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 21:19:03.555115: 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 21:19:08.346296: I tensorflow/compiler/jit/xla_cpu_device.cc:41] Not crea
ting XLA devices, tf_xla_enable_xla_devices not set
2022-01-24 21:19:08.347841: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcuda.so.1
2022-01-24 21:19:08.409777: 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 21:19:08.410379: 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 21:19:08.410414: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 21:19:08.416568: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 21:19:08.416652: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
2022-01-24 21:19:08.419299: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcufft.so.10
```

```
2022-01-24 21:19:08.420364: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcurand.so.10
2022-01-24 21:19:08.426528: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusolver.so.10
2022-01-24 21:19:08.428861: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusparse.so.11
2022-01-24 21:19:08.429740: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
2022-01-24 21:19:08.429921: 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 21:19:08.430690: 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 21:19:08.431351: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862]
Adding visible gpu devices: 0
2022-01-24 21:19:08.432381: 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 21:19:08.432869: I tensorflow/compiler/jit/xla_gpu_device.cc:99] Not crea
ting XLA devices, tf_xla_enable_xla_devices not set
2022-01-24 21:19:08.433118: 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 21:19:08.433802: 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 21:19:08.433835: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 21:19:08.433858: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 21:19:08.433873: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
2022-01-24 21:19:08.433888: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcufft.so.10
2022-01-24 21:19:08.433902: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcurand.so.10
2022-01-24 21:19:08.433917: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusolver.so.10
2022-01-24 21:19:08.433933: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusparse.so.11
2022-01-24 21:19:08.433948: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
2022-01-24 21:19:08.434026: 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 21:19:08.434773: 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 21:19:08.435389: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862]
Adding visible gpu devices: 0
2022-01-24 21:19:08.435460: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 21:19:09.208857: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1261]
Device interconnect StreamExecutor with strength 1 edge matrix:
2022-01-24 21:19:09.208901: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1267]
0
2022-01-24 21:19:09.208909: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1280]
0:   N
```

```
2022-01-24 21:19:09.209147: 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 21:19:09.209647: 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 21:19:09.210082: 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 21:19:09.210513: 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 = 1e-4
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_2.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 21:19:11.515097: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.
cc:116] None of the MLIR optimization passes are enabled (registered 2)
2022-01-24 21:19:11.515901: I tensorflow/core/platform/profile_utils/cpu_utils.cc:11
2] CPU Frequency: 2199880000 Hz
2022-01-24 21:19:11.545356: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
Epoch 1/50
2022-01-24 21:19:13.961902: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 21:19:14.631096: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
996/996 [==============================] - 98s 94ms/step - loss: 0.0449 - model_acc:
0.5690 - val_loss: 0.0289 - val_model_acc: 0.6839
Epoch 2/50
996/996 [==============================] - 86s 86ms/step - loss: 0.0233 - model_acc:
0.7403 - val_loss: 0.0232 - val_model_acc: 0.7568
Epoch 3/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0184 - model_acc:
0.7840 - val_loss: 0.0192 - val_model_acc: 0.7818
Epoch 4/50
996/996 [==============================] - 92s 92ms/step - loss: 0.0159 - model_acc:
0.8118 - val_loss: 0.0219 - val_model_acc: 0.7391
Epoch 5/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0140 - model_acc:
0.8317 - val_loss: 0.0284 - val_model_acc: 0.6814
Epoch 6/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0116 - model_acc:
0.8611 - val_loss: 0.0170 - val_model_acc: 0.8066
Epoch 7/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0101 - model_acc:
0.8799 - val_loss: 0.0169 - val_model_acc: 0.8067
Epoch 8/50
996/996 [==============================] - 97s 97ms/step - loss: 0.0090 - model_acc:
0.8951 - val_loss: 0.0154 - val_model_acc: 0.8050
Epoch 9/50
996/996 [==============================] - 93s 94ms/step - loss: 0.0082 - model_acc:
0.9041 - val_loss: 0.0155 - val_model_acc: 0.8177
Epoch 10/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0072 - model_acc:
0.9160 - val_loss: 0.0153 - val_model_acc: 0.8182
```

