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Deliverable :
Lampiran (Video, data setelah prosessing, dan data setelah di klasifikasi):
https://drive.google.com/drive/folders/1a2KeAgAA_yl6i7O70CVS5kvLCyGhmcI3?usp=sharing
Github: https://github.com/ronggurmahendra/TF4012-TugasBesarHandSign.git

Cat : cara eksekusi program terdapat pada README.md pada repository

1. Teori dasar

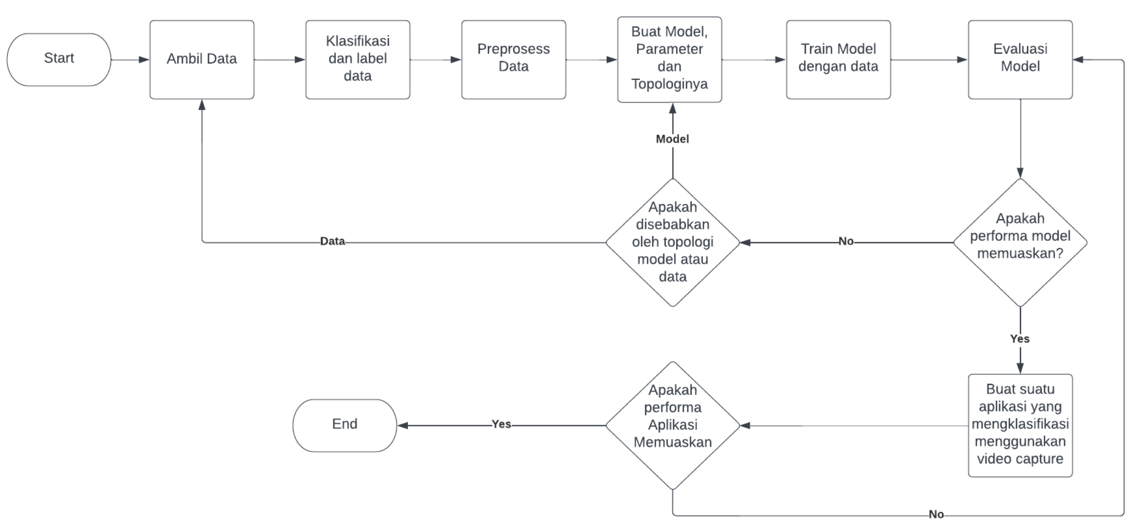
a. CNN(Convolutional Neural Network)

CNN(Convolutional Neural Network) merupakan suatu jenis dari ANN(Artificial Neural Network) yang di design untuk diterapkan pada input citra. CNN menentukan aspek apa saja dalam sebuah gambar yang bisa digunakan algoritma untuk belajar mengklasifikasi gambar.

b. Tensorflow dan keras

Tensorflow dan keras adalah suatu library artificial neural network. Tensorflow dan keras memudahkan developer untuk membuat model dan topologinya tanpa harus mengimplementasi banyak jenis layer pada ANN seperti layer konvolusi dan lain - lain.

2. Desain Eksperimen



a. Pengambilan Data

Data diambil dengan pertama merekam suatu video hand sign, video tersebut kemudian diambil seriap framenya menjadi gambar dan dilabelkan ke kelas huruf alphabet(['A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'K', 'L', 'M', 'N', 'O', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y']). Gambar-gambar tersebut kemudian dilakukan preprocessing resize dan scale ke spesifikasi model yang dibuat. Kumpulan data tersebut kemudian dibagi menjadi 3 bagian yaitu training data, validation data, dan test data dengan rasio 8 : 1 : 1.

b. Pembuatan Model dan Training

Model pertama di buat definisi topologinya. Model tersebut kemudian di compile menggunakan beberapa parameter dan optimizer. Kemudian model tersebut di train menggunakan data yang sudah di buat. Model tersebut kemudian dievaluasi performanyanya dan di save untuk nanti aplikasi load.

c. Pembuatan Aplikasi

Aplikasi pertama meload model yang sudah di train, lalu menginisialisasi video capture lalu pada setiap frame video capture pertama-tama men preprosess frame sama dengan preprocessing training data lalu menggunakan model yang sudah dibuat sebelumnya men predict frame tersebut dan memberikannya ke user.

3. Algoritma

a. Topologi Model_1

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 126, 126, 32)      896

 max_pooling2d (MaxPooling2D  (None, 63, 63, 32)       0
 )

 conv2d_1 (Conv2D)           (None, 61, 61, 64)        18496

 max_pooling2d_1 (MaxPooling  (None, 30, 30, 64)       0
 2D)

 conv2d_2 (Conv2D)           (None, 28, 28, 64)        36928

 flatten (Flatten)           (None, 50176)             0

 dense (Dense)               (None, 120)               6021240

 dense_1 (Dense)             (None, 24)                2904

=================================================================
Total params: 6,080,464
Trainable params: 6,080,464
Non-trainable params: 0
```

b. Topologi Model_2

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_3 (Conv2D)           (None, 128, 128, 16)      448

 conv2d_4 (Conv2D)           (None, 128, 128, 16)      2320

 max_pooling2d_2 (MaxPooling  (None, 127, 127, 16)     0
 2D)

 dropout (Dropout)           (None, 127, 127, 16)      0

 conv2d_5 (Conv2D)           (None, 125, 125, 32)      4640

 conv2d_6 (Conv2D)           (None, 123, 123, 32)      9248

 batch_normalization (BatchN  (None, 123, 123, 32)     128
 ormalization)

 max_pooling2d_3 (MaxPooling  (None, 61, 61, 32)       0
 2D)

 dropout_1 (Dropout)         (None, 61, 61, 32)        0

 conv2d_7 (Conv2D)           (None, 59, 59, 32)        9248

 conv2d_8 (Conv2D)           (None, 57, 57, 32)        9248

 batch_normalization_1 (Batc  (None, 57, 57, 32)       128
 hNormalization)

 conv2d_9 (Conv2D)           (None, 55, 55, 32)        9248

 conv2d_10 (Conv2D)          (None, 53, 53, 32)        9248

 batch_normalization_2 (Batc  (None, 53, 53, 32)       128
 hNormalization)

 max_pooling2d_4 (MaxPooling  (None, 26, 26, 32)       0
 2D)

 dropout_2 (Dropout)         (None, 26, 26, 32)        0
```

```
 flatten_1 (Flatten)        (None, 21632)           0

 dense_2 (Dense)            (None, 120)             2595960

 dense_3 (Dense)            (None, 120)             14520

 dense_4 (Dense)            (None, 24)              2904

=================================================================
Total params: 2,667,416
Trainable params: 2,667,224
Non-trainable params: 192
_________________________________________________________________
```

c. Topologi Model_3

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_11 (Conv2D)          (None, 128, 128, 16)      9424

 conv2d_12 (Conv2D)          (None, 115, 115, 32)      100384

 max_pooling2d_5 (MaxPooling  (None, 114, 114, 32)     0
 2D)

 conv2d_13 (Conv2D)          (None, 101, 101, 32)      200736

 conv2d_14 (Conv2D)          (None, 88, 88, 32)        200736

 max_pooling2d_6 (MaxPooling  (None, 44, 44, 32)       0
 2D)

 dropout_3 (Dropout)         (None, 44, 44, 32)        0

 conv2d_15 (Conv2D)          (None, 31, 31, 64)        401472

 conv2d_16 (Conv2D)          (None, 18, 18, 64)        802880

 batch_normalization_3 (Batc  (None, 18, 18, 64)       256
 hNormalization)

 max_pooling2d_7 (MaxPooling  (None, 9, 9, 64)         0
 2D)
```

```
dropout_4 (Dropout)        (None, 9, 9, 64)         0

flatten_2 (Flatten)        (None, 5184)             0

dense_5 (Dense)            (None, 128)              663680

dense_6 (Dense)            (None, 128)              16512

dense_7 (Dense)            (None, 24)               3096

=================================================================
Total params: 2,399,176
Trainable params: 2,399,048
Non-trainable params: 128
_________________________________________________________________
```

4. Hasil Evaluasi

Model 1 :

- Train Accuracy : 100.00 %
- Validation Accuracy : 99.68%
- Test Accuracy : 95.83%

Model 2 :

- Train Accuracy : 100.00 %
- Validation Accuracy : 6.49 %
- Test Accuracy : 6.09%

Model 3 :

- Train Accuracy : 99.42%
- Validation Accuracy : 99.68%
- Test Accuracy : 100.00%

5. Analisis

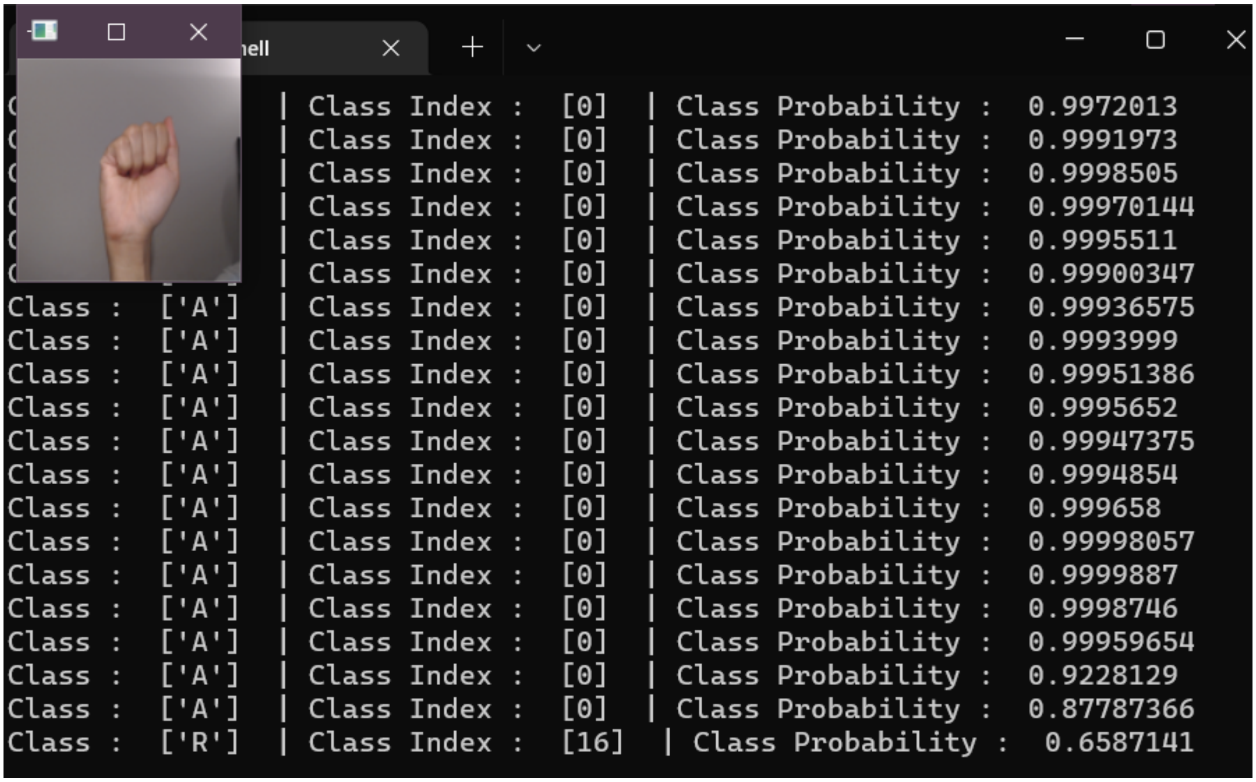
Berdasarkan hasil evaluasi Model_1 dan Model_3 yang mendapatkan accuracy yang memuaskan dan Model_2 walaupun mendapatkan training accuracy yang bagus mendapatkan validation accuracy dan test accuracy yang rendah yang mengindikasikan pada Model_2 terjadi overfit. Pada aplikasi yang dibuat Model_3 yang memberikan klasifikasi yang terbaik dibandingkan 2 model lainya. Aplikasi berhasil mengklasifikasi secara real-time namun memiliki kesulitan mengidentifikasi handsign dengan feature yang mirip i.e. : A, E, M, S(menggenggam), hal ini terjadi karena training data yang homogen karena berasal dari video yang sama dan bisa diselesaikan dengan menambah variasi pada training data.

Lampiran

Referensi Hand Sign

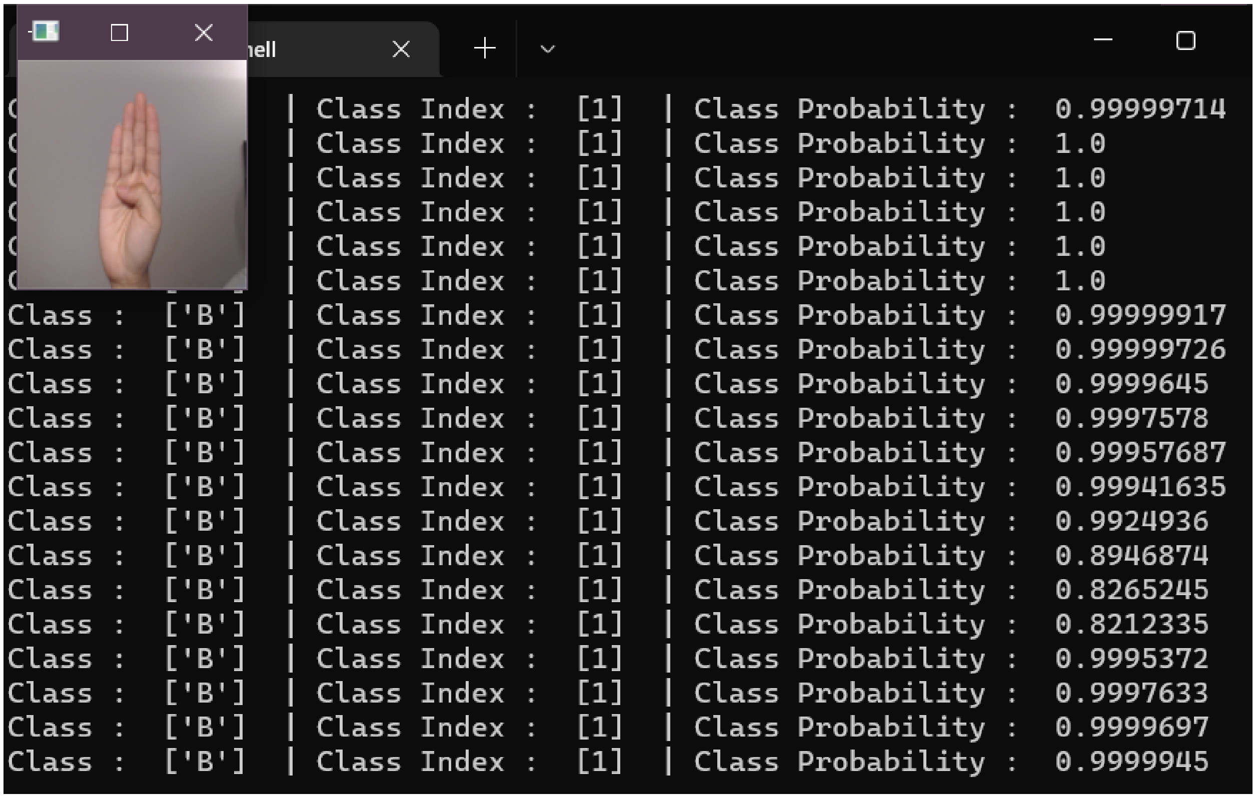
Screenshot aplikasi yang dibuat

Test Case “A” :

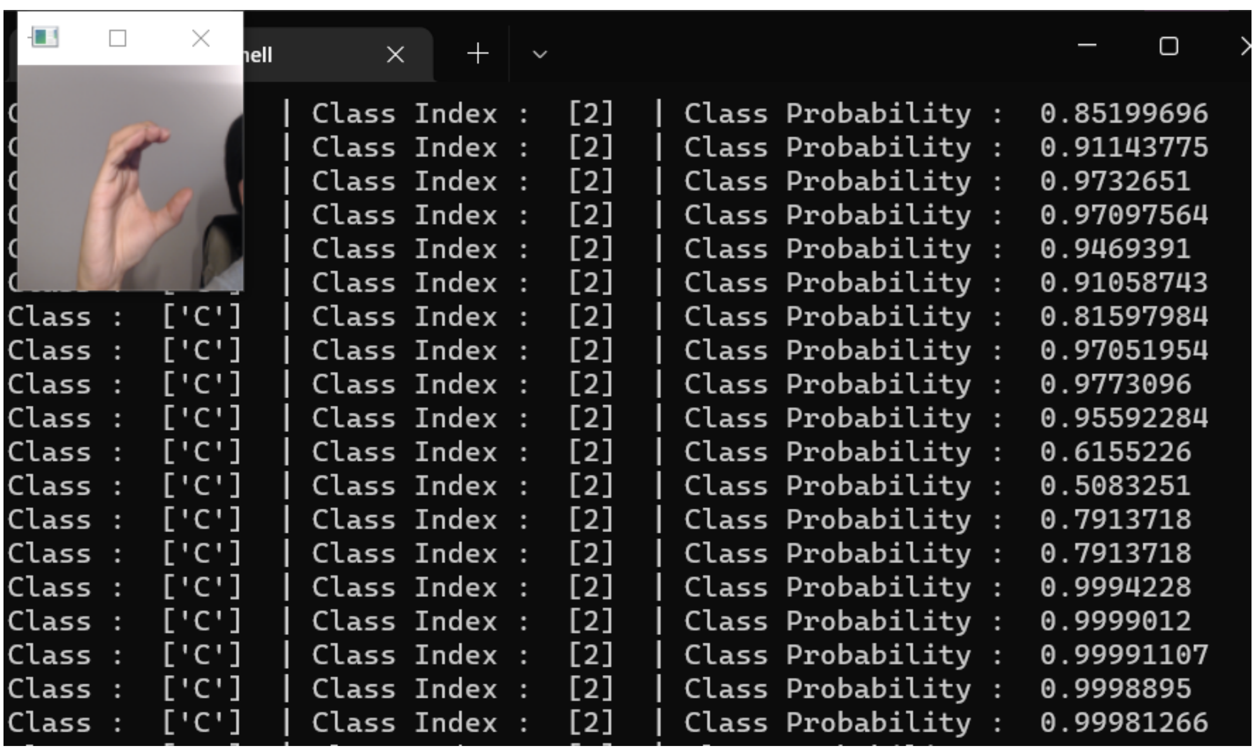


hell
| Class Index : [0] | Class Probability : 0.9972013
| Class Index : [0] | Class Probability : 0.9991973
| Class Index : [0] | Class Probability : 0.9998505
| Class Index : [0] | Class Probability : 0.99970144
| Class Index : [0] | Class Probability : 0.9995511
| Class Index : [0] | Class Probability : 0.99900347
Class : ['A'] | Class Index : [0] | Class Probability : 0.99936575
Class : ['A'] | Class Index : [0] | Class Probability : 0.9993999
Class : ['A'] | Class Index : [0] | Class Probability : 0.99951386
Class : ['A'] | Class Index : [0] | Class Probability : 0.9995652
Class : ['A'] | Class Index : [0] | Class Probability : 0.99947375
Class : ['A'] | Class Index : [0] | Class Probability : 0.9994854
Class : ['A'] | Class Index : [0] | Class Probability : 0.999658
Class : ['A'] | Class Index : [0] | Class Probability : 0.99998057
Class : ['A'] | Class Index : [0] | Class Probability : 0.9999887
Class : ['A'] | Class Index : [0] | Class Probability : 0.9998746
Class : ['A'] | Class Index : [0] | Class Probability : 0.99959654
Class : ['A'] | Class Index : [0] | Class Probability : 0.9228129
Class : ['A'] | Class Index : [0] | Class Probability : 0.87787366
Class : ['R'] | Class Index : [16] | Class Probability : 0.6587141

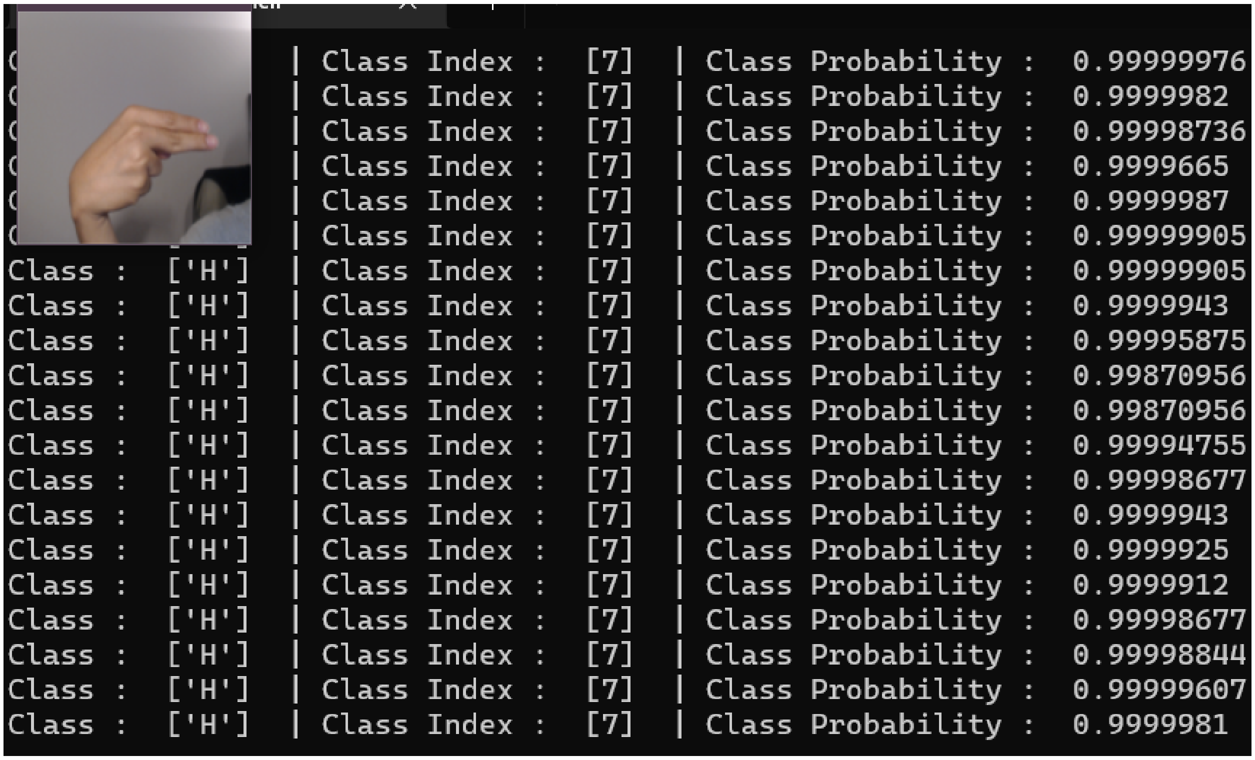
Test Case “B” :


hell
| Class Index : [1] | Class Probability : 0.99999714
| Class Index : [1] | Class Probability : 1.0
| Class Index : [1] | Class Probability : 1.0
| Class Index : [1] | Class Probability : 1.0
| Class Index : [1] | Class Probability : 1.0
| Class Index : [1] | Class Probability : 1.0
Class : ['B'] | Class Index : [1] | Class Probability : 0.99999917
Class : ['B'] | Class Index : [1] | Class Probability : 0.99999726
Class : ['B'] | Class Index : [1] | Class Probability : 0.9999645
Class : ['B'] | Class Index : [1] | Class Probability : 0.9997578
Class : ['B'] | Class Index : [1] | Class Probability : 0.99957687
Class : ['B'] | Class Index : [1] | Class Probability : 0.99941635
Class : ['B'] | Class Index : [1] | Class Probability : 0.9924936
Class : ['B'] | Class Index : [1] | Class Probability : 0.8946874
Class : ['B'] | Class Index : [1] | Class Probability : 0.8265245
Class : ['B'] | Class Index : [1] | Class Probability : 0.8212335
Class : ['B'] | Class Index : [1] | Class Probability : 0.9995372
Class : ['B'] | Class Index : [1] | Class Probability : 0.9997633
Class : ['B'] | Class Index : [1] | Class Probability : 0.9999697
Class : ['B'] | Class Index : [1] | Class Probability : 0.9999945

Test Case “C” :

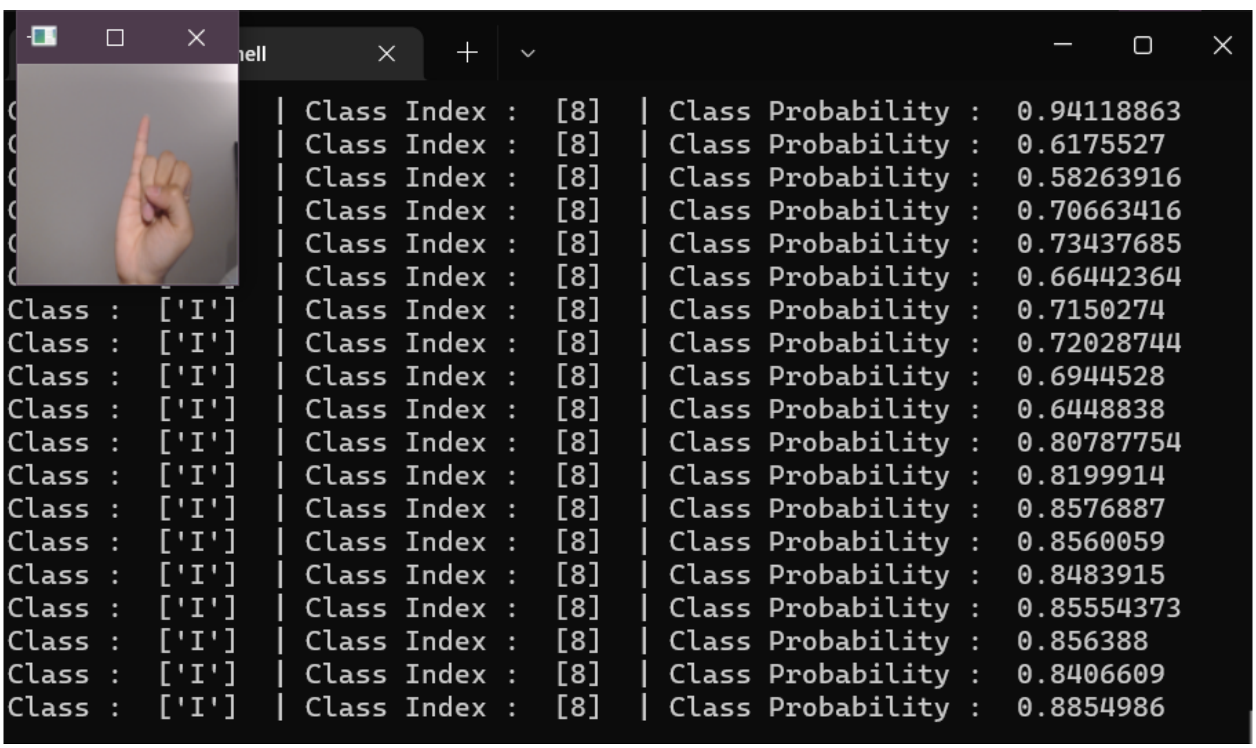

hell
| Class Index : [2] | Class Probability : 0.85199696
| Class Index : [2] | Class Probability : 0.91143775
| Class Index : [2] | Class Probability : 0.9732651
| Class Index : [2] | Class Probability : 0.97097564
| Class Index : [2] | Class Probability : 0.9469391
| Class Index : [2] | Class Probability : 0.91058743
Class : ['C'] | Class Index : [2] | Class Probability : 0.81597984
Class : ['C'] | Class Index : [2] | Class Probability : 0.97051954
Class : ['C'] | Class Index : [2] | Class Probability : 0.9773096
Class : ['C'] | Class Index : [2] | Class Probability : 0.95592284
Class : ['C'] | Class Index : [2] | Class Probability : 0.6155226
Class : ['C'] | Class Index : [2] | Class Probability : 0.5083251
Class : ['C'] | Class Index : [2] | Class Probability : 0.7913718
Class : ['C'] | Class Index : [2] | Class Probability : 0.7913718
Class : ['C'] | Class Index : [2] | Class Probability : 0.9994228
Class : ['C'] | Class Index : [2] | Class Probability : 0.9999012
Class : ['C'] | Class Index : [2] | Class Probability : 0.99991107
Class : ['C'] | Class Index : [2] | Class Probability : 0.9998895
Class : ['C'] | Class Index : [2] | Class Probability : 0.99981266

Test Case “H” :



```
| Class Index :  [7]  | Class Probability :  0.99999976
| Class Index :  [7]  | Class Probability :  0.9999982
| Class Index :  [7]  | Class Probability :  0.99998736
| Class Index :  [7]  | Class Probability :  0.9999665
| Class Index :  [7]  | Class Probability :  0.9999987
| Class Index :  [7]  | Class Probability :  0.99999905
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99999905
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.9999943
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99995875
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99870956
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99870956
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99994755
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99998677
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.9999943
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.9999925
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.9999912
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99998677
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99998844
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.99999607
Class :  ['H']  | Class Index :  [7]  | Class Probability :  0.9999981
```

Test Case “I” :



```
| Class Index :  [8]  | Class Probability :  0.94118863
| Class Index :  [8]  | Class Probability :  0.6175527
| Class Index :  [8]  | Class Probability :  0.58263916
| Class Index :  [8]  | Class Probability :  0.70663416
| Class Index :  [8]  | Class Probability :  0.73437685
| Class Index :  [8]  | Class Probability :  0.66442364
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.7150274
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.72028744
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.6944528
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.6448838
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.80787754
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.8199914
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.8576887
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.8560059
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.8483915
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.85554373
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.856388
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.8406609
Class :  ['I']  | Class Index :  [8]  | Class Probability :  0.8854986
```

Skrip VideoToImages.py (mengubah video menjadi images):

```python
import cv2
outDir = "./Data/Images/%d.jpg"

videoFile = input('Enter Video File Name (file akan di write ke directory ./Data/Images): ')
videoFile ='./Data/Video/Data.mp4'
vidcap = cv2.VideoCapture(videoFile)
success,image = vidcap.read()
count = 0
while success:
  cv2.imwrite(outDir % count, image)     # save frame sebagai JPEG file
  success,image = vidcap.read() # kalau fail berarti bisa masalah file/ tidak ada frame lagi
  print('Read and Save frame %d: '% count, success)
  count += 1
```

Skrip VideoIndentifier.py (untuk indentifikasi video realtime)

```python
# import the opencv library
print("Importing Library...")
import cv2
import tensorflow as tf
from tensorflow.keras import datasets, layers, models
import tensorflow_datasets as tfds
import matplotlib.pyplot as plt
import cv2
import os
import numpy as np
import scipy
from skimage import color, data, restoration
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from random import uniform
from tensorflow.keras.layers import BatchNormalization
# from object_detection.utils import label_map_util
import sys

# constants
modelPath = 'saved_model/Model_3'
width = 128
height = 128
dim = (width, height)
BATCH_SIZE = 32
IMG_SIZE = (128, 128)
labels = ['A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'K', 'L', 'M', 'N', 'O', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y']

print("Loading model from " + modelPath)
# define a video capture object
vid = cv2.VideoCapture(0)

model = tf.keras.models.load_model(modelPath, compile = True)
print("Model Loaded")

os.environ['TF_CPP_MIN_LOG_LEVEL'] = '2'    # Suppress TensorFlow logging

while True:
    ret, image_np = vid.read()

    reshaped_image = cv2.resize(image_np, dim, interpolation = cv2.INTER_AREA)
    input_tensor = tf.convert_to_tensor(np.expand_dims(reshaped_image, 0), dtype=tf.float32)
    y_prob = model.predict(input_tensor, verbose=0)
    y_classes = y_prob.argmax(axis=-1)
    predicted_label = np.array(sorted(labels))[y_classes]
    print("Class : ", predicted_label, " | Class Index : ", y_classes,  " | Class Probability : ",y_prob.max())

    cv2.imshow('object detection', reshaped_image)

    # cv2.imwrite("./temp/temp.jpg", image_np)
    # cv2.imshow('object detection', image_np)
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

# After the loop release the cap object
```

```python
print("Loading model from " + modelPath)
# define a video capture object
vid = cv2.VideoCapture(0)

model = tf.keras.models.load_model(modelPath, compile = True)
print("Model Loaded")

os.environ['TF_CPP_MIN_LOG_LEVEL'] = '2'    # Suppress TensorFlow logging

while True:
    ret, image_np = vid.read()

    reshaped_image = cv2.resize(image_np, dim, interpolation = cv2.INTER_AREA)
    input_tensor = tf.convert_to_tensor(np.expand_dims(reshaped_image, 0), dtype=tf.float32)
    y_prob = model.predict(input_tensor, verbose=0)
    y_classes = y_prob.argmax(axis=-1)
    predicted_label = np.array(sorted(labels))[y_classes]
    print("Class : ", predicted_label, " | Class Index : ", y_classes, " | Class Probability : ",y_prob.max())

    cv2.imshow('object detection', reshaped_image)

    # cv2.imwrite("./temp/temp.jpg", image_np)
    # cv2.imshow('object detection', image_np)
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

# After the loop release the cap object
vid.release()
# Destroy all the windows
cv2.destroyAllWindows()
```

Skrip HardSignToAlphabet.ipynb (untuk training) :

TUGAS BESAR KULIAH SISTEM PENGUKURAN BERBASIS CITRA

Nama : Ronggur Mahendra Widya Putra

NIM : 13519008

In [1]:

```
# Import Library
import tensorflow as tf

from tensorflow.keras import datasets, layers, models
import tensorflow_datasets as tfds
import matplotlib.pyplot as plt
import cv2
import os
import numpy as np
import scipy
from skimage import color, data, restoration
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from random import uniform
from tensorflow.keras.layers import BatchNormalization
```

Loading Data dari folder ./Data/ClassifiedData

In [2]:

```
ClassifiedDataDir = "./Data/ClassifiedData/Train"
BATCH_SIZE = 32
IMG_SIZE = (128, 128)
train_dataset = tf.keras.utils.image_dataset_from_directory(
    directory = ClassifiedDataDir,
        labels='inferred',
        label_mode='int',
        class_names=None,
        color_mode='rgb',
        batch_size=BATCH_SIZE,
        image_size=IMG_SIZE,
        shuffle=True,
        seed=1234,
        subset="training",
        validation_split=0.1,
        interpolation='bilinear',
        follow_links=False,
        crop_to_aspect_ratio=False,
        # rescale = 1./255,
    )
validation_dataset = tf.keras.utils.image_dataset_from_directory(
    directory = ClassifiedDataDir,
        labels='inferred',
        label_mode='int',
        class_names=None,
        color_mode='rgb',
        batch_size=BATCH_SIZE,
        image_size=IMG_SIZE,
        shuffle=True,
        seed=1234,
        subset="validation",
        validation_split=0.1,
        interpolation='bilinear',
        follow_links=False,
        crop_to_aspect_ratio=False,
        # rescale = 1./255,
    )


test_dataset = tf.keras.utils.image_dataset_from_directory(
    directory = "./Data/ClassifiedData/Test",
        labels='inferred',
        label_mode='int',
        class_names=None,
        color_mode='rgb',
        batch_size=BATCH_SIZE,
        image_size=IMG_SIZE,
        shuffle=True,
        seed=None,
        interpolation='bilinear',
        follow_links=False,
        crop_to_aspect_ratio=False,
        # rescale = 1./255,
    )
```

```
Found 3088 files belonging to 24 classes.
Using 2780 files for training.
```

```
Found 3088 files belonging to 24 classes.
Using 308 files for validation.
Found 312 files belonging to 24 classes.
```

List Class

In [3]:

```
# for element in dataset.as_numpy_iterator():
#     print(element)
class_names = train_dataset.class_names
print(class_names)
print(len(class_names))
```

```
['A', 'B', 'C', 'D', 'E', 'F', 'G', 'H', 'I', 'K', 'L', 'M', 'N', 'O', 'P',
'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y']
24
```

In [4]:

```
# print('Number of training batches: %d' % tf.data.experimental.cardinality(train_dataset).
# print('Number of validation batches: %d' % tf.data.experimental.cardinality(validation_da
```

Optimization buffer untuk Dataset

In [5]:

```
# DataSet
AUTOTUNE = tf.data.AUTOTUNE
train_dataset = train_dataset.prefetch(buffer_size=AUTOTUNE)
validation_dataset = validation_dataset.prefetch(buffer_size=AUTOTUNE)
test_dataset = test_dataset.prefetch(buffer_size=AUTOTUNE)
```

Makingsure Training using GPU

In [6]:

```
print(tf.test.is_built_with_cuda())
print(tf.config.list_physical_devices('GPU'))
print("Num GPUs Available: ", len(tf.config.list_physical_devices('GPU')))
```

```
True
[PhysicalDevice(name='/physical_device:GPU:0', device_type='GPU')]
Num GPUs Available:  1
```

Creating CNN Model

Model 1

In [7]:

```
# # Model 1 Initialize
input_size = 128
filter_size = 14
num_filter = 8
maxpool_size = 2
batch_size = BATCH_SIZE
epochs = 30

model_1 = models.Sequential()
model_1.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(input_size, input_siz
model_1.add(layers.MaxPooling2D((2, 2)))
model_1.add(layers.Conv2D(64, (3, 3), activation='relu'))
model_1.add(layers.MaxPooling2D((2, 2)))
model_1.add(layers.Conv2D(64, (3, 3), activation='relu'))

model_1.add(tf.keras.layers.Flatten())
model_1.add(tf.keras.layers.Dense(120))
model_1.add(tf.keras.layers.Dense(24, activation = 'softmax'))

model_1.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d (Conv2D)             (None, 126, 126, 32)      896       
                                                                 
 max_pooling2d (MaxPooling2D  (None, 63, 63, 32)       0         
 )                                                               
                                                                 
 conv2d_1 (Conv2D)           (None, 61, 61, 64)        18496     
                                                                 
 max_pooling2d_1 (MaxPooling  (None, 30, 30, 64)       0         
 2D)                                                             
                                                                 
 conv2d_2 (Conv2D)           (None, 28, 28, 64)        36928     
                                                                 
 flatten (Flatten)           (None, 50176)             0         
                                                                 
 dense (Dense)               (None, 120)               6021240   
                                                                 
 dense_1 (Dense)             (None, 24)                2904      
                                                                 
=================================================================
Total params: 6,080,464
Trainable params: 6,080,464
Non-trainable params: 0
_________________________________________________________________
```

In [8]:

```
# Optimizer
optimizer1 = tf.keras.optimizers.Nadam(
    learning_rate=0.00001, beta_1=0.9, beta_2=0.999, epsilon=1e-07,
    name='Nadam'
) # 0.00001

# Loss Fn
lossfn1 = tf.keras.losses.SparseCategoricalCrossentropy( from_logits=False, reduction=tf.ke

# Model Summary
model_1.compile(
    optimizer="rmsprop",
    loss="sparse_categorical_crossentropy",
    metrics=["sparse_categorical_accuracy"],
)
```

Model 2

In [9]:

```
# # Model 2

input_size = 128
filter_size = 3
num_filter = 8
maxpool_size = 2
batch_size = BATCH_SIZE
epochs = 30

steps_per_epoch = 24720/batch_size

model_2 = tf.keras.models.Sequential()
model_2.add(tf.keras.layers.Conv2D(16, (filter_size,filter_size),
                 input_shape= (input_size,input_size,3),
                 activation ='relu',
                 padding='same'))
model_2.add(tf.keras.layers.Conv2D(16, (filter_size,filter_size),
                 input_shape= (input_size,input_size,3),
                 activation ='relu',
                 padding='same'))
model_2.add(tf.keras.layers.MaxPooling2D(pool_size=(maxpool_size, maxpool_size),strides=1))
model_2.add(tf.keras.layers.Dropout(uniform(0, 1)))

model_2.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_2.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_2.add(BatchNormalization())
model_2.add(tf.keras.layers.MaxPooling2D(pool_size=(maxpool_size, maxpool_size),strides=2))
model_2.add(tf.keras.layers.Dropout(uniform(0, 1)))

model_2.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_2.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_2.add(BatchNormalization())

model_2.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_2.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_2.add(BatchNormalization())
model_2.add(tf.keras.layers.MaxPooling2D(pool_size=(maxpool_size, maxpool_size),strides=2))
model_2.add(tf.keras.layers.Dropout(uniform(0, 1)))

model_2.add(tf.keras.layers.Flatten())
model_2.add(tf.keras.layers.Dense(120, activation='relu'))
model_2.add(tf.keras.layers.Dense(120, activation='relu'))
model_2.add(tf.keras.layers.Dense(24,activation='softmax'))
```

In [10]:

```
METRICS = [ 'sparse_categorical_accuracy']
model_2.compile( optimizer= tf.keras.optimizers.Adam(lr=0.001),loss='sparse_categorical_cro

model_2.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_3 (Conv2D)           (None, 128, 128, 16)      448       
                                                                 
 conv2d_4 (Conv2D)           (None, 128, 128, 16)      2320      
                                                                 
 max_pooling2d_2 (MaxPooling  (None, 127, 127, 16)     0         
 2D)                                                             
                                                                 
 dropout (Dropout)           (None, 127, 127, 16)      0         
                                                                 
 conv2d_5 (Conv2D)           (None, 125, 125, 32)      4640      
                                                                 
 conv2d_6 (Conv2D)           (None, 123, 123, 32)      9248      
                                                                 
 batch_normalization (BatchN  (None, 123, 123, 32)     128       
 ormalization)                                                   
                                                                 
 max_pooling2d_3 (MaxPooling  (None, 61, 61, 32)       0         
 2D)                                                             
                                                                 
 dropout_1 (Dropout)         (None, 61, 61, 32)        0         
                                                                 
 conv2d_7 (Conv2D)           (None, 59, 59, 32)        9248      
                                                                 
 conv2d_8 (Conv2D)           (None, 57, 57, 32)        9248      
                                                                 
 batch_normalization_1 (Batc  (None, 57, 57, 32)       128       
 hNormalization)                                                 
                                                                 
 conv2d_9 (Conv2D)           (None, 55, 55, 32)        9248      
                                                                 
 conv2d_10 (Conv2D)          (None, 53, 53, 32)        9248      
                                                                 
 batch_normalization_2 (Batc  (None, 53, 53, 32)       128       
 hNormalization)                                                 
                                                                 
 max_pooling2d_4 (MaxPooling  (None, 26, 26, 32)       0         
 2D)                                                             
                                                                 
 dropout_2 (Dropout)         (None, 26, 26, 32)        0         
                                                                 
 flatten_1 (Flatten)         (None, 21632)             0         
                                                                 
 dense_2 (Dense)             (None, 120)               2595960   
                                                                 
 dense_3 (Dense)             (None, 120)               14520     
                                                                 
 dense_4 (Dense)             (None, 24)                2904      
                                                                 
=================================================================
Total params: 2,667,416
```

```
Trainable params: 2,667,224
Non-trainable params: 192
_________________________________________________________________

c:\Users\ZEPHYRUS GU502GU\AppData\Local\Programs\Python\Python39\lib\site-pa
ckages\keras\optimizers\optimizer_v2\adam.py:110: UserWarning: The `lr` argu
ment is deprecated, use `learning_rate` instead.
  super(Adam, self).__init__(name, **kwargs)
```

Model 3

In [11]:

```
#Model 3
input_size = 128
filter_size = 14
num_filter = 8
maxpool_size = 2
batch_size = BATCH_SIZE
epochs = 30

model_3 = tf.keras.models.Sequential()
model_3.add(tf.keras.layers.Conv2D(16, (filter_size,filter_size),
                 input_shape= (input_size,input_size,3),
                 activation ='relu',
                 padding='same'))
model_3.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_3.add(tf.keras.layers.MaxPooling2D(pool_size=(maxpool_size, maxpool_size),strides=1))

model_3.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_3.add(tf.keras.layers.Conv2D(32, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_3.add(tf.keras.layers.MaxPooling2D(pool_size=(maxpool_size, maxpool_size),strides=2))
model_3.add(tf.keras.layers.Dropout(uniform(0, 1)))


model_3.add(tf.keras.layers.Conv2D(64, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_3.add(tf.keras.layers.Conv2D(64, (filter_size,filter_size),
                 activation='relu',
                 padding='valid'))
model_3.add(BatchNormalization())
model_3.add(tf.keras.layers.MaxPooling2D(pool_size=(maxpool_size, maxpool_size),strides=2))
model_3.add(tf.keras.layers.Dropout(uniform(0, 1)))


model_3.add(tf.keras.layers.Flatten())
model_3.add(tf.keras.layers.Dense(128, activation='relu'))
model_3.add(tf.keras.layers.Dense(128, activation='relu'))
model_3.add(tf.keras.layers.Dense(24,activation='softmax'))
```

In [12]:

```
METRICS = [ 'sparse_categorical_accuracy']

model_3.compile( optimizer= tf.keras.optimizers.Adam(lr=0.001),loss='sparse_categorical_cro

model_3.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_11 (Conv2D)          (None, 128, 128, 16)      9424      
                                                                 
 conv2d_12 (Conv2D)          (None, 115, 115, 32)      100384    
                                                                 
 max_pooling2d_5 (MaxPooling  (None, 114, 114, 32)     0         
 2D)                                                             
                                                                 
 conv2d_13 (Conv2D)          (None, 101, 101, 32)      200736    
                                                                 
 conv2d_14 (Conv2D)          (None, 88, 88, 32)        200736    
                                                                 
 max_pooling2d_6 (MaxPooling  (None, 44, 44, 32)       0         
 2D)                                                             
                                                                 
 dropout_3 (Dropout)         (None, 44, 44, 32)        0         
                                                                 
 conv2d_15 (Conv2D)          (None, 31, 31, 64)        401472    
                                                                 
 conv2d_16 (Conv2D)          (None, 18, 18, 64)        802880    
                                                                 
 batch_normalization_3 (Batc  (None, 18, 18, 64)       256       
 hNormalization)                                                 
                                                                 
 max_pooling2d_7 (MaxPooling  (None, 9, 9, 64)         0         
 2D)                                                             
                                                                 
 dropout_4 (Dropout)         (None, 9, 9, 64)          0         
                                                                 
 flatten_2 (Flatten)         (None, 5184)              0         
                                                                 
 dense_5 (Dense)             (None, 128)               663680    
                                                                 
 dense_6 (Dense)             (None, 128)               16512     
                                                                 
 dense_7 (Dense)             (None, 24)                3096      
                                                                 
=================================================================
Total params: 2,399,176
Trainable params: 2,399,048
Non-trainable params: 128
_________________________________________________________________
```

Training

In [13]:

```
# Training Model 1
history1 = model_1.fit(
    train_dataset,
    epochs=30,
    shuffle=True,
    validation_data = (validation_dataset)
    )
```

```
Epoch 1/30
87/87 [==============================] - 8s 51ms/step - loss: 165.8931 - s
parse_categorical_accuracy: 0.4658 - val_loss: 0.5191 - val_sparse_categor
ical_accuracy: 0.8864
Epoch 2/30
87/87 [==============================] - 4s 48ms/step - loss: 3.4740 - spa
rse_categorical_accuracy: 0.8590 - val_loss: 0.2727 - val_sparse_categoric
al_accuracy: 0.9318
Epoch 3/30
87/87 [==============================] - 5s 49ms/step - loss: 21.3086 - sp
arse_categorical_accuracy: 0.8338 - val_loss: 0.4336 - val_sparse_categori
cal_accuracy: 0.9675
Epoch 4/30
87/87 [==============================] - 5s 50ms/step - loss: 2.3258 - spa
rse_categorical_accuracy: 0.9421 - val_loss: 0.1463 - val_sparse_categoric
al_accuracy: 0.9870
Epoch 5/30
87/87 [==============================] - 5s 50ms/step - loss: 10.2403 - sp
arse_categorical_accuracy: 0.9428 - val_loss: 0.4589 - val_sparse_categori
cal_accuracy: 0.9903
Epoch 6/30
87/87 [==============================] - 5s 50ms/step - loss: 2.9069 - spa
rse_categorical_accuracy: 0.9723 - val_loss: 0.3268 - val_sparse_categoric
al_accuracy: 0.9968
Epoch 7/30
87/87 [==============================] - 5s 54ms/step - loss: 14.2663 - sp
arse_categorical_accuracy: 0.9622 - val_loss: 0.8427 - val_sparse_categori
cal_accuracy: 0.9675
Epoch 8/30
87/87 [==============================] - 7s 71ms/step - loss: 5.2379 - spa
rse_categorical_accuracy: 0.9781 - val_loss: 1.0001 - val_sparse_categoric
al_accuracy: 0.9903
Epoch 9/30
87/87 [==============================] - 6s 64ms/step - loss: 1.6106 - spa
rse_categorical_accuracy: 0.9903 - val_loss: 0.2118 - val_sparse_categoric
al_accuracy: 0.9903
Epoch 10/30
87/87 [==============================] - 6s 62ms/step - loss: 0.4617 - spa
rse_categorical_accuracy: 0.9932 - val_loss: 0.2118 - val_sparse_categoric
al_accuracy: 0.9968
Epoch 11/30
87/87 [==============================] - 6s 64ms/step - loss: 1.9330 - spa
rse_categorical_accuracy: 0.9827 - val_loss: 7.3122e-04 - val_sparse_categ
orical_accuracy: 1.0000
Epoch 12/30
87/87 [==============================] - 6s 62ms/step - loss: 1.5951 - spa
rse_categorical_accuracy: 0.9903 - val_loss: 0.4488 - val_sparse_categoric
al_accuracy: 0.9903
Epoch 13/30
```

```
87/87 [==============================] - 6s 64ms/step - loss: 0.9665 - spa
rse_categorical_accuracy: 0.9903 - val_loss: 0.0205 - val_sparse_categoric
al_accuracy: 0.9935
Epoch 14/30
87/87 [==============================] - 6s 64ms/step - loss: 0.1011 - spa
rse_categorical_accuracy: 0.9982 - val_loss: 0.4912 - val_sparse_categoric
al_accuracy: 0.9903
Epoch 15/30
87/87 [==============================] - 7s 72ms/step - loss: 6.6320 - spa
rse_categorical_accuracy: 0.9795 - val_loss: 1.3248 - val_sparse_categoric
al_accuracy: 0.9903
Epoch 16/30
87/87 [==============================] - 7s 72ms/step - loss: 1.2581 - spa
rse_categorical_accuracy: 0.9942 - val_loss: 0.1248 - val_sparse_categoric
al_accuracy: 0.9968
Epoch 17/30
87/87 [==============================] - 7s 70ms/step - loss: 2.6191e-04 -
sparse_categorical_accuracy: 0.9996 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 18/30
87/87 [==============================] - 8s 81ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 19/30
87/87 [==============================] - 8s 85ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 20/30
87/87 [==============================] - 7s 77ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 21/30
87/87 [==============================] - 7s 78ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 22/30
87/87 [==============================] - 8s 80ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 23/30
87/87 [==============================] - 7s 71ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 24/30
87/87 [==============================] - 7s 70ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 25/30
87/87 [==============================] - 6s 68ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 26/30
87/87 [==============================] - 6s 68ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 27/30
87/87 [==============================] - 6s 67ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 28/30
87/87 [==============================] - 6s 69ms/step - loss: 0.0000e+00 -
```

```
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 29/30
87/87 [==============================] - 7s 77ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
Epoch 30/30
87/87 [==============================] - 7s 75ms/step - loss: 0.0000e+00 -
sparse_categorical_accuracy: 1.0000 - val_loss: 0.0515 - val_sparse_catego
rical_accuracy: 0.9968
```

In [14]:

```
# Training Model 2
history2 = model_2.fit(
    train_dataset,
    epochs=30,
    shuffle=True,
    validation_data = (validation_dataset)
    )
```

```
Epoch 1/30
87/87 [==============================] - 16s 139ms/step - loss: 2.5268 - spa
rse_categorical_accuracy: 0.3691 - val_loss: 0.8988 - val_sparse_categorical
_accuracy: 0.9123
Epoch 2/30
87/87 [==============================] - 10s 110ms/step - loss: 0.2476 - spa
rse_categorical_accuracy: 0.9342 - val_loss: 23.5757 - val_sparse_categorica
l_accuracy: 0.0779
Epoch 3/30
87/87 [==============================] - 10s 108ms/step - loss: 0.0808 - spa
rse_categorical_accuracy: 0.9770 - val_loss: 23.5948 - val_sparse_categorica
l_accuracy: 0.0455
Epoch 4/30
87/87 [==============================] - 10s 110ms/step - loss: 0.0762 - spa
rse_categorical_accuracy: 0.9773 - val_loss: 25.0027 - val_sparse_categorica
l_accuracy: 0.0357
Epoch 5/30
87/87 [==============================] - 10s 111ms/step - loss: 0.0731 - spa
rse_categorical_accuracy: 0.9795 - val_loss: 21.1595 - val_sparse_categorica
l_accuracy: 0.0357
Epoch 6/30
87/87 [==============================] - 11s 115ms/step - loss: 0.0672 - spa
rse_categorical_accuracy: 0.9809 - val_loss: 21.5560 - val_sparse_categorica
l_accuracy: 0.0357
Epoch 7/30
87/87 [==============================] - 10s 111ms/step - loss: 0.0457 - spa
rse_categorical_accuracy: 0.9881 - val_loss: 17.4330 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 8/30
87/87 [==============================] - 10s 110ms/step - loss: 0.0443 - spa
rse_categorical_accuracy: 0.9867 - val_loss: 27.1873 - val_sparse_categorica
l_accuracy: 0.0357
Epoch 9/30
87/87 [==============================] - 10s 111ms/step - loss: 0.0298 - spa
rse_categorical_accuracy: 0.9932 - val_loss: 28.6865 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 10/30
87/87 [==============================] - 10s 110ms/step - loss: 0.0499 - spa
rse_categorical_accuracy: 0.9842 - val_loss: 32.7295 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 11/30
87/87 [==============================] - 10s 111ms/step - loss: 0.0349 - spa
rse_categorical_accuracy: 0.9910 - val_loss: 28.8760 - val_sparse_categorica
l_accuracy: 0.0357
Epoch 12/30
87/87 [==============================] - 10s 112ms/step - loss: 0.0231 - spa
rse_categorical_accuracy: 0.9939 - val_loss: 27.8960 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 13/30
87/87 [==============================] - 10s 112ms/step - loss: 0.0249 - spa
```

```
rse_categorical_accuracy: 0.9914 - val_loss: 32.0158 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 14/30
87/87 [==============================] - 10s 111ms/step - loss: 0.0182 - spa
rse_categorical_accuracy: 0.9932 - val_loss: 36.6200 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 15/30
87/87 [==============================] - 10s 114ms/step - loss: 0.0438 - spa
rse_categorical_accuracy: 0.9885 - val_loss: 26.5402 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 16/30
87/87 [==============================] - 10s 112ms/step - loss: 0.0231 - spa
rse_categorical_accuracy: 0.9921 - val_loss: 26.7868 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 17/30
87/87 [==============================] - 10s 110ms/step - loss: 0.0131 - spa
rse_categorical_accuracy: 0.9950 - val_loss: 31.2467 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 18/30
87/87 [==============================] - 10s 113ms/step - loss: 0.0270 - spa
rse_categorical_accuracy: 0.9921 - val_loss: 28.0671 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 19/30
87/87 [==============================] - 11s 114ms/step - loss: 0.0313 - spa
rse_categorical_accuracy: 0.9906 - val_loss: 31.5852 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 20/30
87/87 [==============================] - 10s 112ms/step - loss: 0.0251 - spa
rse_categorical_accuracy: 0.9935 - val_loss: 32.7308 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 21/30
87/87 [==============================] - 10s 114ms/step - loss: 0.0588 - spa
rse_categorical_accuracy: 0.9867 - val_loss: 39.3150 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 22/30
87/87 [==============================] - 11s 114ms/step - loss: 0.0476 - spa
rse_categorical_accuracy: 0.9878 - val_loss: 30.4869 - val_sparse_categorica
l_accuracy: 0.0422
Epoch 23/30
87/87 [==============================] - 10s 114ms/step - loss: 0.0246 - spa
rse_categorical_accuracy: 0.9939 - val_loss: 37.6322 - val_sparse_categorica
l_accuracy: 0.0357
Epoch 24/30
87/87 [==============================] - 10s 110ms/step - loss: 0.0174 - spa
rse_categorical_accuracy: 0.9950 - val_loss: 41.3449 - val_sparse_categorica
l_accuracy: 0.0357
Epoch 25/30
87/87 [==============================] - 10s 109ms/step - loss: 0.0386 - spa
rse_categorical_accuracy: 0.9928 - val_loss: 41.1448 - val_sparse_categorica
l_accuracy: 0.0357
Epoch 26/30
87/87 [==============================] - 7s 82ms/step - loss: 0.0343 - spars
e_categorical_accuracy: 0.9917 - val_loss: 40.6883 - val_sparse_categorical_
accuracy: 0.0487
Epoch 27/30
87/87 [==============================] - 8s 84ms/step - loss: 0.0172 - spars
e_categorical_accuracy: 0.9950 - val_loss: 45.6515 - val_sparse_categorical_
accuracy: 0.0649
Epoch 28/30
87/87 [==============================] - 8s 84ms/step - loss: 0.0388 - spars
e_categorical_accuracy: 0.9881 - val_loss: 40.4782 - val_sparse_categorical_
```

```
accuracy: 0.0422
Epoch 29/30
87/87 [==============================] - 10s 113ms/step - loss: 0.0378 - spa
rse_categorical_accuracy: 0.9910 - val_loss: 42.0297 - val_sparse_categorica
l_accuracy: 0.0487
Epoch 30/30
87/87 [==============================] - 10s 109ms/step - loss: 0.0302 - spa
rse_categorical_accuracy: 0.9924 - val_loss: 34.0295 - val_sparse_categorica
l_accuracy: 0.0649
```

In [15]:

```
# Training Model 3
history3 = model_3.fit(
    train_dataset,
    epochs=30,
    shuffle=True,
    validation_data = (validation_dataset)
    )
```

```
Epoch 1/30
87/87 [==============================] - 34s 273ms/step - loss: 2.0481 - spa
rse_categorical_accuracy: 0.3917 - val_loss: 3.6334 - val_sparse_categorical
_accuracy: 0.2468
Epoch 2/30
87/87 [==============================] - 13s 137ms/step - loss: 0.4149 - spa
rse_categorical_accuracy: 0.8651 - val_loss: 38.4023 - val_sparse_categorica
l_accuracy: 0.2208
Epoch 3/30
87/87 [==============================] - 13s 138ms/step - loss: 0.2008 - spa
rse_categorical_accuracy: 0.9450 - val_loss: 25.1020 - val_sparse_categorica
l_accuracy: 0.1461
Epoch 4/30
87/87 [==============================] - 13s 139ms/step - loss: 0.1757 - spa
rse_categorical_accuracy: 0.9478 - val_loss: 2.5688 - val_sparse_categorical
_accuracy: 0.6006
Epoch 5/30
87/87 [==============================] - 13s 138ms/step - loss: 0.0963 - spa
rse_categorical_accuracy: 0.9737 - val_loss: 5.8490 - val_sparse_categorical
_accuracy: 0.3604
Epoch 6/30
87/87 [==============================] - 13s 139ms/step - loss: 0.1112 - spa
rse_categorical_accuracy: 0.9669 - val_loss: 0.2579 - val_sparse_categorical
_accuracy: 0.9318
Epoch 7/30
87/87 [==============================] - 13s 138ms/step - loss: 0.1061 - spa
rse_categorical_accuracy: 0.9683 - val_loss: 9.2605 - val_sparse_categorical
_accuracy: 0.2597
Epoch 8/30
87/87 [==============================] - 12s 136ms/step - loss: 0.0749 - spa
rse_categorical_accuracy: 0.9777 - val_loss: 0.8603 - val_sparse_categorical
_accuracy: 0.7175
Epoch 9/30
87/87 [==============================] - 13s 141ms/step - loss: 0.0574 - spa
rse_categorical_accuracy: 0.9853 - val_loss: 0.6230 - val_sparse_categorical
_accuracy: 0.8377
Epoch 10/30
87/87 [==============================] - 13s 140ms/step - loss: 0.0516 - spa
rse_categorical_accuracy: 0.9842 - val_loss: 8.5928 - val_sparse_categorical
_accuracy: 0.3409
Epoch 11/30
87/87 [==============================] - 13s 139ms/step - loss: 0.0507 - spa
rse_categorical_accuracy: 0.9849 - val_loss: 14.6717 - val_sparse_categorica
l_accuracy: 0.3149
Epoch 12/30
87/87 [==============================] - 13s 138ms/step - loss: 0.0579 - spa
rse_categorical_accuracy: 0.9845 - val_loss: 14.6992 - val_sparse_categorica
l_accuracy: 0.2175
Epoch 13/30
87/87 [==============================] - 13s 141ms/step - loss: 0.0322 - spa
```

```
rse_categorical_accuracy: 0.9899 - val_loss: 2.1610 - val_sparse_categorical
_accuracy: 0.6656
Epoch 14/30
87/87 [==============================] - 12s 135ms/step - loss: 0.0225 - spa
rse_categorical_accuracy: 0.9921 - val_loss: 2.1411 - val_sparse_categorical
_accuracy: 0.7013
Epoch 15/30
87/87 [==============================] - 12s 135ms/step - loss: 0.0467 - spa
rse_categorical_accuracy: 0.9863 - val_loss: 14.7012 - val_sparse_categorica
l_accuracy: 0.2857
Epoch 16/30
87/87 [==============================] - 12s 135ms/step - loss: 0.0461 - spa
rse_categorical_accuracy: 0.9853 - val_loss: 3.9097 - val_sparse_categorical
_accuracy: 0.4318
Epoch 17/30
87/87 [==============================] - 13s 141ms/step - loss: 0.0326 - spa
rse_categorical_accuracy: 0.9888 - val_loss: 1.6834 - val_sparse_categorical
_accuracy: 0.6656
Epoch 18/30
87/87 [==============================] - 13s 141ms/step - loss: 0.0275 - spa
rse_categorical_accuracy: 0.9924 - val_loss: 6.0157 - val_sparse_categorical
_accuracy: 0.3279
Epoch 19/30
87/87 [==============================] - 13s 142ms/step - loss: 0.0272 - spa
rse_categorical_accuracy: 0.9928 - val_loss: 23.4782 - val_sparse_categorica
l_accuracy: 0.2890
Epoch 20/30
87/87 [==============================] - 13s 137ms/step - loss: 0.0462 - spa
rse_categorical_accuracy: 0.9845 - val_loss: 0.0415 - val_sparse_categorical
_accuracy: 0.9870
Epoch 21/30
87/87 [==============================] - 13s 140ms/step - loss: 0.0323 - spa
rse_categorical_accuracy: 0.9899 - val_loss: 15.0468 - val_sparse_categorica
l_accuracy: 0.1916
Epoch 22/30
87/87 [==============================] - 13s 140ms/step - loss: 0.0200 - spa
rse_categorical_accuracy: 0.9939 - val_loss: 20.5498 - val_sparse_categorica
l_accuracy: 0.3084
Epoch 23/30
87/87 [==============================] - 13s 146ms/step - loss: 0.0256 - spa
rse_categorical_accuracy: 0.9942 - val_loss: 5.4647 - val_sparse_categorical
_accuracy: 0.4416
Epoch 24/30
87/87 [==============================] - 10s 113ms/step - loss: 0.0430 - spa
rse_categorical_accuracy: 0.9860 - val_loss: 9.5315 - val_sparse_categorical
_accuracy: 0.3929
Epoch 25/30
87/87 [==============================] - 10s 106ms/step - loss: 0.0416 - spa
rse_categorical_accuracy: 0.9871 - val_loss: 9.7630 - val_sparse_categorical
_accuracy: 0.3377
Epoch 26/30
87/87 [==============================] - 10s 113ms/step - loss: 0.0204 - spa
rse_categorical_accuracy: 0.9932 - val_loss: 28.4930 - val_sparse_categorica
l_accuracy: 0.1299
Epoch 27/30
87/87 [==============================] - 13s 137ms/step - loss: 0.0144 - spa
rse_categorical_accuracy: 0.9950 - val_loss: 10.6105 - val_sparse_categorica
l_accuracy: 0.3831
Epoch 28/30
87/87 [==============================] - 13s 138ms/step - loss: 0.0156 - spa
rse_categorical_accuracy: 0.9950 - val_loss: 26.9795 - val_sparse_categorica
```

```
l_accuracy: 0.2013
Epoch 29/30
87/87 [==============================] - 12s 137ms/step - loss: 0.0317 - spa
rse_categorical_accuracy: 0.9924 - val_loss: 4.2126 - val_sparse_categorical
_accuracy: 0.4675
Epoch 30/30
87/87 [==============================] - 13s 138ms/step - loss: 0.0125 - spa
rse_categorical_accuracy: 0.9942 - val_loss: 0.0127 - val_sparse_categorical
_accuracy: 0.9968
```

Save Model

In [29]:

```
modelFileDirectoryName1 = 'saved_model/Model_1'
modelFileDirectoryName2 = 'saved_model/Model_2'
modelFileDirectoryName3 = 'saved_model/Model_3'
model_1.save(modelFileDirectoryName1)
model_2.save(modelFileDirectoryName2)
model_3.save(modelFileDirectoryName3)
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op,
_jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (sho
wing 3 of 3). These functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: saved_model/Model_1\assets

INFO:tensorflow:Assets written to: saved_model/Model_1\assets
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op,
_jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_co
nvolution_op, _jit_compiled_convolution_op while saving (showing 5 of 8). Th
ese functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: saved_model/Model_2\assets

INFO:tensorflow:Assets written to: saved_model/Model_2\assets
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op,
_jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_co
nvolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). Th
ese functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: saved_model/Model_3\assets

INFO:tensorflow:Assets written to: saved_model/Model_3\assets
```

Model Evaluation and History

In [36]:

```
# Model 1
loss, acc = model_1.evaluate(test_dataset)
print("Test accuracy: {:5.2f}%".format(100 * acc))
```

```
10/10 [==============================] - 1s 36ms/step - loss: 5.3646 - spars
e_categorical_accuracy: 0.9583
Test accuracy: 95.83%
```

In [40]:

```
# Model 2
loss, acc = model_2.evaluate(test_dataset)
print("Test accuracy: {:5.2f}%".format(100 * acc))
```

```
10/10 [==============================] - 1s 18ms/step - loss: 33.6375 - spar
se_categorical_accuracy: 0.0609
Test accuracy:  6.09%
```

In [39]:

```
# Model 3
loss, acc = model_3.evaluate(test_dataset)
print("Test accuracy: {:5.2f}%".format(100 * acc))
```

```
10/10 [==============================] - 1s 26ms/step - loss: 0.0051 - spars
e_categorical_accuracy: 1.0000
Test accuracy: 100.00%
```

In [ ]: