In [1]:

```
import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
import os
import pickle
import gc
from tensorflow.python.keras import layers, Sequential,losses, metrics, optimizers,
from tensorflow.python.keras.models import Model
from tensorflow.python.keras.applications import vgg16
from tensorflow.python.keras.optimizer_v2 import adam
```

```
2022-01-24 19:28:07.861086: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
```

In [2]:

```
image_height = 48
image_width = 48
emotions_count = 8
emotion_labels = ['neutral', 'happiness', 'surprise', 'sadness', 'anger', 'disgust',
```

In [3]:

```
image_path = "./dataset/images.npy"
emotion_path = "./dataset/emotions_multi.npy"

images = np.load(image_path)
images = tf.convert_to_tensor(images)
images = layers.Rescaling(1./127.5, offset=-1)(images)
images = tf.image.grayscale_to_rgb(images)

emotions = np.load(emotion_path)
emotions = tf.convert_to_tensor(emotions)

training_samples = 28317
validation_samples = 3541
training_size = training_samples + validation_samples

training_images = images[:training_size]
test_images = images[training_size:]
training_emotions = emotions[:training_size]
test_emotions = emotions[training_size:]
```

```
2022-01-24 19:28:13.225421: I tensorflow/compiler/jit/xla_cpu_device.cc:41] Not crea
ting XLA devices, tf_xla_enable_xla_devices not set
2022-01-24 19:28:13.226670: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcuda.so.1
2022-01-24 19:28:13.292418: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:9
41] successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:13.293063: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1720]
Found device 0 with properties:
pciBusID: 0000:05:00.0 name: GeForce RTX 2080 Ti computeCapability: 7.5
coreClock: 1.545GHz coreCount: 68 deviceMemorySize: 10.76GiB deviceMemoryBandwidth:
573.69GiB/s
2022-01-24 19:28:13.293093: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 19:28:13.298505: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 19:28:13.298610: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
2022-01-24 19:28:13.301096: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcufft.so.10
```

```
2022-01-24 19:28:13.302406: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcurand.so.10
2022-01-24 19:28:13.307571: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusolver.so.10
2022-01-24 19:28:13.309357: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusparse.so.11
2022-01-24 19:28:13.310390: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
2022-01-24 19:28:13.310552: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:9
41] successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:13.311278: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:9
41] successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:13.311917: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862]
Adding visible gpu devices: 0
2022-01-24 19:28:13.312818: I tensorflow/core/platform/cpu_feature_guard.cc:142] Thi
s TensorFlow binary is optimized with oneAPI Deep Neural Network Library (oneDNN) to
use the following CPU instructions in performance-critical operations:  AVX2 AVX512F
FMA
To enable them in other operations, rebuild TensorFlow with the appropriate compiler
flags.
2022-01-24 19:28:13.313128: I tensorflow/compiler/jit/xla_gpu_device.cc:99] Not crea
ting XLA devices, tf_xla_enable_xla_devices not set
2022-01-24 19:28:13.313293: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:9
41] successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:13.313996: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1720]
Found device 0 with properties:
pciBusID: 0000:05:00.0 name: GeForce RTX 2080 Ti computeCapability: 7.5
coreClock: 1.545GHz coreCount: 68 deviceMemorySize: 10.76GiB deviceMemoryBandwidth:
573.69GiB/s
2022-01-24 19:28:13.314031: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 19:28:13.314055: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 19:28:13.314070: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
2022-01-24 19:28:13.314085: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcufft.so.10
2022-01-24 19:28:13.314099: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcurand.so.10
2022-01-24 19:28:13.314113: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusolver.so.10
2022-01-24 19:28:13.314130: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusparse.so.11
2022-01-24 19:28:13.314145: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
2022-01-24 19:28:13.314223: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:9
41] successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:13.314907: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:9
41] successful NUMA node read from SysFS had negative value (-1), but there must be
at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:13.315533: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862]
Adding visible gpu devices: 0
2022-01-24 19:28:13.315583: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 19:28:14.183156: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1261]
Device interconnect StreamExecutor with strength 1 edge matrix:
2022-01-24 19:28:14.183199: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1267]
0
2022-01-24 19:28:14.183207: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1280]
0:   N
```

```
2022-01-24 19:28:14.183507: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:14.184067: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:14.184536: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2022-01-24 19:28:14.184969: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1406] Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:0 with 10071 MB memory) -> physical GPU (device: 0, name: GeForce RTX 2080 Ti, pci bus id: 0000:05:00.0, compute capability: 7.5)
```