```
Epoch 11/50
996/996 [==============================] - 81s 81ms/step - loss: 0.0067 - model_acc:
0.9219 - val_loss: 0.0149 - val_model_acc: 0.8265
Epoch 12/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0063 - model_acc:
0.9211 - val_loss: 0.0177 - val_model_acc: 0.8050
Epoch 13/50
996/996 [==============================] - 93s 93ms/step - loss: 0.0059 - model_acc:
0.9280 - val_loss: 0.0146 - val_model_acc: 0.8202
Epoch 14/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0058 - model_acc:
0.9281 - val_loss: 0.0135 - val_model_acc: 0.8363
Epoch 15/50
996/996 [==============================] - 93s 93ms/step - loss: 0.0052 - model_acc:
0.9345 - val_loss: 0.0175 - val_model_acc: 0.7813
Epoch 16/50
996/996 [==============================] - 93s 93ms/step - loss: 0.0049 - model_acc:
0.9371 - val_loss: 0.0142 - val_model_acc: 0.8250
Epoch 17/50
996/996 [==============================] - 98s 99ms/step - loss: 0.0048 - model_acc:
0.9390 - val_loss: 0.0135 - val_model_acc: 0.8276
Epoch 18/50
996/996 [==============================] - 93s 93ms/step - loss: 0.0047 - model_acc:
0.9391 - val_loss: 0.0138 - val_model_acc: 0.8234
Epoch 19/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0043 - model_acc:
0.9452 - val_loss: 0.0140 - val_model_acc: 0.8239
Epoch 20/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0043 - model_acc:
0.9452 - val_loss: 0.0132 - val_model_acc: 0.8337
Epoch 21/50
996/996 [==============================] - 97s 98ms/step - loss: 0.0040 - model_acc:
0.9466 - val_loss: 0.0135 - val_model_acc: 0.8253
Epoch 22/50
996/996 [==============================] - 93s 94ms/step - loss: 0.0038 - model_acc:
0.9473 - val_loss: 0.0129 - val_model_acc: 0.8329
Epoch 23/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0035 - model_acc:
0.9529 - val_loss: 0.0134 - val_model_acc: 0.8290
Epoch 24/50
996/996 [==============================] - 91s 91ms/step - loss: 0.0035 - model_acc:
0.9515 - val_loss: 0.0127 - val_model_acc: 0.8343
Epoch 25/50
996/996 [==============================] - 97s 97ms/step - loss: 0.0034 - model_acc:
0.9502 - val_loss: 0.0130 - val_model_acc: 0.8394
Epoch 26/50
996/996 [==============================] - 87s 87ms/step - loss: 0.0032 - model_acc:
0.9536 - val_loss: 0.0132 - val_model_acc: 0.8318
Epoch 27/50
996/996 [==============================] - 92s 93ms/step - loss: 0.0031 - model_acc:
0.9548 - val_loss: 0.0129 - val_model_acc: 0.8425
Epoch 28/50
996/996 [==============================] - 93s 93ms/step - loss: 0.0029 - model_acc:
0.9579 - val_loss: 0.0124 - val_model_acc: 0.8357
Epoch 29/50
996/996 [==============================] - 93s 94ms/step - loss: 0.0027 - model_acc:
0.9600 - val_loss: 0.0127 - val_model_acc: 0.8363
Epoch 30/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0028 - model_acc:
0.9574 - val_loss: 0.0132 - val_model_acc: 0.8341
Epoch 31/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0027 - model_acc:
0.9576 - val_loss: 0.0130 - val_model_acc: 0.8360
Epoch 32/50
```

```
996/996 [==============================] - 94s 94ms/step - loss: 0.0025 - model_acc:
0.9607 - val_loss: 0.0130 - val_model_acc: 0.8393
Epoch 33/50
996/996 [==============================] - 86s 86ms/step - loss: 0.0026 - model_acc:
0.9598 - val_loss: 0.0136 - val_model_acc: 0.8323
Epoch 34/50
996/996 [==============================] - 97s 97ms/step - loss: 0.0023 - model_acc:
0.9646 - val_loss: 0.0123 - val_model_acc: 0.8403
Epoch 35/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0022 - model_acc:
0.9639 - val_loss: 0.0123 - val_model_acc: 0.8419
Epoch 36/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0022 - model_acc:
0.9642 - val_loss: 0.0130 - val_model_acc: 0.8287
Epoch 37/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0021 - model_acc:
0.9661 - val_loss: 0.0129 - val_model_acc: 0.8397
Epoch 38/50
996/996 [==============================] - 97s 98ms/step - loss: 0.0020 - model_acc:
0.9657 - val_loss: 0.0124 - val_model_acc: 0.8408
Epoch 39/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0019 - model_acc:
0.9695 - val_loss: 0.0128 - val_model_acc: 0.8346
Epoch 40/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0019 - model_acc:
0.9667 - val_loss: 0.0124 - val_model_acc: 0.8391
Epoch 41/50
996/996 [==============================] - 97s 97ms/step - loss: 0.0019 - model_acc:
0.9667 - val_loss: 0.0124 - val_model_acc: 0.8366
Epoch 42/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0018 - model_acc:
0.9669 - val_loss: 0.0126 - val_model_acc: 0.8417
Epoch 43/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0017 - model_acc:
0.9694 - val_loss: 0.0123 - val_model_acc: 0.8434
Epoch 44/50
996/996 [==============================] - 92s 93ms/step - loss: 0.0017 - model_acc:
0.9713 - val_loss: 0.0121 - val_model_acc: 0.8436
Epoch 45/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0018 - model_acc:
0.9689 - val_loss: 0.0124 - val_model_acc: 0.8419
Epoch 46/50
996/996 [==============================] - 92s 93ms/step - loss: 0.0016 - model_acc:
0.9728 - val_loss: 0.0123 - val_model_acc: 0.8405
Epoch 47/50
996/996 [==============================] - 97s 97ms/step - loss: 0.0015 - model_acc:
0.9732 - val_loss: 0.0124 - val_model_acc: 0.8411
Epoch 48/50
996/996 [==============================] - 87s 87ms/step - loss: 0.0015 - model_acc:
0.9730 - val_loss: 0.0126 - val_model_acc: 0.8410
Epoch 49/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0015 - model_acc:
0.9714 - val_loss: 0.0128 - val_model_acc: 0.8388
Epoch 50/50
996/996 [==============================] - 92s 93ms/step - loss: 0.0016 - model_acc:
0.9730 - val_loss: 0.0131 - val_model_acc: 0.8315
```

In [ ]: