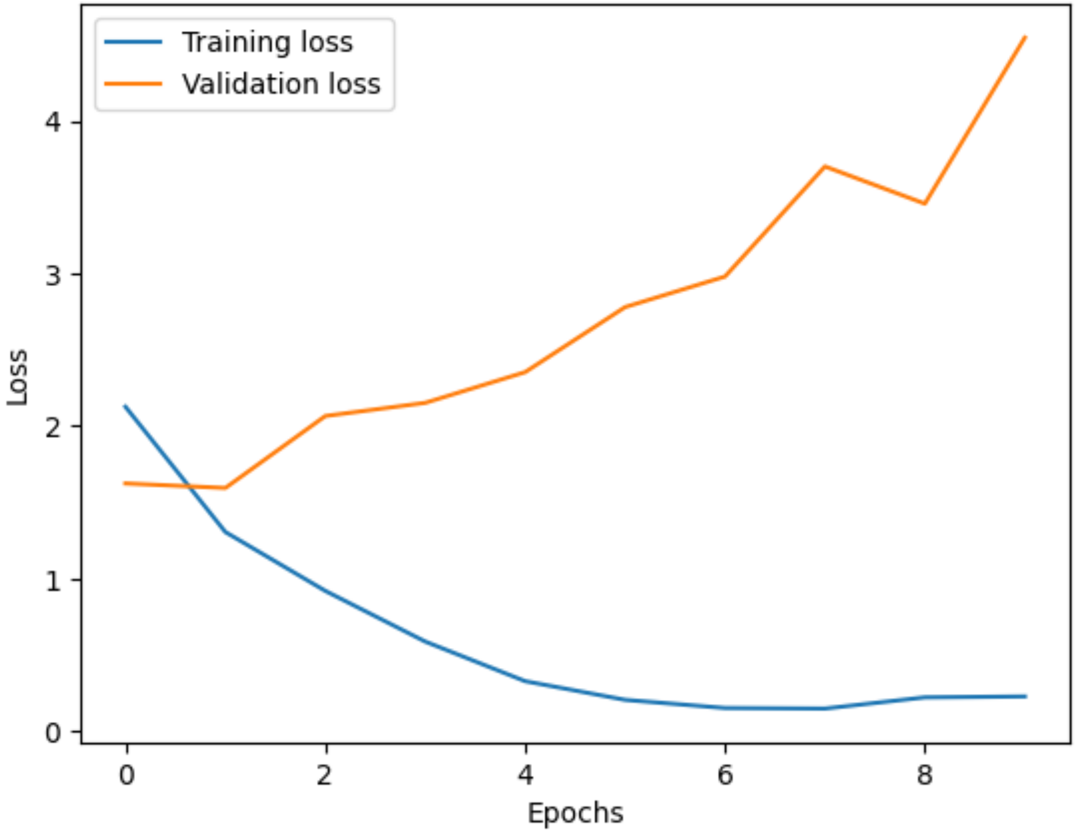
```python
# Subtask 6

result_df_6 = pd.DataFrame(
    columns=[
        'Conv Kernel Size',
        'Conv Filter Size',
        'Pooling Layers',
        'Activation Function',
        'No. of Dense Layers after Flatten',
        'Dropout Rate',
        'Test Loss',
        'Test Accuracy',
        'Test F1 Score',
        'Batch Normalization Presence',
        'No. of Extra Conv Layers',
        'Training Time(in seconds)'
    ]
)

filters = [16,32,64]
epochs = 10
extra_conv_layers =  [0,1,2,3]


for c in extra_conv_layers:
  filter_copy=[]
  kernel_copy=[]

  for filt,ker in zip(filters,best_kernel):
    filter_copy.append(filt)
    kernel_copy.append(ker)

  test_loss,test_accuracy,test_f1,train_time,_ = train_model(
      kernels=kernel_copy,
      filters=filter_copy,
      activation_func=best_activation_function,
      pool=best_pool,
      dropout_rate=best_dropout,
      num_dense_layers=best_num_dense,
      X_train=X_train,
      y_train=y_train,
      X_test=X_test,
      y_test=y_test,
      num_epochs=epochs,
      add_batch_normalization=best_do_batch,
      extra_conv_layers=c
      )

  result_df_6.loc[len(result_df_6.index)]=[
      kernel_copy,
      filter_copy,
      best_pool,
      best_activation_function,
      best_num_dense,
      best_dropout,
      test_loss,
      test_accuracy,
      test_f1,
      best_do_batch,
      c,
      train_time
  ]
```

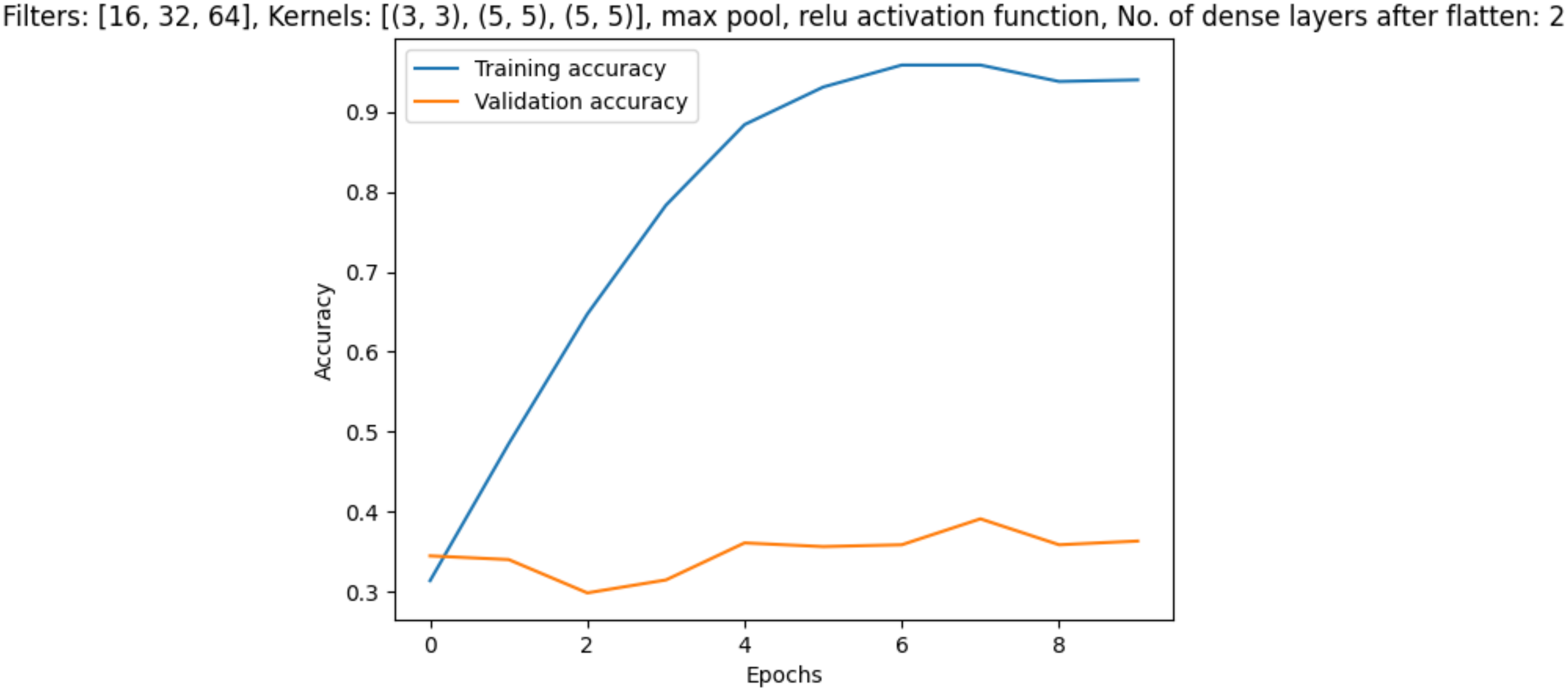
```
Model: "sequential_6"
```

```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                          ┃ Output Shape                 ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_9 (Conv2D)                     │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ max_pooling2d_6 (MaxPooling2D)        │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ batch_normalization_6                 │ ?                            │     0 (unbuilt) │
│ (BatchNormalization)                  │                              │                 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ flatten_6 (Flatten)                   │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_18 (Dense)                      │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_19 (Dense)                      │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_20 (Dense)                      │ ?                            │     0 (unbuilt) │
└───────────────────────────────────────┴──────────────────────────────┴─────────────────┘
 Total params: 0 (0.00 B)
 Trainable params: 0 (0.00 B)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 6s 28ms/step - accuracy: 0.2902 - f1_score: 0.2789 - loss: 2.7041 - val_accuracy: 0.3449 - val_f1_s
core: 0.2868 - val_loss: 1.6243
Epoch 2/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 2s 6ms/step - accuracy: 0.4680 - f1_score: 0.4586 - loss: 1.3390 - val_accuracy: 0.3403 - val_f1_sc
ore: 0.3248 - val_loss: 1.5946
Epoch 3/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 4ms/step - accuracy: 0.6392 - f1_score: 0.6378 - loss: 0.9517 - val_accuracy: 0.2986 - val_f1_sc
ore: 0.2681 - val_loss: 2.0661
Epoch 4/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 4ms/step - accuracy: 0.7875 - f1_score: 0.7874 - loss: 0.5885 - val_accuracy: 0.3148 - val_f1_sc
ore: 0.3014 - val_loss: 2.1523
Epoch 5/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 4ms/step - accuracy: 0.8937 - f1_score: 0.8939 - loss: 0.3075 - val_accuracy: 0.3611 - val_f1_sc
ore: 0.3543 - val_loss: 2.3535
Epoch 6/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 4ms/step - accuracy: 0.9372 - f1_score: 0.9372 - loss: 0.1979 - val_accuracy: 0.3565 - val_f1_sc
ore: 0.3462 - val_loss: 2.7796
Epoch 7/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - accuracy: 0.9613 - f1_score: 0.9613 - loss: 0.1452 - val_accuracy: 0.3588 - val_f1_sc
ore: 0.3531 - val_loss: 2.9799
Epoch 8/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9716 - f1_score: 0.9716 - loss: 0.1070 - val_accuracy: 0.3912 - val_f1_sc
ore: 0.3877 - val_loss: 3.7011
Epoch 9/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - accuracy: 0.9527 - f1_score: 0.9527 - loss: 0.1891 - val_accuracy: 0.3588 - val_f1_sc
ore: 0.3555 - val_loss: 3.4572
Epoch 10/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 0s 4ms/step - accuracy: 0.9521 - f1_score: 0.9521 - loss: 0.1813 - val_accuracy: 0.3634 - val_f1_sc
ore: 0.3502 - val_loss: 4.5450
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - accuracy: 0.3482 - f1_score: 0.3309 - loss: 1.6105
Test Loss: 1.611054539680481, Test Accuracy: 0.33796295523643494, Test F1 Score: 0.3220447897911072
Time required to train the model is 12.167885541915894 seconds
```

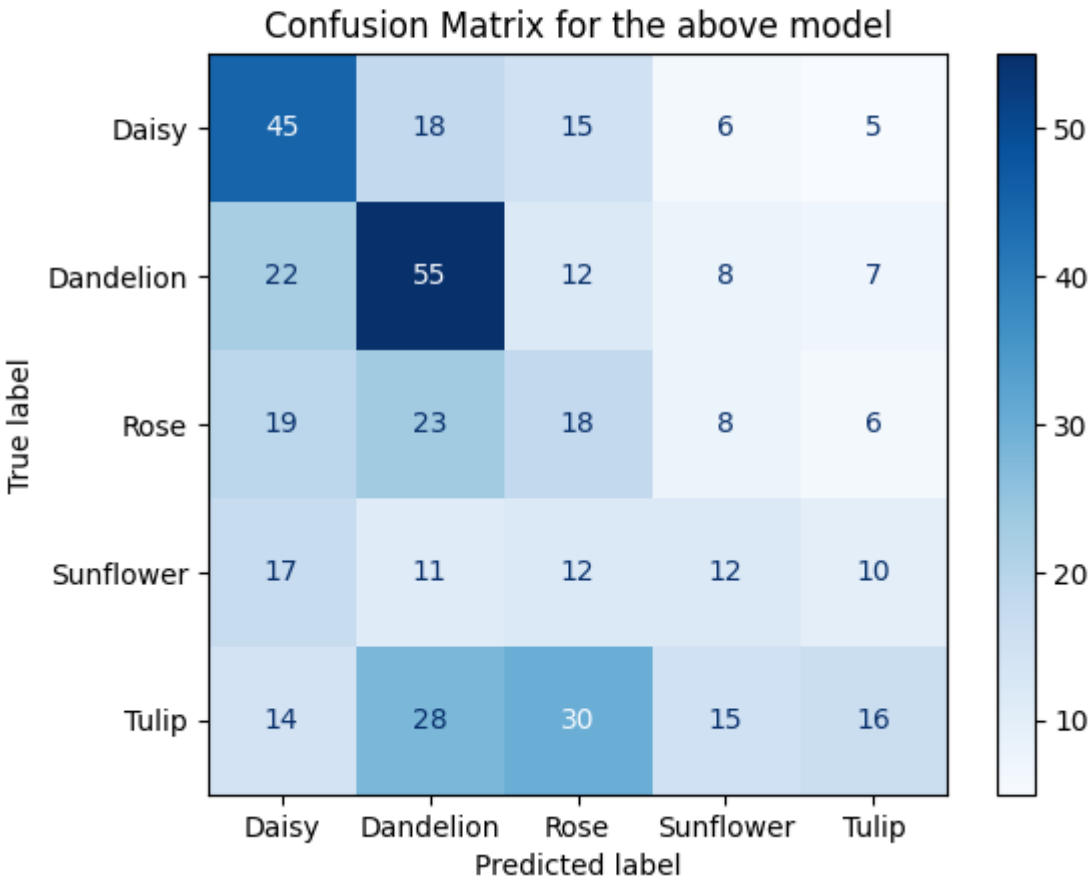
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2





Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

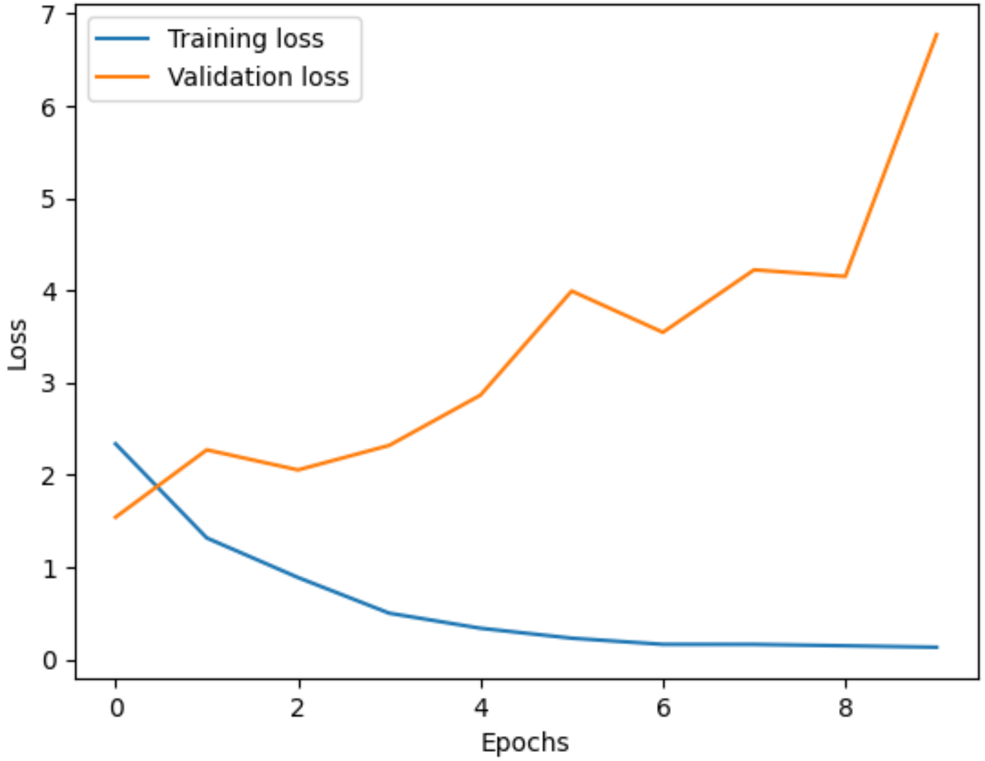
```
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step
```



```
Model: "sequential_7"
```

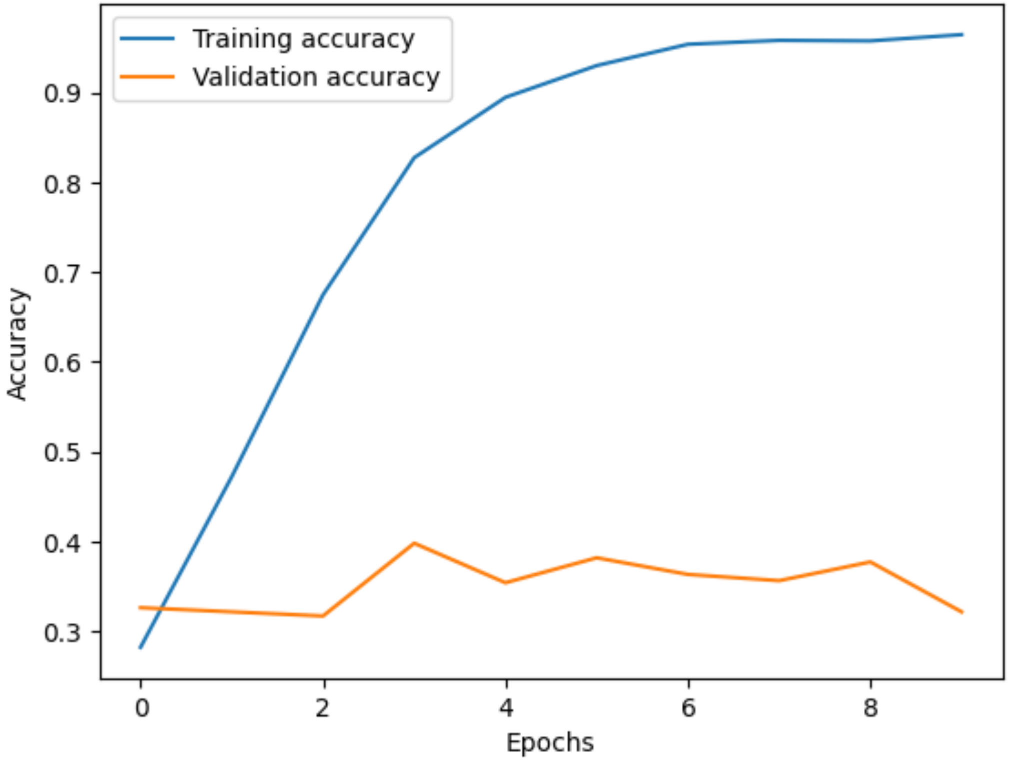
```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_10 (Conv2D)                   │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_7 (MaxPooling2D)       │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ batch_normalization_7                │ ?                           │     0 (unbuilt) │
│ (BatchNormalization)                 │                             │                 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ conv2d_11 (Conv2D)                   │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_7 (Flatten)                  │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_21 (Dense)                     │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_22 (Dense)                     │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_23 (Dense)                     │ ?                           │     0 (unbuilt) │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 0 (0.00 B)
 Trainable params: 0 (0.00 B)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 9s 53ms/step - accuracy: 0.2472 - f1_score: 0.2428 - loss: 3.8436 - val_accuracy: 0.3264 - val_f1_s
core: 0.3001 - val_loss: 1.5401
Epoch 2/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 4s 10ms/step - accuracy: 0.4568 - f1_score: 0.4535 - loss: 1.3349 - val_accuracy: 0.3218 - val_f1_s
core: 0.2507 - val_loss: 2.2705
Epoch 3/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - accuracy: 0.6738 - f1_score: 0.6730 - loss: 0.8941 - val_accuracy: 0.3171 - val_f1_s
core: 0.2621 - val_loss: 2.0527
Epoch 4/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.8262 - f1_score: 0.8267 - loss: 0.5211 - val_accuracy: 0.3981 - val_f1_sc
ore: 0.3835 - val_loss: 2.3187
Epoch 5/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.9072 - f1_score: 0.9072 - loss: 0.3232 - val_accuracy: 0.3542 - val_f1_sc
ore: 0.3458 - val_loss: 2.8635
Epoch 6/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - accuracy: 0.9336 - f1_score: 0.9336 - loss: 0.2581 - val_accuracy: 0.3819 - val_f1_s
core: 0.3539 - val_loss: 3.9928
Epoch 7/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - accuracy: 0.9620 - f1_score: 0.9620 - loss: 0.1399 - val_accuracy: 0.3634 - val_f1_s
core: 0.3541 - val_loss: 3.5446
Epoch 8/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - accuracy: 0.9722 - f1_score: 0.9722 - loss: 0.1136 - val_accuracy: 0.3565 - val_f1_s
core: 0.3536 - val_loss: 4.2221
Epoch 9/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.9624 - f1_score: 0.9624 - loss: 0.1448 - val_accuracy: 0.3773 - val_f1_sc
ore: 0.3833 - val_loss: 4.1511
Epoch 10/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.9690 - f1_score: 0.9690 - loss: 0.1124 - val_accuracy: 0.3218 - val_f1_sc
ore: 0.2925 - val_loss: 6.7719
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - accuracy: 0.2958 - f1_score: 0.2447 - loss: 1.5640
Test Loss: 1.5418537855148315, Test Accuracy: 0.3194444477558136, Test F1 Score: 0.2875923216342926
Time required to train the model is 22.891176462173462 seconds
```

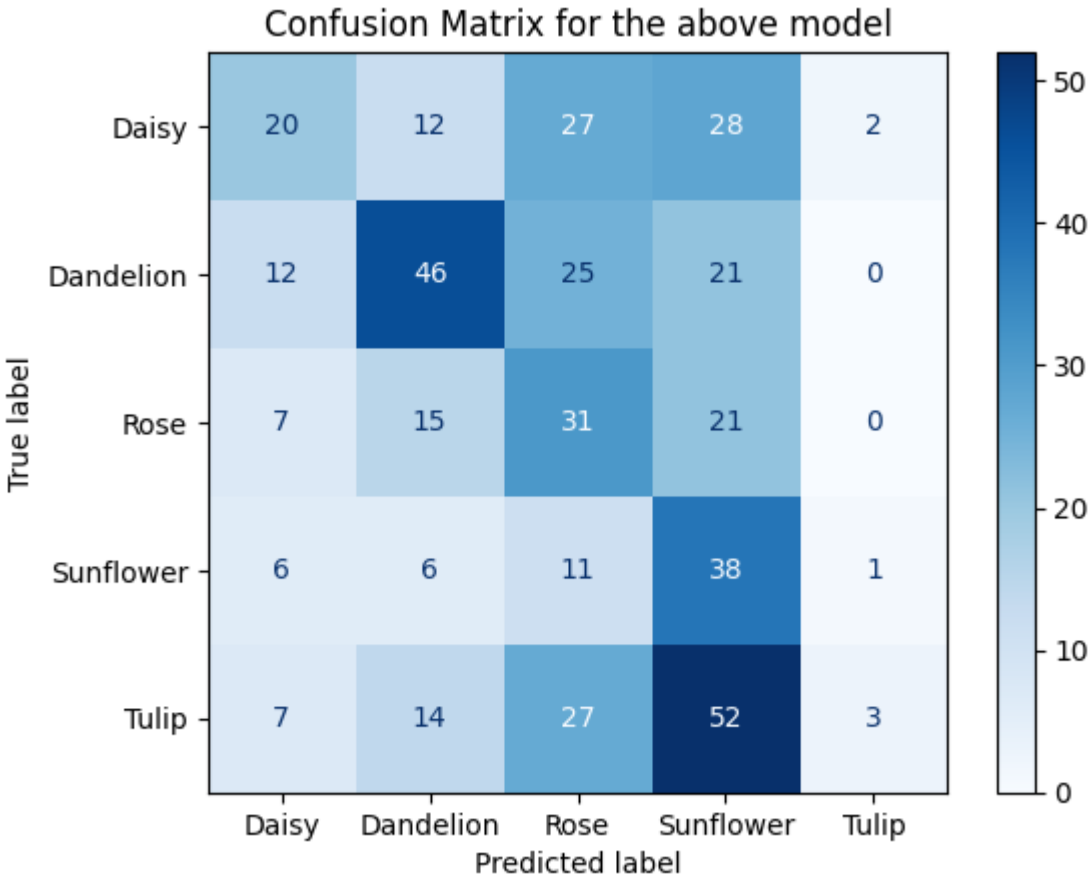


Filters: [16, 32, 64, 128], Kernels: [(3, 3), (5, 5), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

Filters: [16, 32, 64, 128], Kernels: [(3, 3), (5, 5), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



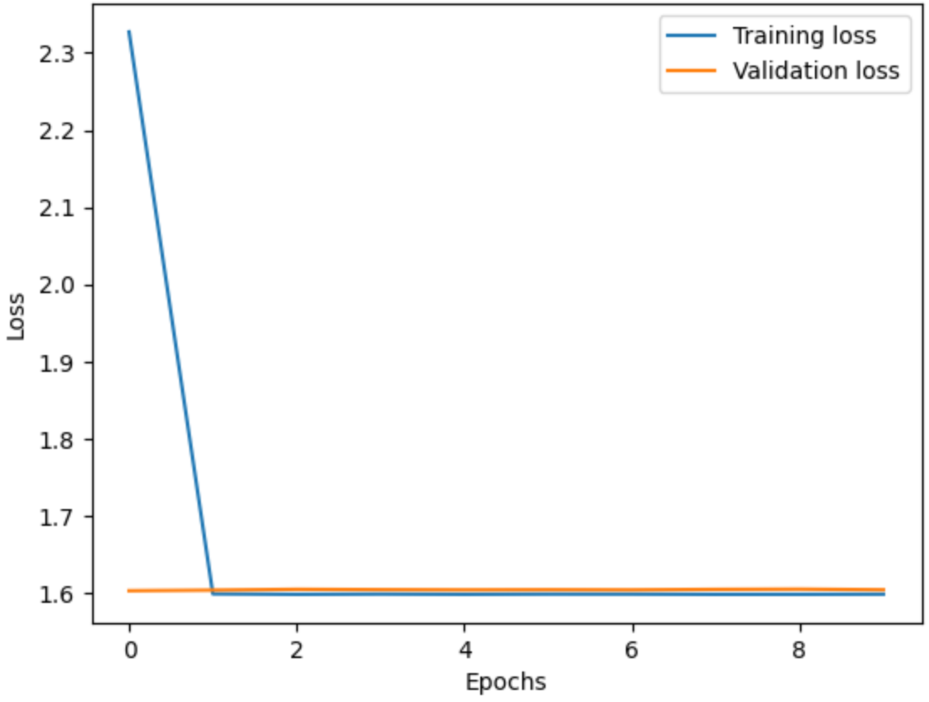
```
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
```



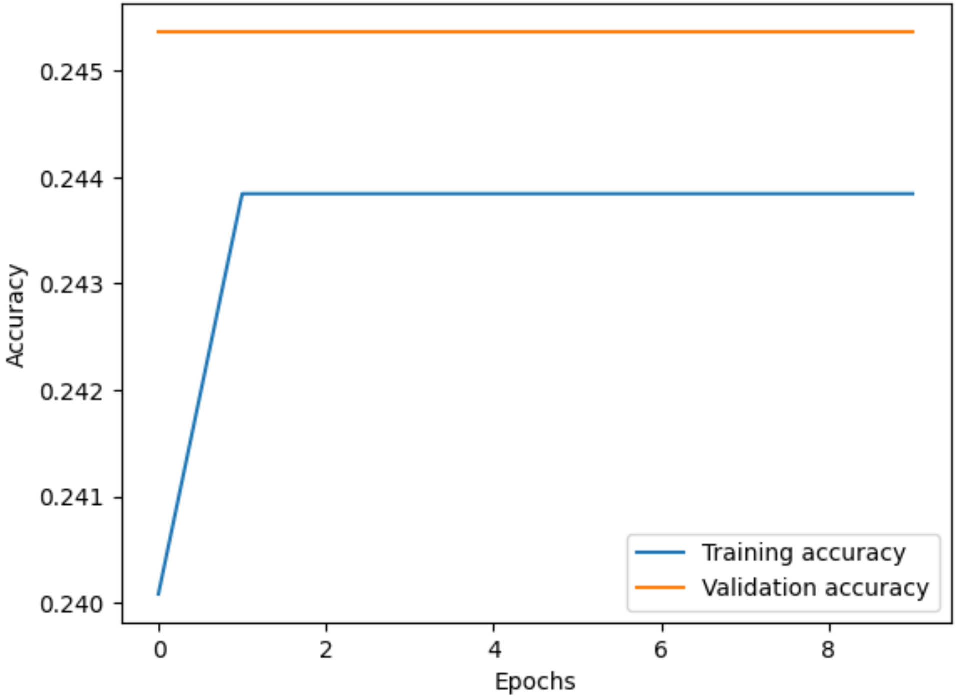
```
Model: "sequential_8"
```

```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_12 (Conv2D)                   │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_8 (MaxPooling2D)       │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ batch_normalization_8                │ ?                           │     0 (unbuilt) │
│ (BatchNormalization)                 │                             │                 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ conv2d_13 (Conv2D)                   │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ conv2d_14 (Conv2D)                   │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_8 (Flatten)                  │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_24 (Dense)                     │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_25 (Dense)                     │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_26 (Dense)                     │ ?                           │     0 (unbuilt) │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 0 (0.00 B)
 Trainable params: 0 (0.00 B)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 80ms/step - accuracy: 0.2309 - f1_score: 0.1277 - loss: 4.4110 - val_accuracy: 0.2454 - val_f1_
score: 0.0967 - val_loss: 1.6031
Epoch 2/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 3s 32ms/step - accuracy: 0.2505 - f1_score: 0.1004 - loss: 1.5976 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6039
Epoch 3/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 5s 32ms/step - accuracy: 0.2345 - f1_score: 0.0892 - loss: 1.6025 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6050
Epoch 4/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 3s 31ms/step - accuracy: 0.2368 - f1_score: 0.0908 - loss: 1.6019 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6045
Epoch 5/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 3s 31ms/step - accuracy: 0.2544 - f1_score: 0.1033 - loss: 1.5904 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6043
Epoch 6/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 5s 33ms/step - accuracy: 0.2486 - f1_score: 0.0993 - loss: 1.5965 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6044
Epoch 7/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 3s 32ms/step - accuracy: 0.2507 - f1_score: 0.1006 - loss: 1.5965 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6042
Epoch 8/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 5s 32ms/step - accuracy: 0.2524 - f1_score: 0.1019 - loss: 1.5955 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6049
Epoch 9/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 5s 32ms/step - accuracy: 0.2477 - f1_score: 0.0985 - loss: 1.5987 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6052
Epoch 10/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 5s 31ms/step - accuracy: 0.2369 - f1_score: 0.0910 - loss: 1.6006 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6044
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.1992 - f1_score: 0.0693 - loss: 1.6065
Test Loss: 1.598532795906067, Test Accuracy: 0.24074074625968933, Test F1 Score: 0.09342177957296371
Time required to train the model is 53.9805862903595 seconds
```

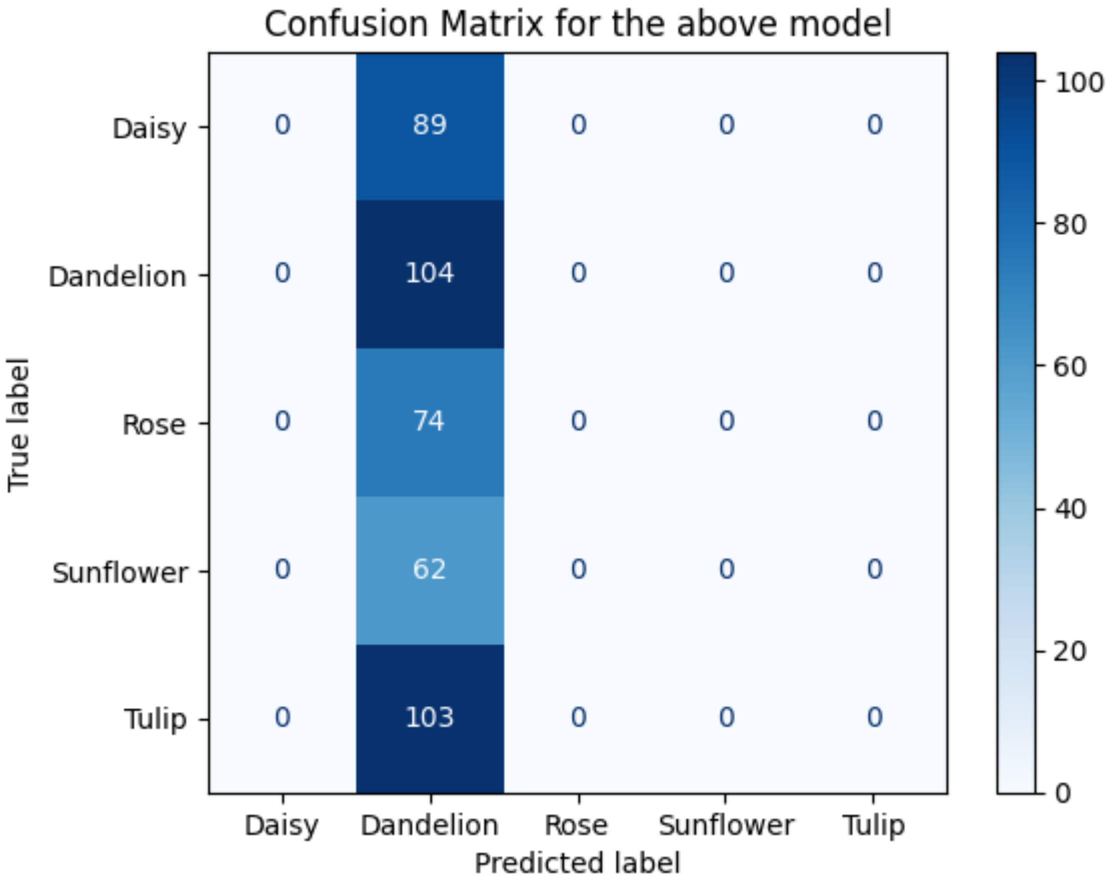


Filters: [16, 32, 64, 128, 256], Kernels: [(3, 3), (5, 5), (5, 5), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



Filters: [16, 32, 64, 128, 256], Kernels: [(3, 3), (5, 5), (5, 5), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2

```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 25ms/step
```



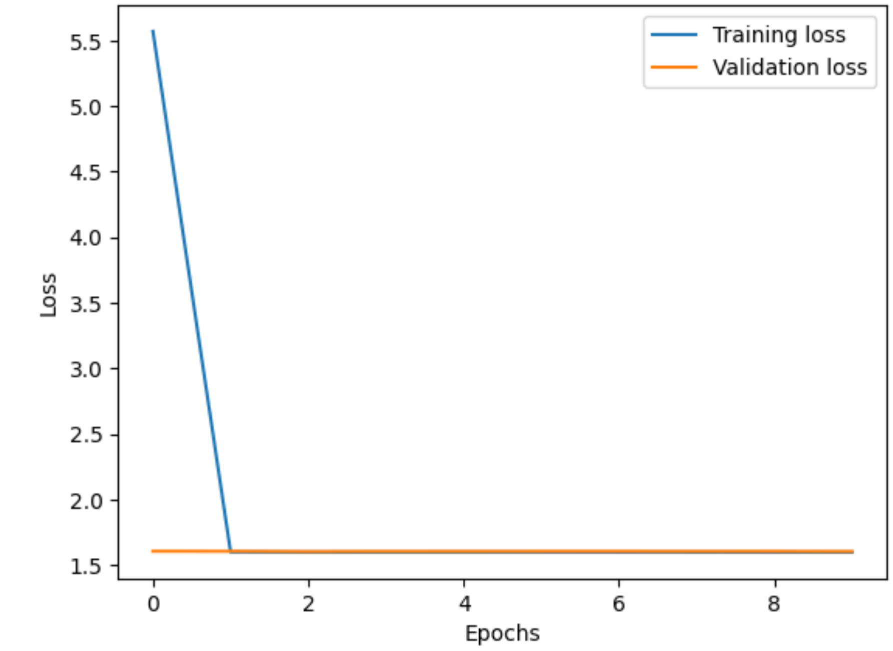
	Daisy	Dandelion	Rose	Sunflower	Tulip
Daisy	0	89	0	0	0
Dandelion	0	104	0	0	0
Rose	0	74	0	0	0
Sunflower	0	62	0	0	0
Tulip	0	103	0	0	0

```
Model: "sequential_9"
```

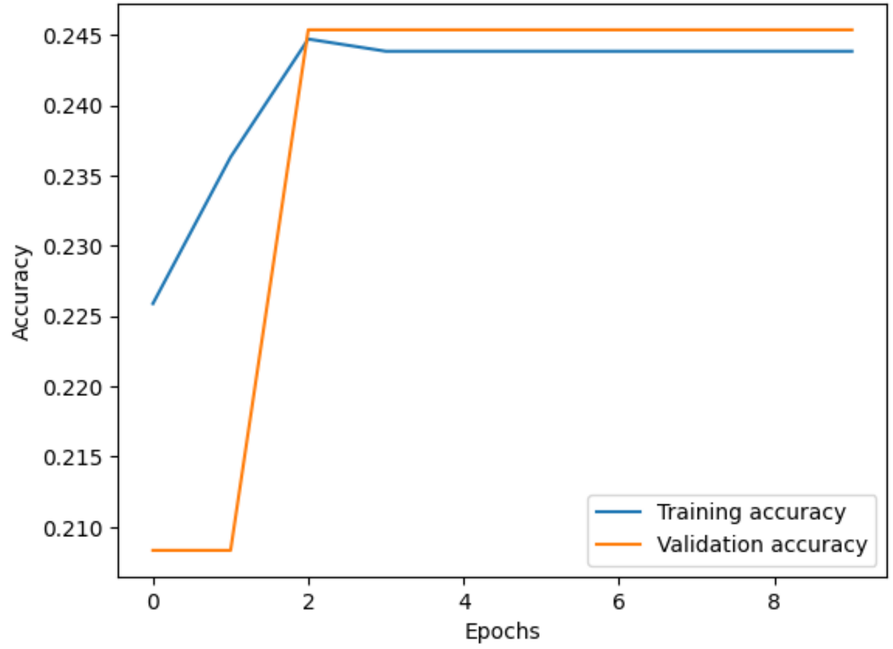
```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                        ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_15 (Conv2D)                  │ ?                           │     0 (unbuilt) │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d_9 (MaxPooling2D)      │ ?                           │     0 (unbuilt) │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ batch_normalization_9               │ ?                           │     0 (unbuilt) │
│ (BatchNormalization)                │                             │                 │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ conv2d_16 (Conv2D)                  │ ?                           │     0 (unbuilt) │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ conv2d_17 (Conv2D)                  │ ?                           │     0 (unbuilt) │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ conv2d_18 (Conv2D)                  │ ?                           │     0 (unbuilt) │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten_9 (Flatten)                 │ ?                           │     0 (unbuilt) │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_27 (Dense)                    │ ?                           │     0 (unbuilt) │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_28 (Dense)                    │ ?                           │     0 (unbuilt) │
├─────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_29 (Dense)                    │ ?                           │     0 (unbuilt) │
└─────────────────────────────────────┴─────────────────────────────┴─────────────────┘
 Total params: 0 (0.00 B)
 Trainable params: 0 (0.00 B)
 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 39s 233ms/step - accuracy: 0.2140 - f1_score: 0.1530 - loss: 18.3655 - val_accuracy: 0.2083 - val_f
1_score: 0.0718 - val_loss: 1.6065
Epoch 2/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 16s 82ms/step - accuracy: 0.2346 - f1_score: 0.1042 - loss: 1.6045 - val_accuracy: 0.2083 - val_f1_
score: 0.0718 - val_loss: 1.6060
Epoch 3/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 9s 80ms/step - accuracy: 0.2551 - f1_score: 0.1448 - loss: 1.5932 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6032
Epoch 4/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 9s 79ms/step - accuracy: 0.2338 - f1_score: 0.0887 - loss: 1.6002 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6048
Epoch 5/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 9s 80ms/step - accuracy: 0.2420 - f1_score: 0.0944 - loss: 1.5970 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6047
Epoch 6/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 78ms/step - accuracy: 0.2407 - f1_score: 0.0934 - loss: 1.6009 - val_accuracy: 0.2454 - val_f1_
score: 0.0967 - val_loss: 1.6052
Epoch 7/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 8s 78ms/step - accuracy: 0.2403 - f1_score: 0.0932 - loss: 1.6002 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6053
Epoch 8/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 9s 79ms/step - accuracy: 0.2419 - f1_score: 0.0944 - loss: 1.5988 - val_accuracy: 0.2454 - val_f1_s
core: 0.0967 - val_loss: 1.6049
Epoch 9/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 79ms/step - accuracy: 0.2359 - f1_score: 0.0901 - loss: 1.6003 - val_accuracy: 0.2454 - val_f1_
score: 0.0967 - val_loss: 1.6052
Epoch 10/10
108/108 ━━━━━━━━━━━━━━━━━━━━ 10s 77ms/step - accuracy: 0.2481 - f1_score: 0.0987 - loss: 1.5984 - val_accuracy: 0.2454 - val_f1_
score: 0.0967 - val_loss: 1.6042
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step - accuracy: 0.1992 - f1_score: 0.0693 - loss: 1.6048
Test Loss: 1.5982946157455444, Test Accuracy: 0.24074074625968933, Test F1 Score: 0.09342177957296371
Time required to train the model is 128.19466972351074 seconds
```

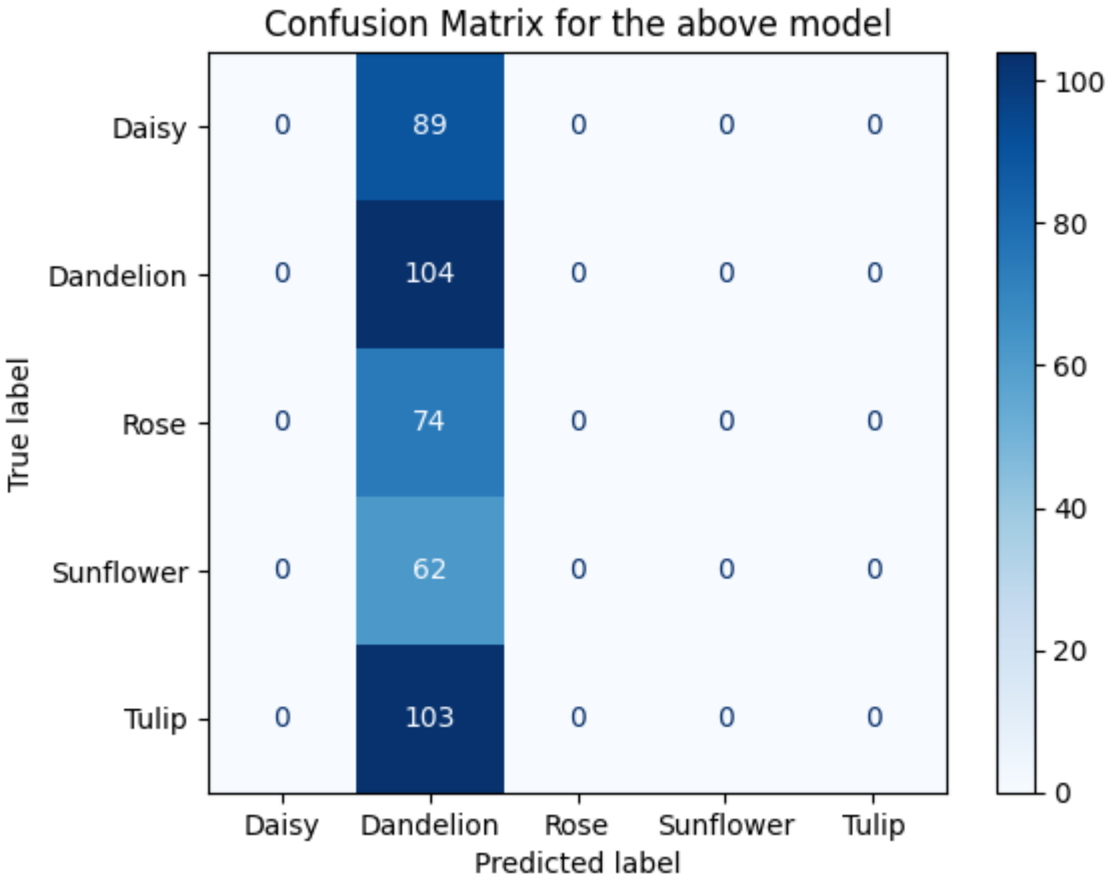
Filters: [16, 32, 64, 128, 256, 512], Kernels: [(3, 3), (5, 5), (5, 5), (5, 5), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



Filters: [16, 32, 64, 128, 256, 512], Kernels: [(3, 3), (5, 5), (5, 5), (5, 5), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 47ms/step
```



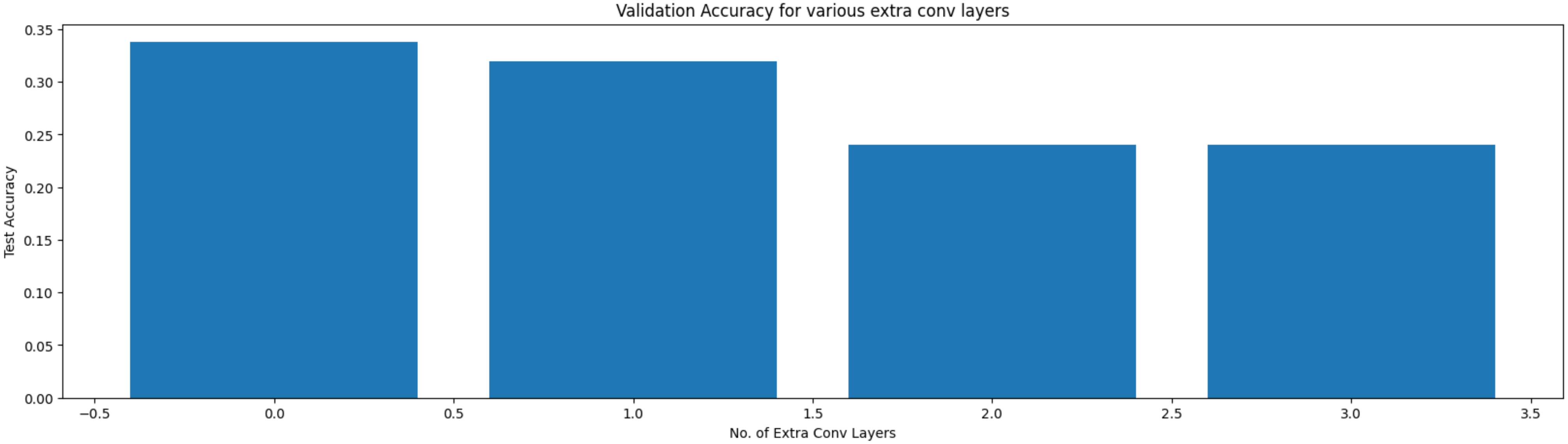
```
In [ ]: result_df_6
```

Out[ ]:

	Conv Kernel Size	Conv Filter Size	Pooling Layers	Activation Function	No. of Dense Layers after Flatten	Dropout Rate	Test Loss	Test Accuracy	Test F1 Score	Batch Normalization Presence	No. of Extra Conv Layers	Training Time(in seconds)
0	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.0	1.611055	0.337963	0.322045	True	0	12.167886
1	[(3, 3), (5, 5), (5, 5), (5, 5)]	[16, 32, 64, 128]	max	relu	2	0.0	1.541854	0.319444	0.287592	True	1	22.891176
2	[(3, 3), (5, 5), (5, 5), (5, 5), (5, 5)]	[16, 32, 64, 128, 256]	max	relu	2	0.0	1.598533	0.240741	0.093422	True	2	53.980586
3	[(3, 3), (5, 5), (5, 5), (5, 5), (5, 5), (5, 5)]	[16, 32, 64, 128, 256, 512]	max	relu	2	0.0	1.598295	0.240741	0.093422	True	3	128.194670

In [ ]:

```python
plt.figure(figsize=(20,5))
plt.bar(
    result_df_6['No. of Extra Conv Layers'],
    result_df_6['Test Accuracy']
)

plt.ylabel('Test Accuracy')
plt.xlabel('No. of Extra Conv Layers')
plt.title('Validation Accuracy for various extra conv layers')
plt.show()
```



In [ ]:

```
best_conv = result_df_6.sort_values(
    by=['Test Accuracy','Test F1 Score'],
    ascending=[False,False]
)['No. of Extra Conv Layers'].iloc[0]

best_conv
```

Out[ ]:

```
0
```

In [ ]:

```
# Subtask 7

# Prepare the RGB dataset

X_rgb = []  # Contains the images
Y_rgb = []  # Contains the labels
```

In [ ]:

```
def train_data_rgb(flower_type,path_dir):
  for img in tqdm(os.listdir(path_dir)):
        label=flower_type
        path = os.path.join(path_dir,img)
        img_array = Image.open(path)
        img_array = img_array.resize((IMG_SIZE,IMG_SIZE))
        img_array = np.array(img_array)
        X_rgb.append(np.array(img_array))
        Y_rgb.append(str(label))
```

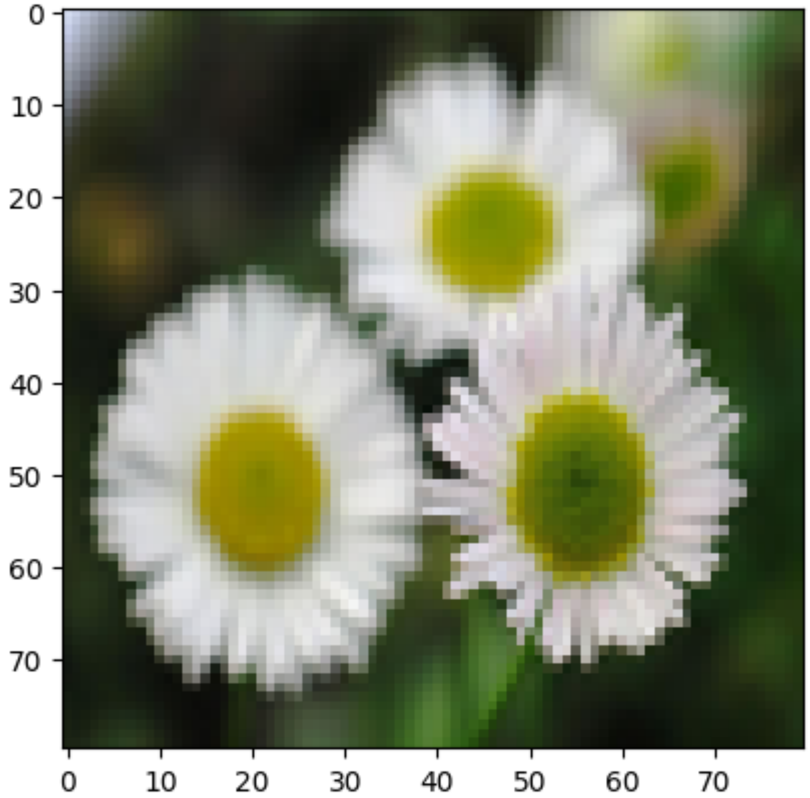
In [ ]:

```
train_data_rgb('Daisy',FLOWER_DAISY_DIR)
train_data_rgb('Sunflower',FLOWER_SUNFLOWER_DIR)
train_data_rgb('Tulip',FLOWER_TULIP_DIR)
train_data_rgb('Dandelion',FLOWER_DANDI_DIR)
train_data_rgb('Rose',FLOWER_ROSE_DIR)
```

```
100%|██████████| 764/764 [00:03<00:00, 240.91it/s]
100%|██████████| 733/733 [00:03<00:00, 188.78it/s]
100%|██████████| 984/984 [00:04<00:00, 212.28it/s]
100%|██████████| 1052/1052 [00:04<00:00, 237.51it/s]
100%|██████████| 784/784 [00:03<00:00, 220.30it/s]
```

In [ ]:
```
import matplotlib.image as mpimg
plt.imshow(X_rgb[223])

print(Y_rgb[223])
```

```
Daisy
```



In [ ]:
```
from sklearn.model_selection import train_test_split

X_train_rgb,X_rem_rgb,y_train_rgb,y_rem_rgb = train_test_split(X_rgb,Y_rgb,test_size=0.2,random_state=5)
X_test_rgb,X_val_rgb,y_test_rgb,y_val_rgb = train_test_split(X_rem_rgb,y_rem_rgb,test_size=0.5,random_state=5)
```

```
print(len(X_train_rgb))
print(len(y_train_rgb))
print(len(X_val_rgb))
print(len(y_val_rgb))
print(len(X_test_rgb))
print(len(y_test_rgb))
```

```
3453
3453
432
432
432
432
```

In [ ]:

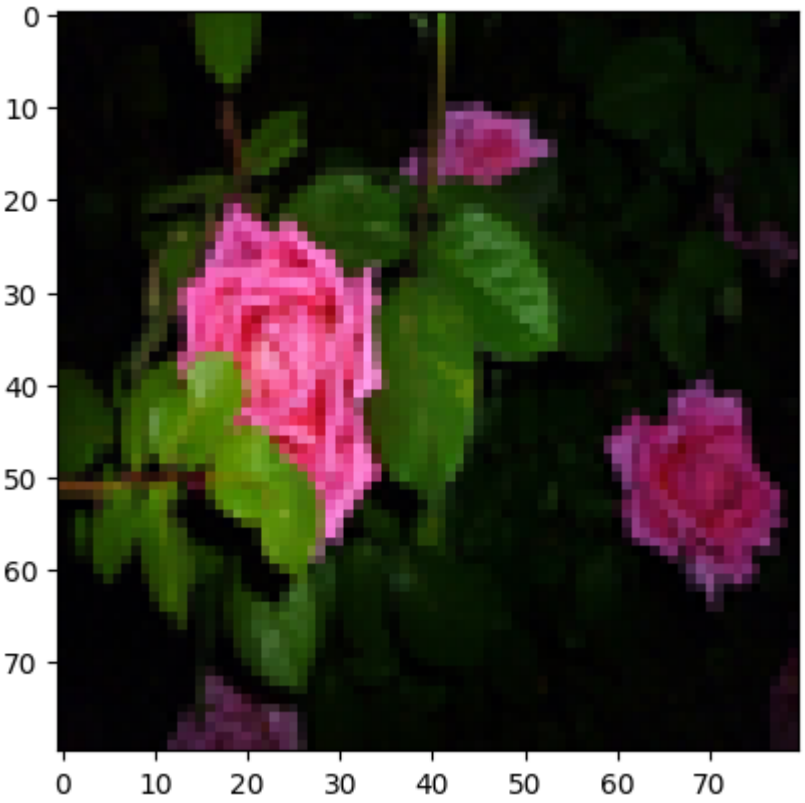
```
# Convert to np array for tf processing
X_train_rgb=np.array(X_train_rgb)
X_val_rgb=np.array(X_val_rgb)
X_test_rgb=np.array(X_test_rgb)
y_train_rgb=np.array(y_train_rgb)
y_val_rgb=np.array(y_val_rgb)
y_test_rgb=np.array(y_test_rgb)

# Reshape
X_train_rgb = X_train_rgb.reshape(-1,IMG_SIZE,IMG_SIZE,3)
X_val_rgb = X_val_rgb.reshape(-1,IMG_SIZE,IMG_SIZE,3)
X_test_rgb = X_test_rgb.reshape(-1,IMG_SIZE,IMG_SIZE,3)
```

In [ ]:

```
# One hot encode the labels
label_encoder = LabelEncoder()

label_encoder.fit(['Daisy','Sunflower','Tulip','Dandelion','Rose'])

y_train_rgb = label_encoder.transform(y_train_rgb)
y_val_rgb = label_encoder.transform(y_val_rgb)
y_test_rgb = label_encoder.transform(y_test_rgb)

y_train_rgb = pd.get_dummies(y_train_rgb,dtype='int').to_numpy()
y_val_rgb = pd.get_dummies(y_val_rgb,dtype='int').to_numpy()
y_test_rgb = pd.get_dummies(y_test_rgb,dtype='int').to_numpy()
```

In [ ]:

```
plt.imshow(X_train_rgb[24])
plt.show()
```



In [ ]:

```
y_train_rgb[24]
```

Out[ ]:

```
array([0, 0, 1, 0, 0])
```

In [ ]:

```
result_df_7 = pd.DataFrame(
    columns=[
        'Conv Kernel Size',
        'Conv Filter Size',
        'Pooling Layers',
        'Activation Function',
        'No. of Dense Layers after Flatten',
        'Dropout Rate',
        'Test Loss',
        'Test Accuracy',
        'Test F1 Score',
        'Batch Normalization Presence',
        'No. of Extra Conv Layers',
        'Color Mode',
        'Training Time(in seconds)'
    ]
```

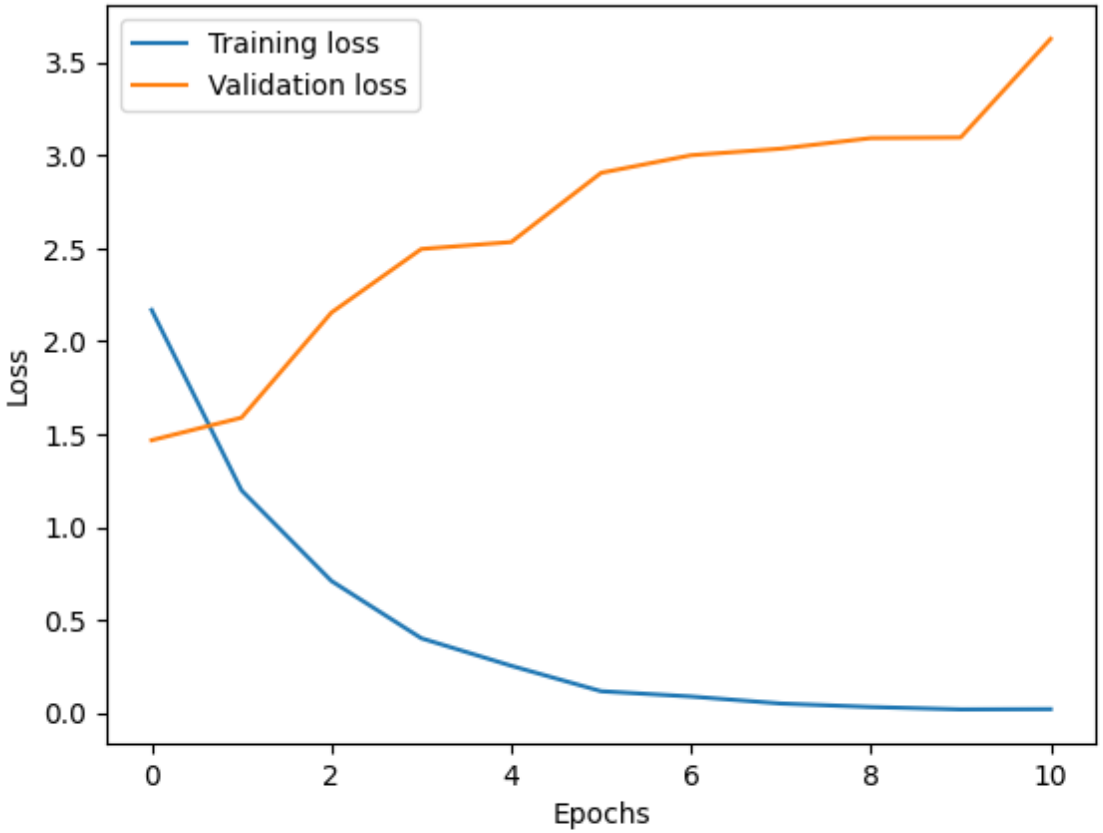
```
)

filters = [16,32,64]
epochs = 20

test_loss,test_accuracy,test_f1,train_time,_ = train_model(
      kernels=best_kernel,
      filters=filters,
      activation_func=best_activation_function,
      pool=best_pool,
      dropout_rate=best_dropout,
      num_dense_layers=best_num_dense,
      X_train=X_train,
      y_train=y_train,
      X_test=X_test,
      y_test=y_test,
      num_epochs=epochs,
      add_batch_normalization=best_do_batch,
      extra_conv_layers=best_conv
      )

result_df_7.loc[len(result_df_7.index)]=[
      best_kernel,
      filters,
      best_pool,
      best_activation_function,
      best_num_dense,
      best_dropout,
      test_loss,
      test_accuracy,
      test_f1,
      best_do_batch,
      best_conv,
      'grayscale',
      train_time
  ]

test_loss,test_accuracy,test_f1,train_time,_ = train_model(
      kernels=best_kernel,
      filters=filters,
      activation_func=best_activation_function,
      pool=best_pool,
      dropout_rate=best_dropout,
      num_dense_layers=best_num_dense,
      X_train=X_train_rgb,
      y_train=y_train_rgb,
```

```python
      X_test=X_test_rgb,
      y_test=y_test_rgb,
      num_epochs=epochs,
      add_batch_normalization=best_do_batch,
      extra_conv_layers=best_conv,
      is_rgb=True
      )

result_df_7.loc[len(result_df_7.index)]=[
      best_kernel,
      filters,
      best_pool,
      best_activation_function,
      best_num_dense,
      best_dropout,
      test_loss,
      test_accuracy,
      test_f1,
      best_do_batch,
      best_conv,
      'rgb',
      train_time
  ]
```

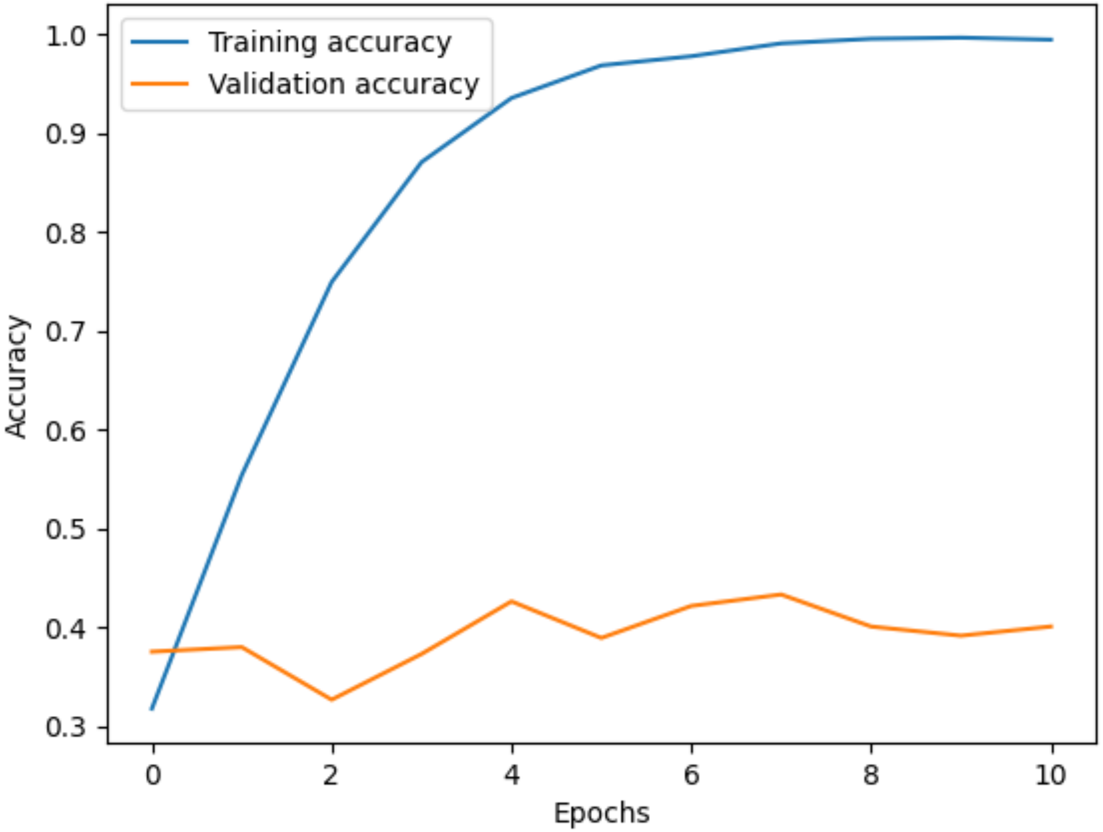
```
Model: "sequential_39"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                           ┃ Output Shape                 ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_58 (Conv2D)                     │ ?                            │     0 (unbuilt) │
├────────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ max_pooling2d_38 (MaxPooling2D)        │ ?                            │     0 (unbuilt) │
├────────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ batch_normalization_23                 │ ?                            │     0 (unbuilt) │
│ (BatchNormalization)                   │                              │                 │
├────────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ flatten_39 (Flatten)                   │ ?                            │     0 (unbuilt) │
├────────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_109 (Dense)                      │ ?                            │     0 (unbuilt) │
├────────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_110 (Dense)                      │ ?                            │     0 (unbuilt) │
├────────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_111 (Dense)                      │ ?                            │     0 (unbuilt) │
└────────────────────────────────────────┴──────────────────────────────┴─────────────────┘

 Total params: 0 (0.00 B)

 Trainable params: 0 (0.00 B)
```

```
Non-trainable params: 0 (0.00 B)
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 16s 124ms/step - accuracy: 0.2898 - f1_score: 0.2828 - loss: 2.6201 - val_accuracy: 0.3750 - val_f1
_score: 0.3660 - val_loss: 1.4675
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 121ms/step - accuracy: 0.5534 - f1_score: 0.5431 - loss: 1.2021 - val_accuracy: 0.3796 - val_f1
_score: 0.3757 - val_loss: 1.5889
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 119ms/step - accuracy: 0.7582 - f1_score: 0.7554 - loss: 0.6858 - val_accuracy: 0.3264 - val_f1
_score: 0.3189 - val_loss: 2.1540
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 125ms/step - accuracy: 0.8745 - f1_score: 0.8745 - loss: 0.4143 - val_accuracy: 0.3727 - val_f1
_score: 0.3744 - val_loss: 2.4959
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 124ms/step - accuracy: 0.9413 - f1_score: 0.9412 - loss: 0.2176 - val_accuracy: 0.4259 - val_f1
_score: 0.4236 - val_loss: 2.5334
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 115ms/step - accuracy: 0.9698 - f1_score: 0.9698 - loss: 0.1033 - val_accuracy: 0.3889 - val_f1
_score: 0.3845 - val_loss: 2.9056
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 123ms/step - accuracy: 0.9838 - f1_score: 0.9838 - loss: 0.0656 - val_accuracy: 0.4213 - val_f1
_score: 0.4097 - val_loss: 3.0003
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 13s 119ms/step - accuracy: 0.9862 - f1_score: 0.9862 - loss: 0.0642 - val_accuracy: 0.4329 - val_f1
_score: 0.4233 - val_loss: 3.0358
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 120ms/step - accuracy: 0.9961 - f1_score: 0.9961 - loss: 0.0331 - val_accuracy: 0.4005 - val_f1
_score: 0.4002 - val_loss: 3.0924
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 14s 125ms/step - accuracy: 0.9950 - f1_score: 0.9950 - loss: 0.0189 - val_accuracy: 0.3912 - val_f1
_score: 0.3864 - val_loss: 3.0958
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 124ms/step - accuracy: 0.9962 - f1_score: 0.9962 - loss: 0.0175 - val_accuracy: 0.4005 - val_f1
_score: 0.3901 - val_loss: 3.6262
14/14 ━━━━━━━━━━━━━━━━━━━━ 0s 29ms/step - accuracy: 0.3190 - f1_score: 0.3046 - loss: 1.5945
Test Loss: 1.5915693044662476, Test Accuracy: 0.32870370149612427, Test F1 Score: 0.30711865425109863
Time required to train the model is 206.1395878791809 seconds
```

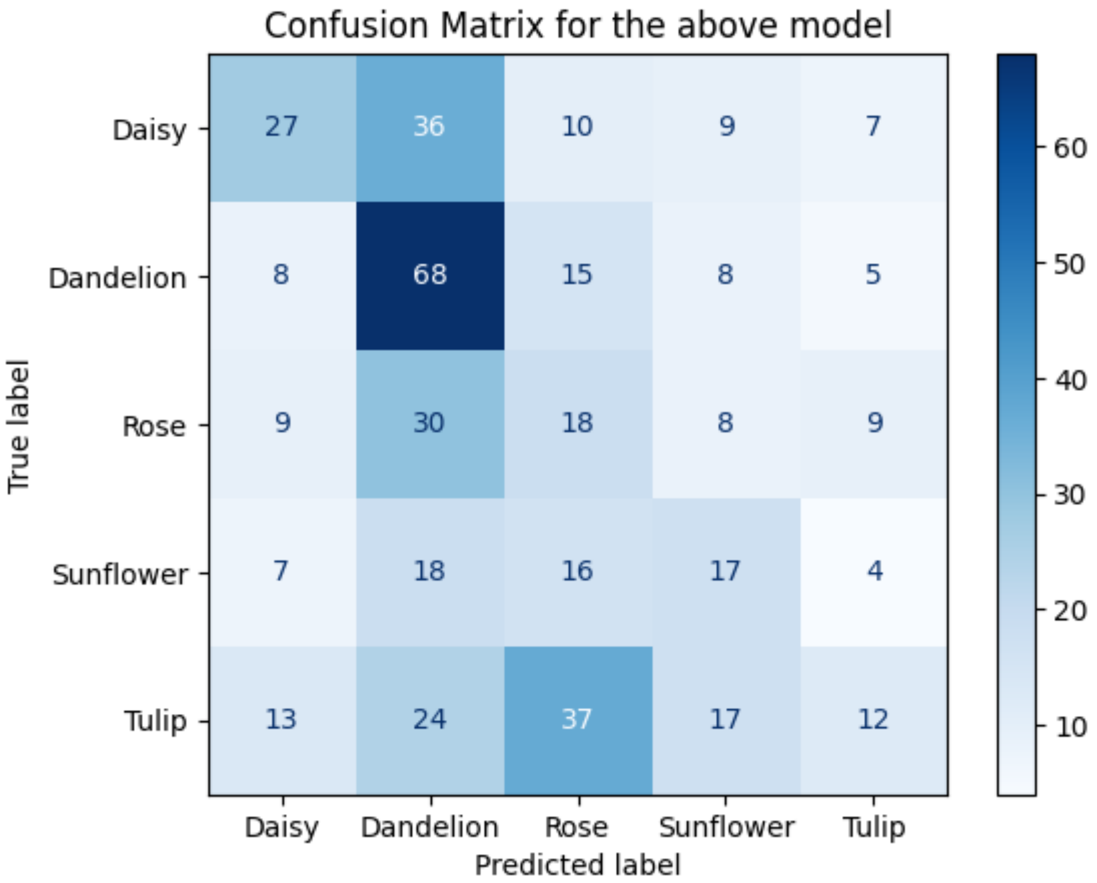
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



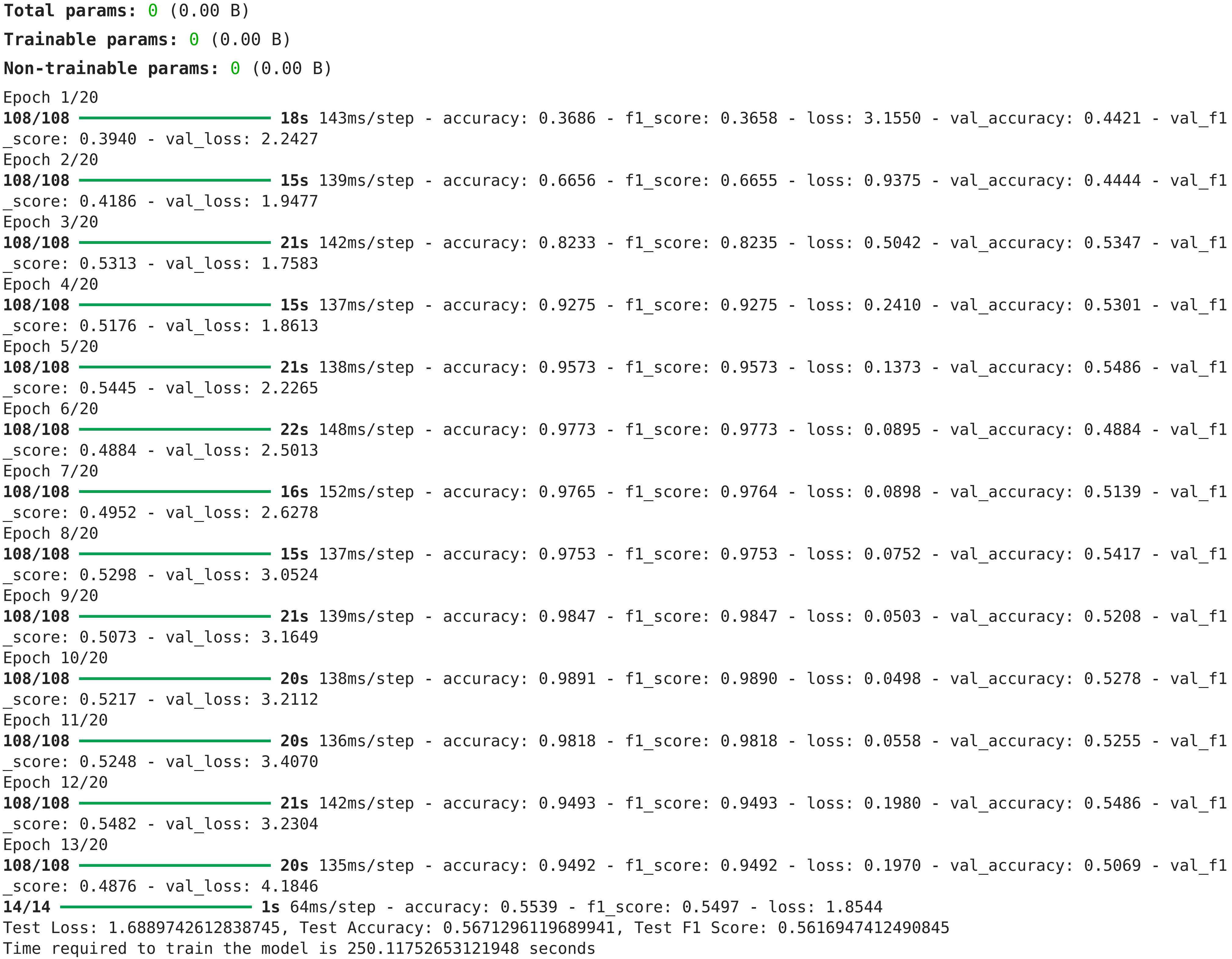
Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



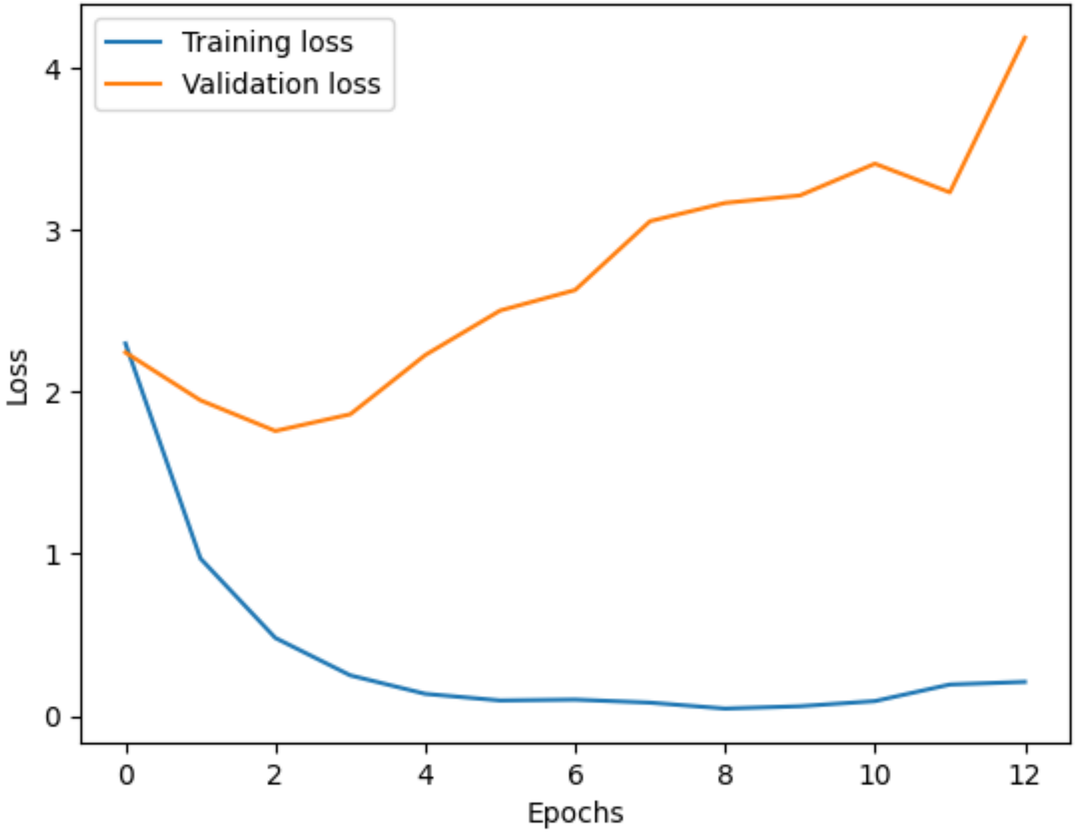
```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 36ms/step
```



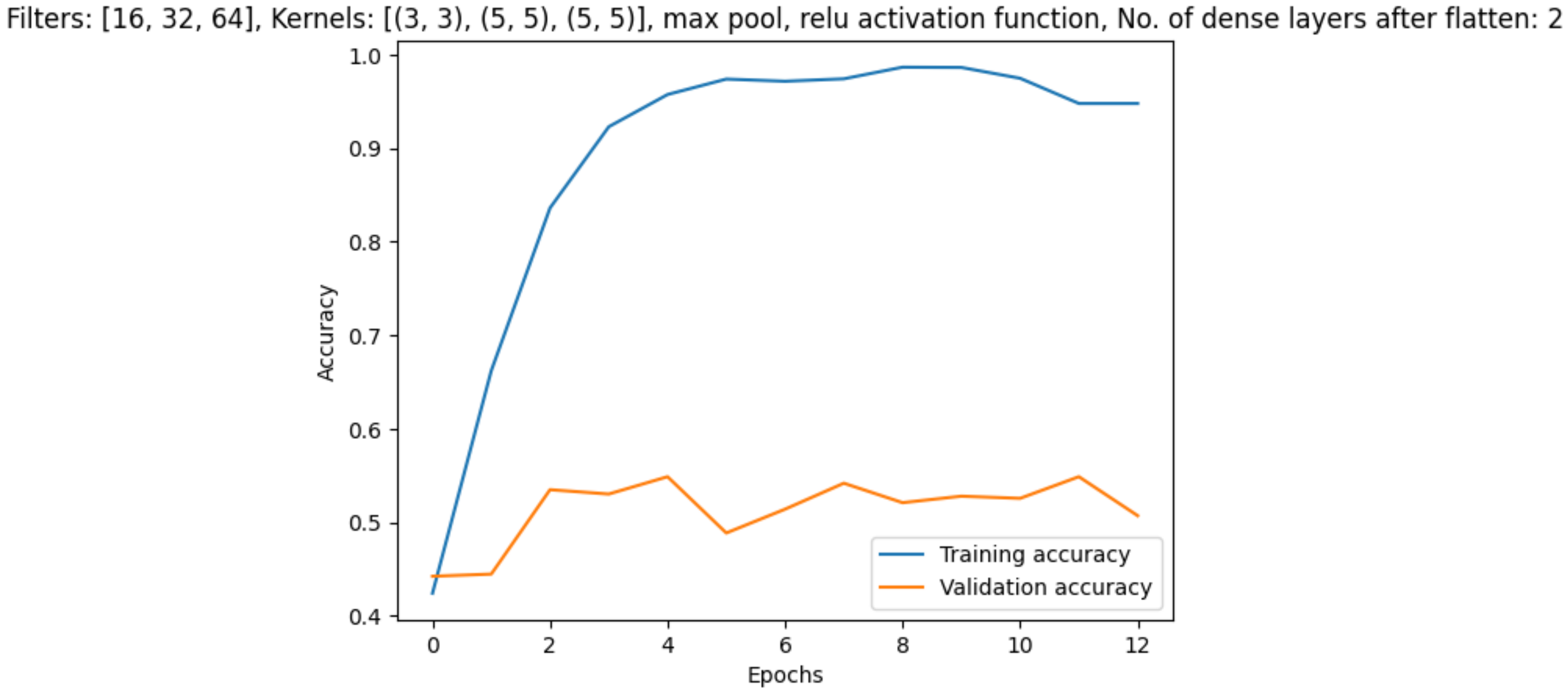
```
Model: "sequential_40"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                          ┃ Output Shape                 ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_59 (Conv2D)                    │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ max_pooling2d_39 (MaxPooling2D)       │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ batch_normalization_24                │ ?                            │     0 (unbuilt) │
│ (BatchNormalization)                  │                              │                 │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ flatten_40 (Flatten)                  │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_112 (Dense)                     │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_113 (Dense)                     │ ?                            │     0 (unbuilt) │
├───────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_114 (Dense)                     │ ?                            │     0 (unbuilt) │
└───────────────────────────────────────┴──────────────────────────────┴─────────────────┘
```



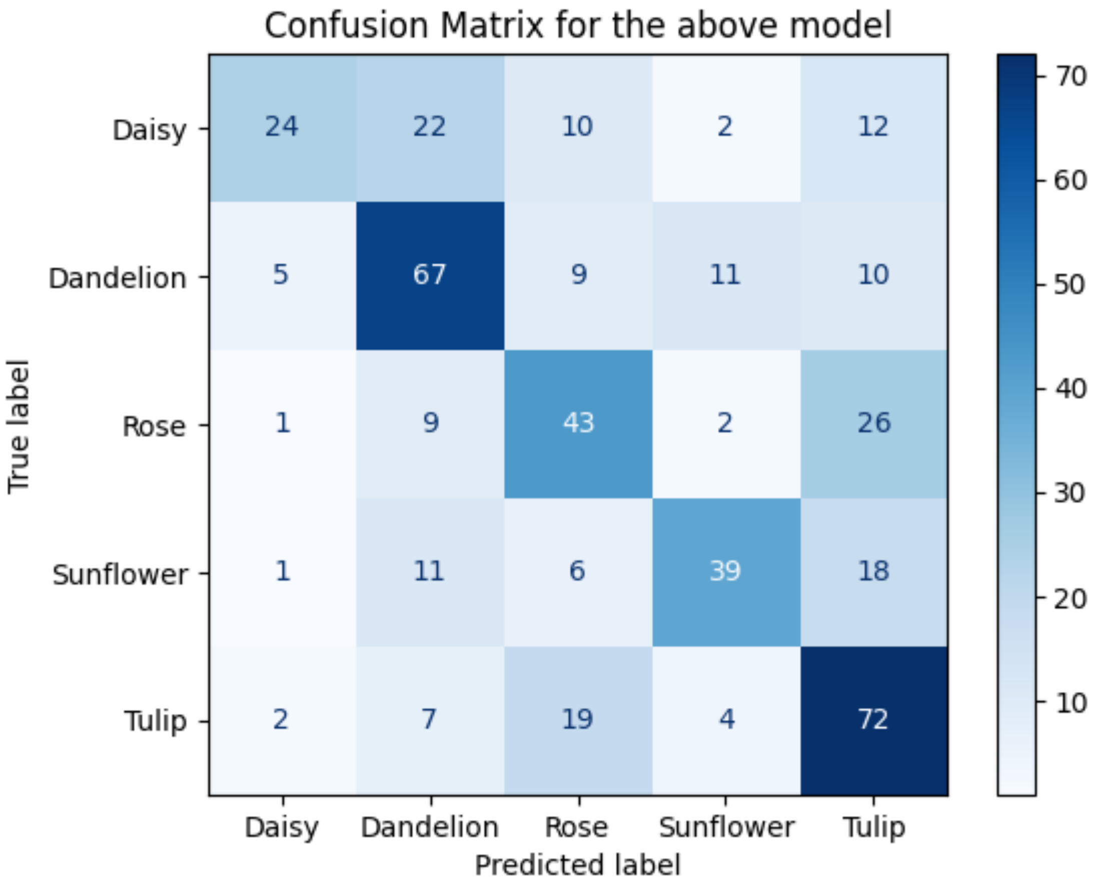
```
Total params: 0 (0.00 B)
Trainable params: 0 (0.00 B)
Non-trainable params: 0 (0.00 B)
Epoch 1/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 18s 143ms/step - accuracy: 0.3686 - f1_score: 0.3658 - loss: 3.1550 - val_accuracy: 0.4421 - val_f1
_score: 0.3940 - val_loss: 2.2427
Epoch 2/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 139ms/step - accuracy: 0.6656 - f1_score: 0.6655 - loss: 0.9375 - val_accuracy: 0.4444 - val_f1
_score: 0.4186 - val_loss: 1.9477
Epoch 3/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 142ms/step - accuracy: 0.8233 - f1_score: 0.8235 - loss: 0.5042 - val_accuracy: 0.5347 - val_f1
_score: 0.5313 - val_loss: 1.7583
Epoch 4/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 137ms/step - accuracy: 0.9275 - f1_score: 0.9275 - loss: 0.2410 - val_accuracy: 0.5301 - val_f1
_score: 0.5176 - val_loss: 1.8613
Epoch 5/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 138ms/step - accuracy: 0.9573 - f1_score: 0.9573 - loss: 0.1373 - val_accuracy: 0.5486 - val_f1
_score: 0.5445 - val_loss: 2.2265
Epoch 6/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 22s 148ms/step - accuracy: 0.9773 - f1_score: 0.9773 - loss: 0.0895 - val_accuracy: 0.4884 - val_f1
_score: 0.4884 - val_loss: 2.5013
Epoch 7/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 16s 152ms/step - accuracy: 0.9765 - f1_score: 0.9764 - loss: 0.0898 - val_accuracy: 0.5139 - val_f1
_score: 0.4952 - val_loss: 2.6278
Epoch 8/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 15s 137ms/step - accuracy: 0.9753 - f1_score: 0.9753 - loss: 0.0752 - val_accuracy: 0.5417 - val_f1
_score: 0.5298 - val_loss: 3.0524
Epoch 9/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 139ms/step - accuracy: 0.9847 - f1_score: 0.9847 - loss: 0.0503 - val_accuracy: 0.5208 - val_f1
_score: 0.5073 - val_loss: 3.1649
Epoch 10/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 138ms/step - accuracy: 0.9891 - f1_score: 0.9890 - loss: 0.0498 - val_accuracy: 0.5278 - val_f1
_score: 0.5217 - val_loss: 3.2112
Epoch 11/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 136ms/step - accuracy: 0.9818 - f1_score: 0.9818 - loss: 0.0558 - val_accuracy: 0.5255 - val_f1
_score: 0.5248 - val_loss: 3.4070
Epoch 12/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 21s 142ms/step - accuracy: 0.9493 - f1_score: 0.9493 - loss: 0.1980 - val_accuracy: 0.5486 - val_f1
_score: 0.5482 - val_loss: 3.2304
Epoch 13/20
108/108 ━━━━━━━━━━━━━━━━━━━━ 20s 135ms/step - accuracy: 0.9492 - f1_score: 0.9492 - loss: 0.1970 - val_accuracy: 0.5069 - val_f1
_score: 0.4876 - val_loss: 4.1846
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 64ms/step - accuracy: 0.5539 - f1_score: 0.5497 - loss: 1.8544
Test Loss: 1.6889742612838745, Test Accuracy: 0.5671296119689941, Test F1 Score: 0.5616947412490845
Time required to train the model is 250.11752653121948 seconds
```



Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



```
14/14 ━━━━━━━━━━━━━━━━━━━━ 1s 43ms/step
```

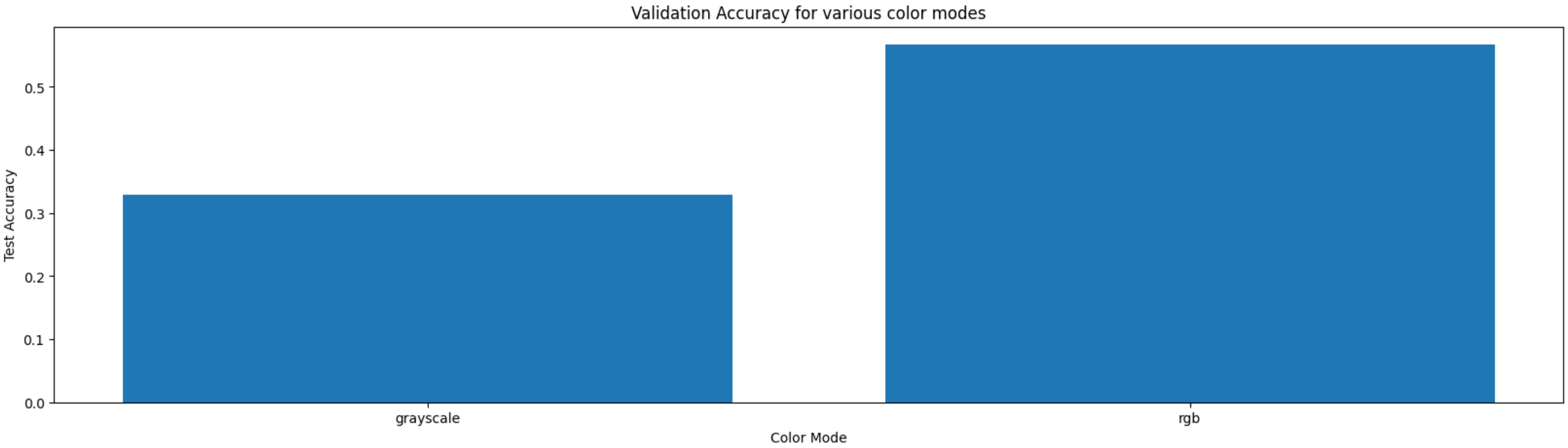


In [ ]:
```
result_df_7
```

Out[ ]:

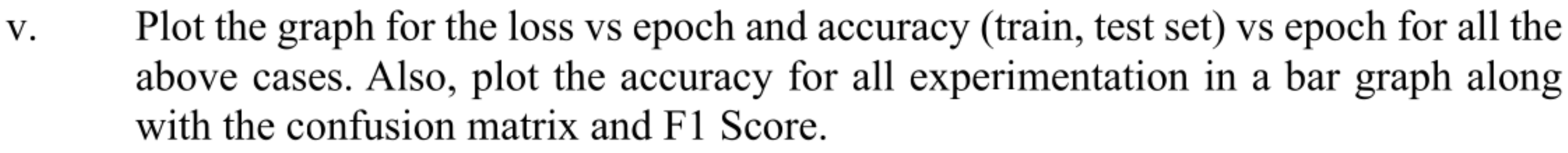
	Conv Kernel Size	Conv Filter Size	Pooling Layers	Activation Function	No. of Dense Layers after Flatten	Dropout Rate	Test Loss	Test Accuracy	Test F1 Score	Batch Normalization Presence	No. of Extra Conv Layers	Color Mode	Training Time(in seconds)
0	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.0	1.591569	0.328704	0.307119	True	0	grayscale	206.139588
1	[(3, 3), (5, 5), (5, 5)]	[16, 32, 64]	max	relu	2	0.0	1.688974	0.567130	0.561695	True	0	rgb	250.117527

In [ ]:
```
plt.figure(figsize=(20,5))
plt.bar(
    result_df_7['Color Mode'],
    result_df_7['Test Accuracy']
)

plt.ylabel('Test Accuracy')
plt.xlabel('Color Mode')
plt.title('Validation Accuracy for various color modes')
plt.show()
```



Clearly the model performs better with rgb channel images

Question 05



v. Plot the graph for the loss vs epoch and accuracy (train, test set) vs epoch for all the above cases. Also, plot the accuracy for all experimentation in a bar graph along with the confusion matrix and F1 Score.

Already done in continuation of question 4

Question 06

vi. For the best model on the MNIST dataset in Assignment 4, train a model with MNIST data using the best set of parameters obtained in Question *iv*. Compare the test accuracy and the self-created images.

```
In [ ]: from keras.datasets import mnist
        (X_train, y_train), (X_test, y_test) = mnist.load_data()
```

```
In [ ]: X_train.shape, y_train.shape, X_test.shape, y_test.shape
```

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

```
In [ ]: X_train = np.concatenate((X_train, X_test),axis=0)
        y_train = np.concatenate((y_train, y_test),axis=0)
        X_train.shape
```

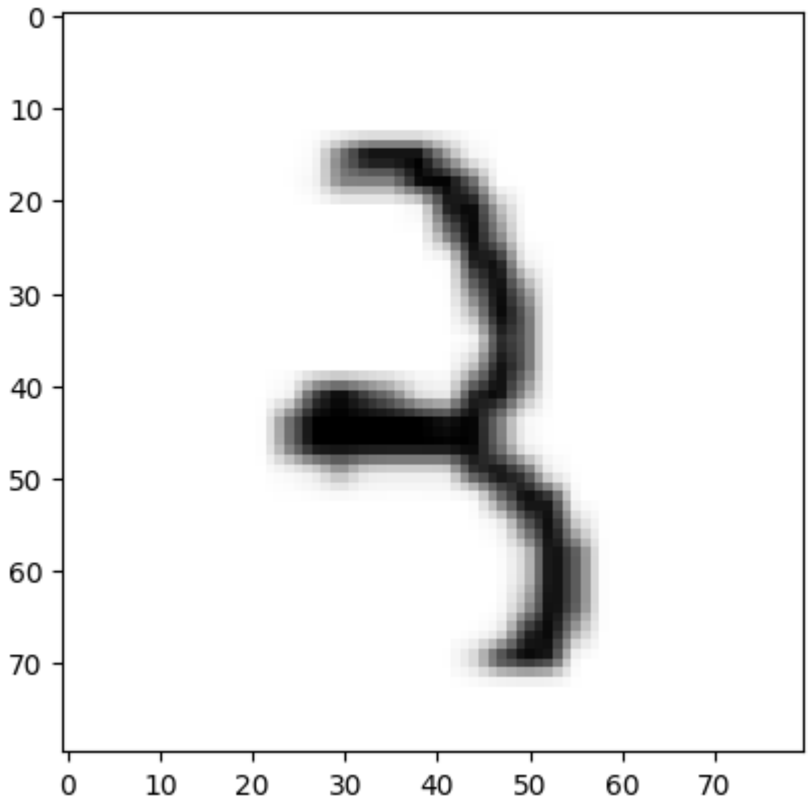
```
Out[ ]: (70000, 28, 28)
```

```
In [ ]: # Training Data -> 80% , Validation Data -> 10% , Testing Data -> 10%

        from sklearn.model_selection import train_test_split

        X_train, X_rem, y_train, y_rem = train_test_split(X_train, y_train, test_size=0.2, random_state=4)
        X_val, X_test, y_val, y_test = train_test_split(X_rem, y_rem, test_size=0.5, random_state=4)
```

```
In [ ]: # Resizing to 80x80
        from tensorflow.image import resize

        X_train = np.reshape(X_train,(-1,28,28,1))
        X_train=X_train/255
        X_train = resize(X_train,(80,80))

        X_val = np.reshape(X_val,(-1,28,28,1))
        X_val=X_val/255
        X_val = resize(X_val,(80,80))

        X_test = np.reshape(X_test,(-1,28,28,1))
        X_test=X_test/255
        X_test = resize(X_test,(80,80))
```

In [ ]:
```
plt.imshow(X_train[23],cmap='Greys')
```

Out[ ]:
```
<matplotlib.image.AxesImage at 0x7a38cf234760>
```



In [ ]:
```
y_train[23]
```

Out[ ]:
```
3
```

In [ ]:
```
# Categorical encoding of y
y_train = pd.get_dummies(y_train,dtype='int').to_numpy()
y_val = pd.get_dummies(y_val,dtype='int').to_numpy()
y_test = pd.get_dummies(y_test,dtype='int').to_numpy()

y_train[23]
```

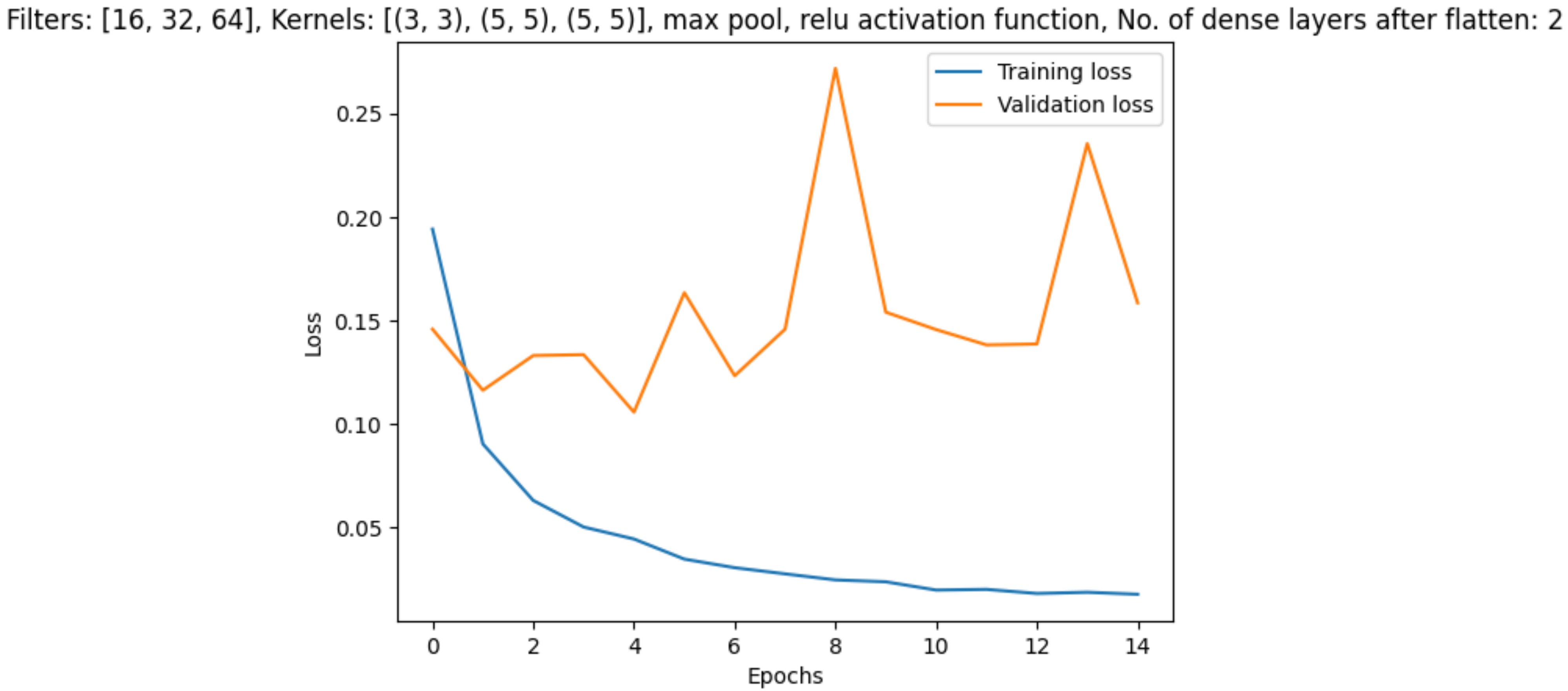
Out[ ]:
```
array([0, 0, 0, 1, 0, 0, 0, 0, 0, 0])
```

In [ ]:
```
result_df_8 = pd.DataFrame(
    columns=[
        'Conv Kernel Size',
        'Conv Filter Size',
        'Pooling Layers',
        'Activation Function',
        'No. of Dense Layers after Flatten',
        'Dropout Rate',
        'Test Loss',
        'Test Accuracy',
        'Test F1 Score',
        'Batch Normalization Presence',
        'No. of Extra Conv Layers',
        'Color Mode',
        'Training Time(in seconds)'
    ]
)

filters = [16,32,64]
epochs = 20

test_loss,test_accuracy,test_f1,train_time,model = train_model(
      kernels=best_kernel,
      filters=filters,
      activation_func=best_activation_function,
      pool=best_pool,
      dropout_rate=best_dropout,
      num_dense_layers=best_num_dense,
      X_train=X_train,
      y_train=y_train,
      X_test=X_test,
      y_test=y_test,
      num_epochs=epochs,
      add_batch_normalization=best_do_batch,
      extra_conv_layers=best_conv,
      is_mnist=True
      )

result_df_8.loc[len(result_df_8.index)]=[
      best_kernel,
      filters,
      best_pool,
      best_activation_function,
      best_num_dense,
      best_dropout,
      test_loss,
      test_accuracy,
      test_f1,
      best_do_batch,
      best_conv,
      'grayscale',
      train_time
  ]
```

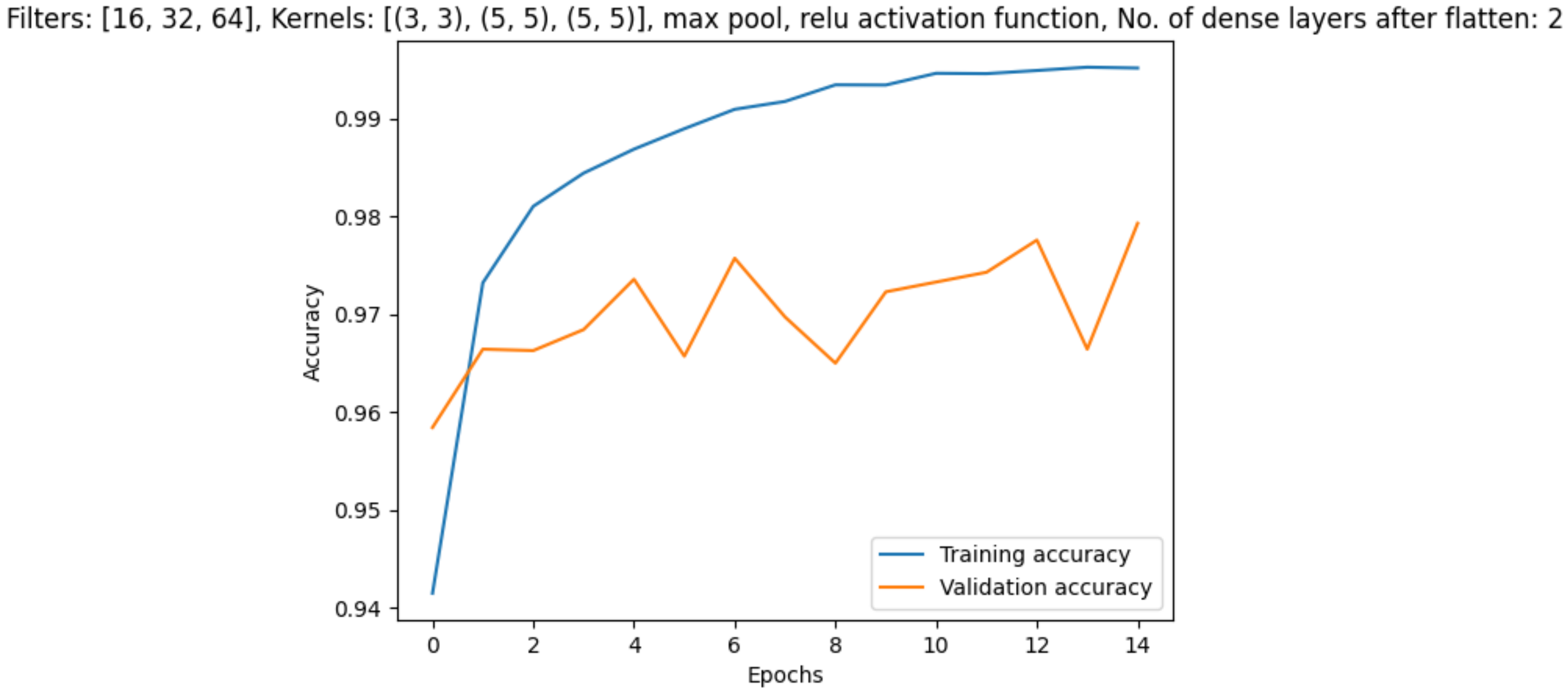
```
Model: "sequential"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d (Conv2D)                      │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ max_pooling2d (MaxPooling2D)         │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ batch_normalization                  │ ?                           │     0 (unbuilt) │
│ (BatchNormalization)                 │                             │                 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ flatten (Flatten)                    │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense (Dense)                        │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_1 (Dense)                      │ ?                           │     0 (unbuilt) │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────┤
│ dense_2 (Dense)                      │ ?                           │     0 (unbuilt) │
└──────────────────────────────────────┴─────────────────────────────┴─────────────────┘

 Total params: 0 (0.00 B)

 Trainable params: 0 (0.00 B)

 Non-trainable params: 0 (0.00 B)
```

```
Epoch 1/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 14s 4ms/step - accuracy: 0.9007 - f1_score: 0.9007 - loss: 0.3188 - val_accuracy: 0.9584 - val_f1
_score: 0.9585 - val_loss: 0.1457
Epoch 2/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 16s 4ms/step - accuracy: 0.9731 - f1_score: 0.9731 - loss: 0.0883 - val_accuracy: 0.9664 - val_f1
_score: 0.9664 - val_loss: 0.1161
Epoch 3/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 6s 3ms/step - accuracy: 0.9824 - f1_score: 0.9824 - loss: 0.0580 - val_accuracy: 0.9663 - val_f1_
score: 0.9665 - val_loss: 0.1329
Epoch 4/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 11s 4ms/step - accuracy: 0.9855 - f1_score: 0.9855 - loss: 0.0465 - val_accuracy: 0.9684 - val_f1
_score: 0.9685 - val_loss: 0.1333
Epoch 5/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 6s 4ms/step - accuracy: 0.9881 - f1_score: 0.9881 - loss: 0.0382 - val_accuracy: 0.9736 - val_f1_
score: 0.9736 - val_loss: 0.1055
Epoch 6/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 10s 4ms/step - accuracy: 0.9909 - f1_score: 0.9909 - loss: 0.0275 - val_accuracy: 0.9657 - val_f1
_score: 0.9657 - val_loss: 0.1633
Epoch 7/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 10s 4ms/step - accuracy: 0.9925 - f1_score: 0.9925 - loss: 0.0257 - val_accuracy: 0.9757 - val_f1
_score: 0.9757 - val_loss: 0.1231
Epoch 8/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 7s 4ms/step - accuracy: 0.9927 - f1_score: 0.9927 - loss: 0.0239 - val_accuracy: 0.9697 - val_f1_
score: 0.9696 - val_loss: 0.1456
Epoch 9/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 7s 4ms/step - accuracy: 0.9943 - f1_score: 0.9943 - loss: 0.0216 - val_accuracy: 0.9650 - val_f1_
score: 0.9650 - val_loss: 0.2718
Epoch 10/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 7s 4ms/step - accuracy: 0.9934 - f1_score: 0.9934 - loss: 0.0234 - val_accuracy: 0.9723 - val_f1_
score: 0.9723 - val_loss: 0.1539
Epoch 11/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 10s 4ms/step - accuracy: 0.9957 - f1_score: 0.9957 - loss: 0.0141 - val_accuracy: 0.9733 - val_f1
_score: 0.9734 - val_loss: 0.1454
Epoch 12/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 10s 4ms/step - accuracy: 0.9956 - f1_score: 0.9956 - loss: 0.0159 - val_accuracy: 0.9743 - val_f1
_score: 0.9743 - val_loss: 0.1380
Epoch 13/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 10s 3ms/step - accuracy: 0.9947 - f1_score: 0.9947 - loss: 0.0175 - val_accuracy: 0.9776 - val_f1
_score: 0.9776 - val_loss: 0.1385
Epoch 14/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 7s 4ms/step - accuracy: 0.9962 - f1_score: 0.9962 - loss: 0.0151 - val_accuracy: 0.9664 - val_f1_
score: 0.9664 - val_loss: 0.2354
Epoch 15/20
1750/1750 ━━━━━━━━━━━━━━━━━━━━ 6s 3ms/step - accuracy: 0.9956 - f1_score: 0.9956 - loss: 0.0149 - val_accuracy: 0.9793 - val_f1_
score: 0.9793 - val_loss: 0.1584
219/219 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - accuracy: 0.9758 - f1_score: 0.9759 - loss: 0.0872
```

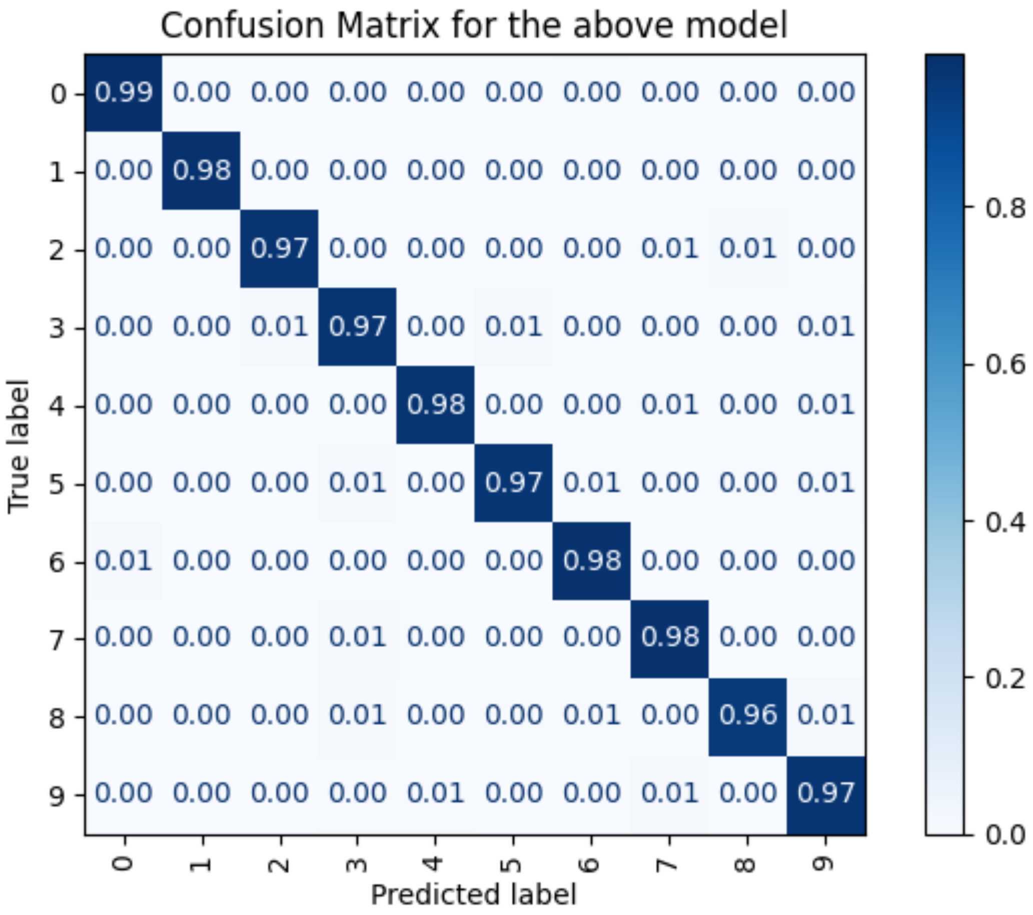
```
Test Loss: 0.098985366652326584, Test Accuracy: 0.97628569602966 31, Test F1 Score: 0.97628694772720 34
Time required to train the model is 142.12913298606873 seconds
```



Filters: [16, 32, 64], Kernels: [(3, 3), (5, 5), (5, 5)], max pool, relu activation function, No. of dense layers after flatten: 2



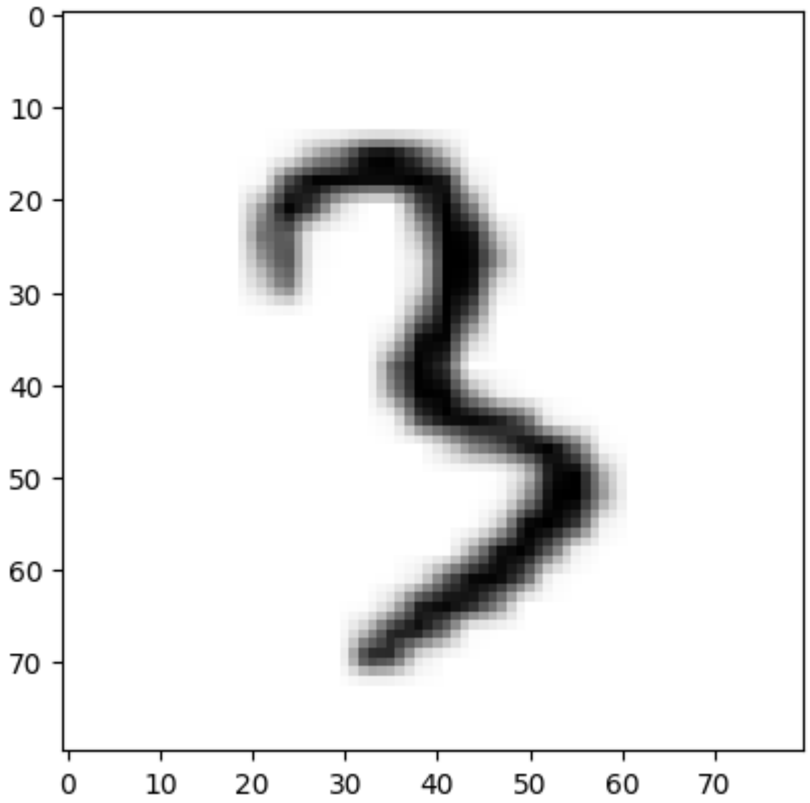
```
219/219 ━━━━━━━━━━━━━━━━━━━━ 1s 3ms/step
```



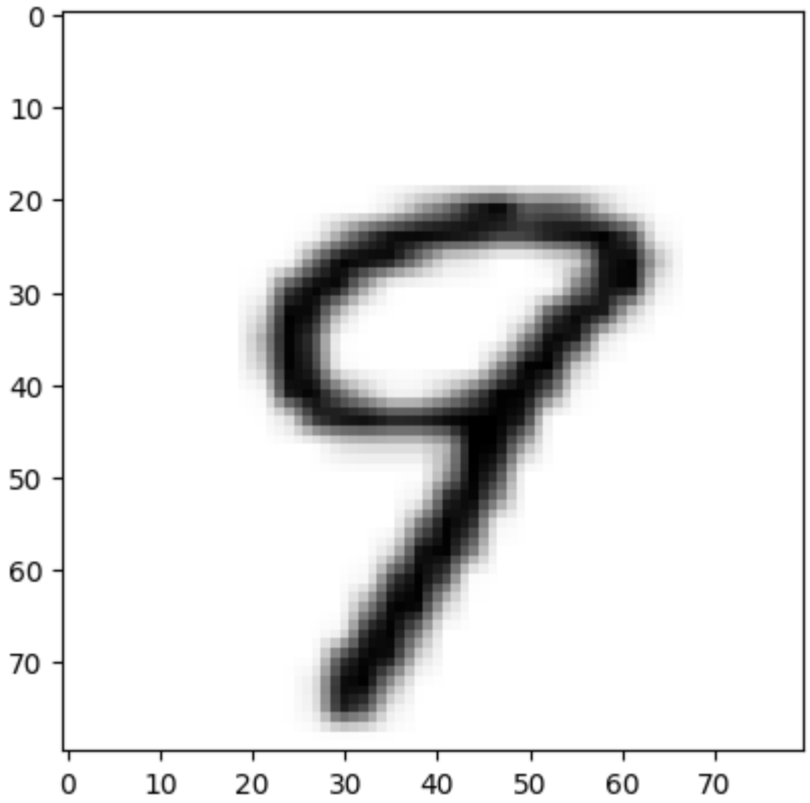
In [ ]:

```python
import random

random_indices = random.sample(range(0,len(X_test)),10)

img_predict = np.array([X_test[ind] for ind in random_indices])
true_label = np.array([y_test[ind] for ind in random_indices])

cat_pred = model.predict(img_predict)

for img,cat_pred,true_val in zip(img_predict,cat_pred,true_label):
  plt.imshow(img,cmap="Greys")
  plt.show()
  prediction=np.argmax(cat_pred)
  print(f"Predicted value:- {prediction}")
  print(f"True value:- {np.argmax(true_val)}")
```

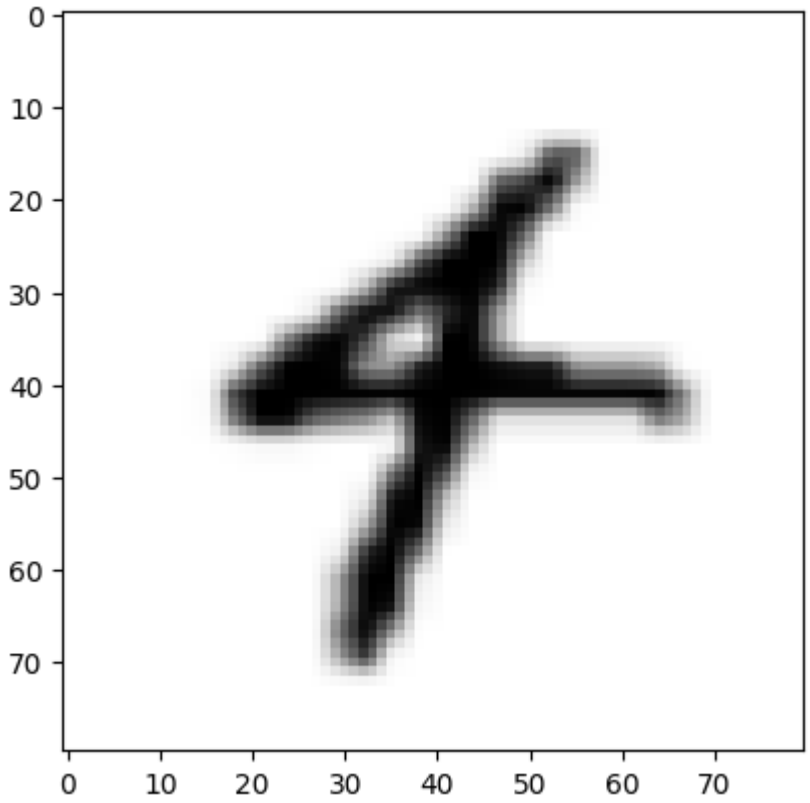
```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
```



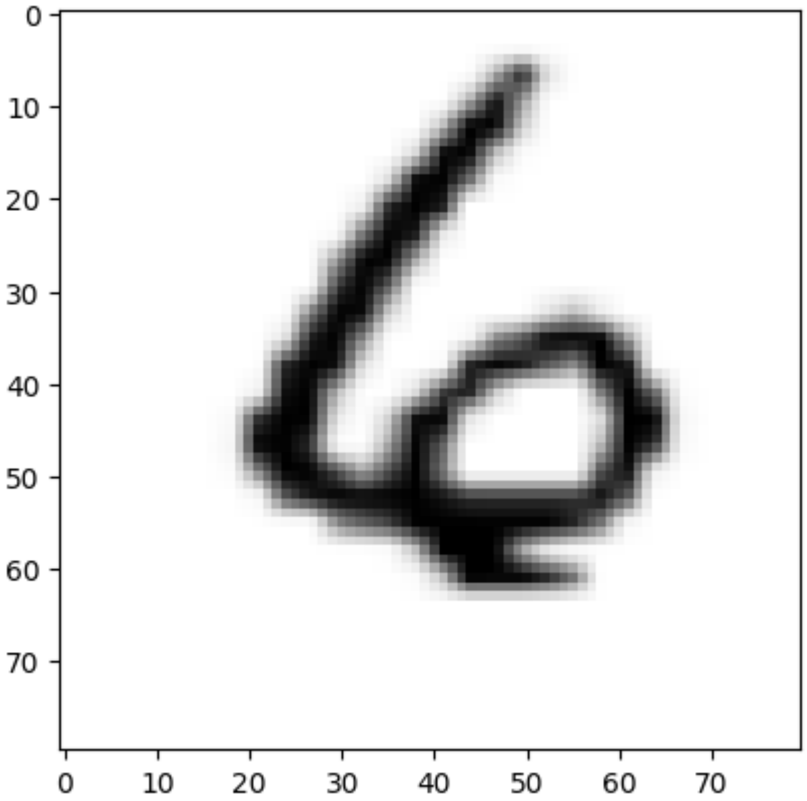
```
Predicted value:- 3
True value:- 3
```



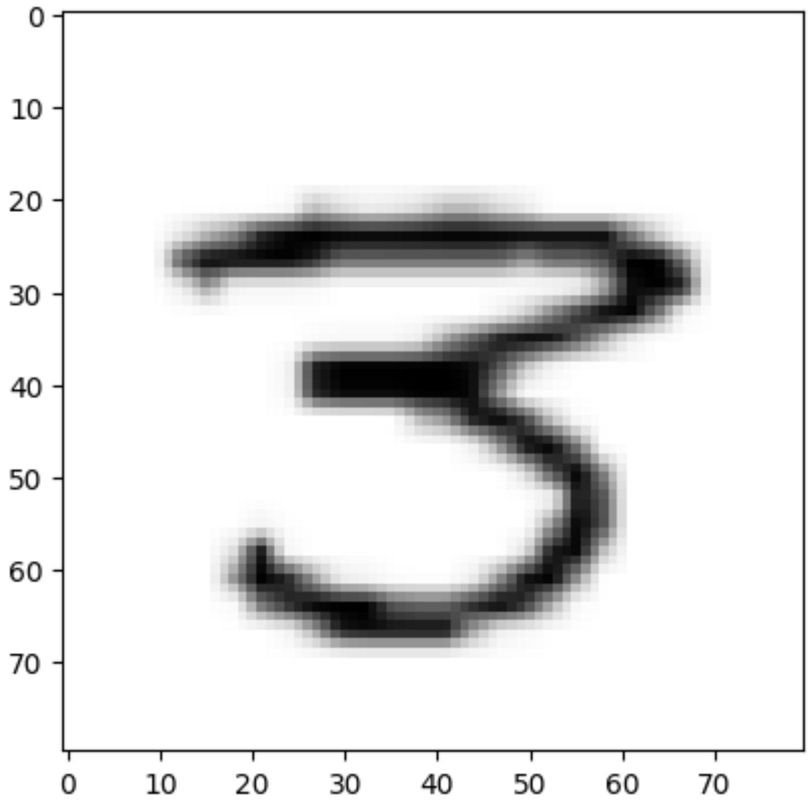
```
Predicted value:- 9
True value:- 9
```



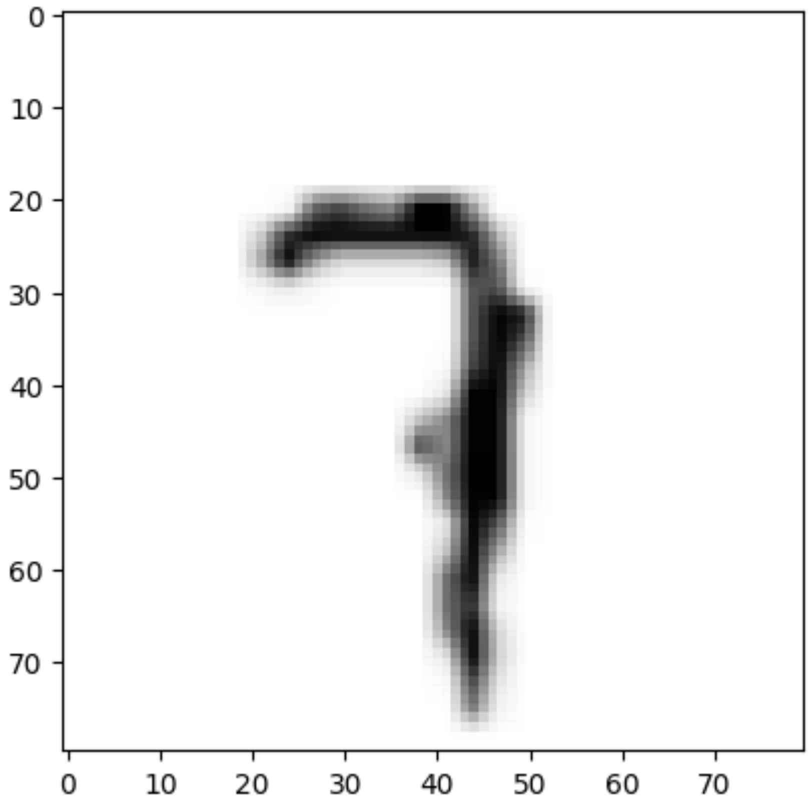
```
Predicted value:- 4
True value:- 4
```



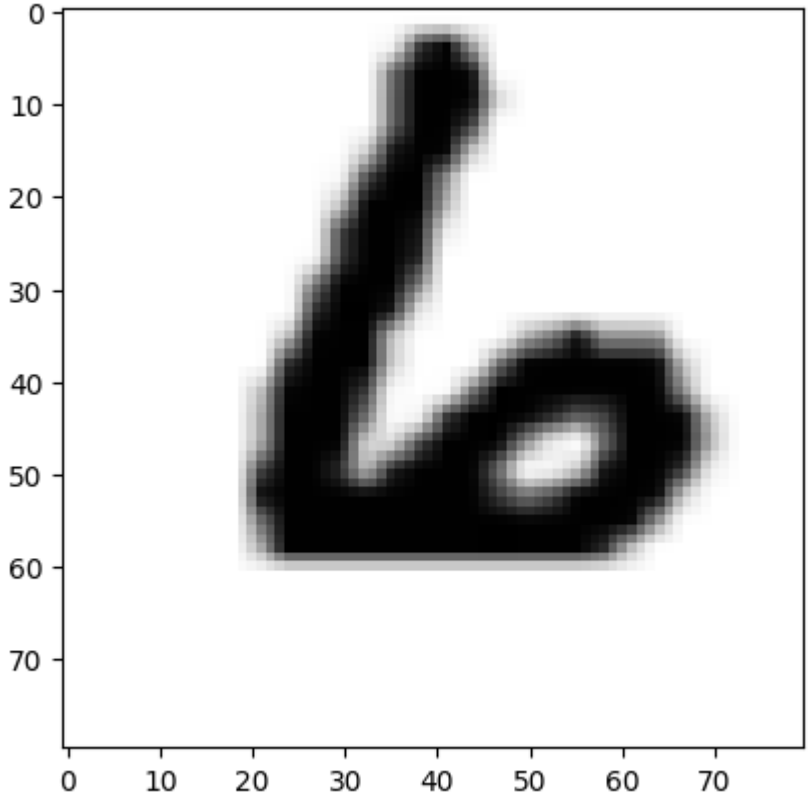
```
Predicted value:- 6
True value:- 6
```



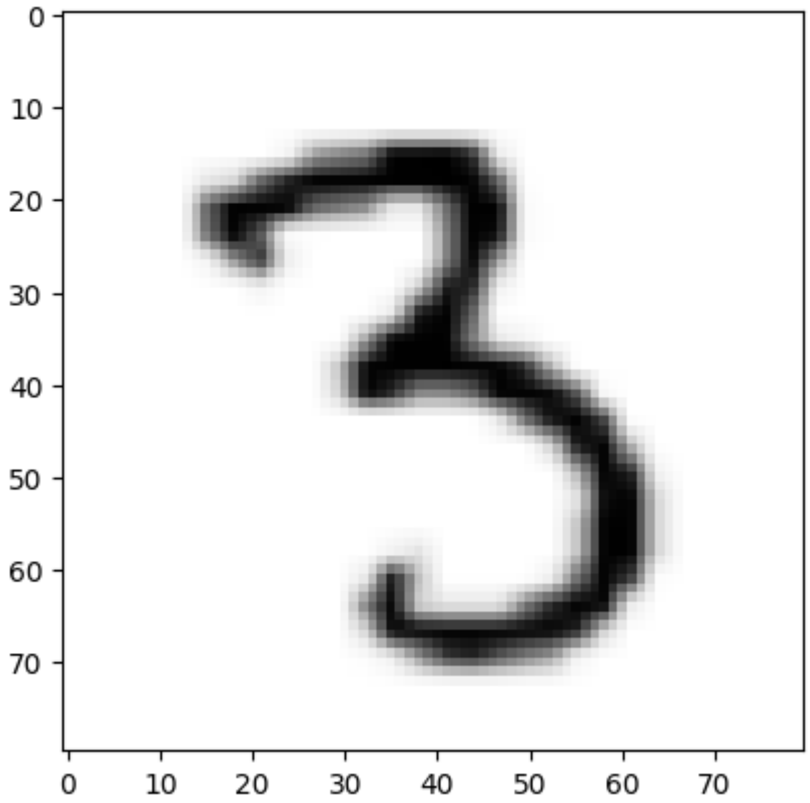
```
Predicted value:- 3
True value:- 3
```



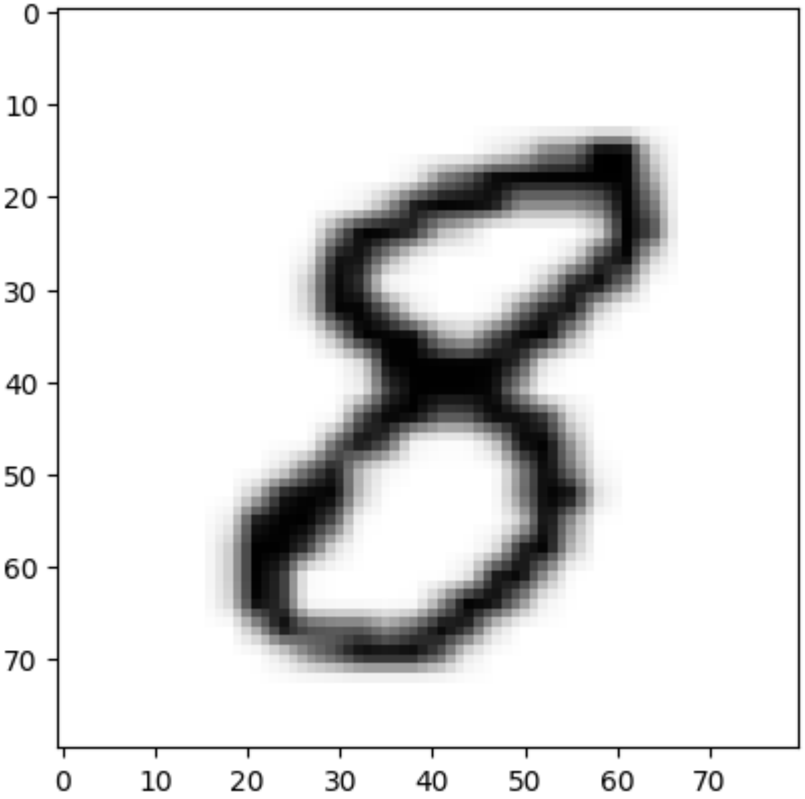
```
Predicted value:- 7
True value:- 7
```



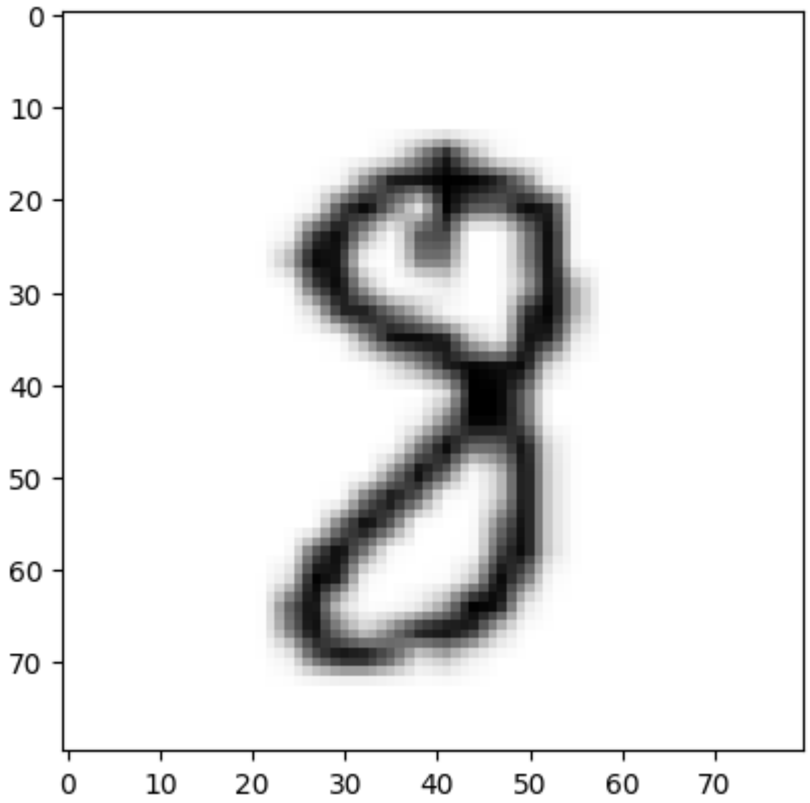
```
Predicted value:- 6
True value:- 6
```



```
Predicted value:- 3
True value:- 3
```



```
Predicted value:- 8
True value:- 8
```



```
Predicted value:- 8
True value:- 8
```

As we can see there is 100% accuracy achieved here, which was not the case for the earlier assignment's ANN model