In [4]:

```
tf.config.run_functions_eagerly(True)
def model_acc(y_true, y_pred):
    size = y_true.shape[0]
    acc = 0
    for i in range(size):
        true = y_true[i]
        pred = y_pred[i]
        index_max = tf.argmax(pred).numpy()
        if true[index_max].numpy()==tf.reduce_max(true).numpy():
            acc += 1
    return acc/size
```

In [5]:

```
def train(model, learning_rate, loss, num_epochs, batch_size):
    model.compile(optimizer=adam.Adam(learning_rate=learning_rate),
                  loss=loss,
                  metrics = [model_acc])
    history = model.fit(x=training_images,
                        y=training_emotions,
                        batch_size=batch_size,
                        epochs=num_epochs,
                        validation_data=(test_images, test_emotions))
    del model
    gc.collect()
    return history
```

In [6]:

```
from tensorflow.keras.initializers import RandomNormal, Constant
def create_model(base_model):
    base_model.trainable=True
    return Sequential([
        base_model,
        layers.GlobalAveragePooling2D(),
        layers.Dense(4096, activation='relu'),
        layers.BatchNormalization(
            momentum=0.95,
            epsilon=0.005,
            beta_initializer=RandomNormal(mean=0.0, stddev=0.05),
            gamma_initializer=Constant(value=0.9)
        ),
        layers.Dense(4096, activation='relu'),
        layers.BatchNormalization(
            momentum=0.95,
            epsilon=0.005,
            beta_initializer=RandomNormal(mean=0.0, stddev=0.05),
            gamma_initializer=Constant(value=0.9)
        ),
        layers.Dense(emotions_count, activation='softmax'),
    ])
```

In [7]:

```
if not os.path.isdir('./results/'):
    os.mkdir('./results/')

learning_rate = 5e-5
num_epochs = 50
batch_size = 32
loss = losses.MeanSquaredError()

for i in range(0,1,1):
    base_model = vgg16.VGG16(include_top=False, weights='imagenet', input_shape=(48,
    history_save_path = './history/BN_1.txt'
    model = create_model(base_model)
    history = train(model, learning_rate, loss, num_epochs, batch_size)
    with open(history_save_path, 'wb') as file_pi:
        pickle.dump(history.history, file_pi)
```

```
/userhome/cs/fym666/anaconda3/envs/tensorflow/lib/python3.8/site-packages/tensorflo
w/python/data/ops/dataset_ops.py:3503: UserWarning: Even though the tf.config.experi
mental_run_functions_eagerly option is set, this option does not apply to tf.data fu
nctions. tf.data functions are still traced and executed as graphs.
  warnings.warn(
2022-01-24 19:28:16.304863: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.
cc:116] None of the MLIR optimization passes are enabled (registered 2)
2022-01-24 19:28:16.305552: I tensorflow/core/platform/profile_utils/cpu_utils.cc:11
2] CPU Frequency: 2199880000 Hz
2022-01-24 19:28:16.332769: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
Epoch 1/50
2022-01-24 19:28:18.573988: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 19:28:19.161591: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
996/996 [==============================] - 91s 88ms/step - loss: 0.0488 - model_acc:
0.5474 - val_loss: 0.0314 - val_model_acc: 0.6714
Epoch 2/50
996/996 [==============================] - 88s 88ms/step - loss: 0.0242 - model_acc:
0.7384 - val_loss: 0.0247 - val_model_acc: 0.7401
Epoch 3/50
996/996 [==============================] - 91s 92ms/step - loss: 0.0196 - model_acc:
0.7745 - val_loss: 0.0192 - val_model_acc: 0.7782
Epoch 4/50
996/996 [==============================] - 97s 97ms/step - loss: 0.0167 - model_acc:
0.8044 - val_loss: 0.0194 - val_model_acc: 0.7759
Epoch 5/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0144 - model_acc:
0.8304 - val_loss: 0.0200 - val_model_acc: 0.7602
Epoch 6/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0125 - model_acc:
0.8461 - val_loss: 0.0164 - val_model_acc: 0.7945
Epoch 7/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0106 - model_acc:
0.8724 - val_loss: 0.0164 - val_model_acc: 0.8118
Epoch 8/50
996/996 [==============================] - 92s 93ms/step - loss: 0.0094 - model_acc:
0.8898 - val_loss: 0.0153 - val_model_acc: 0.8095
Epoch 9/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0081 - model_acc:
0.9006 - val_loss: 0.0157 - val_model_acc: 0.8127
Epoch 10/50
996/996 [==============================] - 93s 93ms/step - loss: 0.0072 - model_acc:
0.9141 - val_loss: 0.0151 - val_model_acc: 0.8163
```

```
Epoch 11/50
996/996 [==============================] - 89s 89ms/step - loss: 0.0064 - model_acc:
0.9256 - val_loss: 0.0159 - val_model_acc: 0.8169
Epoch 12/50
996/996 [==============================] - 93s 93ms/step - loss: 0.0063 - model_acc:
0.9224 - val_loss: 0.0147 - val_model_acc: 0.8259
Epoch 13/50
996/996 [==============================] - 94s 95ms/step - loss: 0.0056 - model_acc:
0.9308 - val_loss: 0.0150 - val_model_acc: 0.8289
Epoch 14/50
996/996 [==============================] - 84s 85ms/step - loss: 0.0054 - model_acc:
0.9354 - val_loss: 0.0140 - val_model_acc: 0.8303
Epoch 15/50
996/996 [==============================] - 91s 92ms/step - loss: 0.0050 - model_acc:
0.9403 - val_loss: 0.0140 - val_model_acc: 0.8321
Epoch 16/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0046 - model_acc:
0.9426 - val_loss: 0.0134 - val_model_acc: 0.8315
Epoch 17/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0043 - model_acc:
0.9471 - val_loss: 0.0136 - val_model_acc: 0.8284
Epoch 18/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0042 - model_acc:
0.9502 - val_loss: 0.0142 - val_model_acc: 0.8270
Epoch 19/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0040 - model_acc:
0.9475 - val_loss: 0.0139 - val_model_acc: 0.8323
Epoch 20/50
996/996 [==============================] - 98s 98ms/step - loss: 0.0036 - model_acc:
0.9505 - val_loss: 0.0128 - val_model_acc: 0.8377
Epoch 21/50
996/996 [==============================] - 92s 93ms/step - loss: 0.0033 - model_acc:
0.9536 - val_loss: 0.0132 - val_model_acc: 0.8371
Epoch 22/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0032 - model_acc:
0.9531 - val_loss: 0.0132 - val_model_acc: 0.8304
Epoch 23/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0032 - model_acc:
0.9561 - val_loss: 0.0135 - val_model_acc: 0.8349
Epoch 24/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0030 - model_acc:
0.9550 - val_loss: 0.0134 - val_model_acc: 0.8292
Epoch 25/50
996/996 [==============================] - 94s 95ms/step - loss: 0.0029 - model_acc:
0.9594 - val_loss: 0.0127 - val_model_acc: 0.8360
Epoch 26/50
996/996 [==============================] - 93s 93ms/step - loss: 0.0027 - model_acc:
0.9590 - val_loss: 0.0126 - val_model_acc: 0.8289
Epoch 27/50
996/996 [==============================] - 90s 91ms/step - loss: 0.0026 - model_acc:
0.9599 - val_loss: 0.0144 - val_model_acc: 0.8290
Epoch 28/50
996/996 [==============================] - 87s 88ms/step - loss: 0.0026 - model_acc:
0.9600 - val_loss: 0.0128 - val_model_acc: 0.8354
Epoch 29/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0024 - model_acc:
0.9644 - val_loss: 0.0128 - val_model_acc: 0.8416
Epoch 30/50
996/996 [==============================] - 99s 99ms/step - loss: 0.0022 - model_acc:
0.9630 - val_loss: 0.0126 - val_model_acc: 0.8366
Epoch 31/50
996/996 [==============================] - 92s 93ms/step - loss: 0.0022 - model_acc:
0.9640 - val_loss: 0.0127 - val_model_acc: 0.8357
Epoch 32/50
```

```
996/996 [==============================] - 84s 84ms/step - loss: 0.0021 - model_acc:
0.9650 - val_loss: 0.0127 - val_model_acc: 0.8363
Epoch 33/50
996/996 [==============================] - 82s 82ms/step - loss: 0.0020 - model_acc:
0.9690 - val_loss: 0.0124 - val_model_acc: 0.8380
Epoch 34/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0020 - model_acc:
0.9689 - val_loss: 0.0132 - val_model_acc: 0.8253
Epoch 35/50
996/996 [==============================] - 87s 88ms/step - loss: 0.0018 - model_acc:
0.9688 - val_loss: 0.0132 - val_model_acc: 0.8368
Epoch 36/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0019 - model_acc:
0.9660 - val_loss: 0.0128 - val_model_acc: 0.8366
Epoch 37/50
996/996 [==============================] - 94s 95ms/step - loss: 0.0018 - model_acc:
0.9689 - val_loss: 0.0129 - val_model_acc: 0.8388
Epoch 38/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0016 - model_acc:
0.9715 - val_loss: 0.0127 - val_model_acc: 0.8383
Epoch 39/50
996/996 [==============================] - 88s 88ms/step - loss: 0.0017 - model_acc:
0.9716 - val_loss: 0.0122 - val_model_acc: 0.8473
Epoch 40/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0016 - model_acc:
0.9686 - val_loss: 0.0127 - val_model_acc: 0.8419
Epoch 41/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0015 - model_acc:
0.9725 - val_loss: 0.0122 - val_model_acc: 0.8425
Epoch 42/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0016 - model_acc:
0.9713 - val_loss: 0.0123 - val_model_acc: 0.8436
Epoch 43/50
996/996 [==============================] - 93s 94ms/step - loss: 0.0015 - model_acc:
0.9736 - val_loss: 0.0125 - val_model_acc: 0.8448
Epoch 44/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0015 - model_acc:
0.9731 - val_loss: 0.0125 - val_model_acc: 0.8411
Epoch 45/50
996/996 [==============================] - 92s 92ms/step - loss: 0.0014 - model_acc:
0.9737 - val_loss: 0.0126 - val_model_acc: 0.8408
Epoch 46/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0013 - model_acc:
0.9754 - val_loss: 0.0127 - val_model_acc: 0.8362
Epoch 47/50
996/996 [==============================] - 97s 98ms/step - loss: 0.0013 - model_acc:
0.9749 - val_loss: 0.0128 - val_model_acc: 0.8439
Epoch 48/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0013 - model_acc:
0.9770 - val_loss: 0.0124 - val_model_acc: 0.8397
Epoch 49/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0012 - model_acc:
0.9775 - val_loss: 0.0129 - val_model_acc: 0.8431
Epoch 50/50
996/996 [==============================] - 90s 90ms/step - loss: 0.0012 - model_acc:
0.9762 - val_loss: 0.0124 - val_model_acc: 0.8391
```

In [ ]: