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 22:49:53.218712: 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 22:49:58.583609: I tensorflow/compiler/jit/xla_cpu_device.cc:41] Not crea
ting XLA devices, tf_xla_enable_xla_devices not set
2022-01-24 22:49:58.584896: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcuda.so.1
2022-01-24 22:49:58.638351: 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 22:49:58.638990: 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 22:49:58.639022: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 22:49:58.644324: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 22:49:58.644406: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
2022-01-24 22:49:58.647219: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcufft.so.10
```

```
2022-01-24 22:49:58.648542: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcurand.so.10
2022-01-24 22:49:58.653574: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusolver.so.10
2022-01-24 22:49:58.655652: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusparse.so.11
2022-01-24 22:49:58.656761: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
2022-01-24 22:49:58.656935: 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 22:49:58.657741: 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 22:49:58.658416: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862]
Adding visible gpu devices: 0
2022-01-24 22:49:58.659199: 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 22:49:58.659557: I tensorflow/compiler/jit/xla_gpu_device.cc:99] Not crea
ting XLA devices, tf_xla_enable_xla_devices not set
2022-01-24 22:49:58.659859: 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 22:49:58.660582: 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 22:49:58.660620: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 22:49:58.660651: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 22:49:58.660669: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
2022-01-24 22:49:58.660688: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcufft.so.10
2022-01-24 22:49:58.660706: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcurand.so.10
2022-01-24 22:49:58.660724: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusolver.so.10
2022-01-24 22:49:58.660744: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcusparse.so.11
2022-01-24 22:49:58.660762: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
2022-01-24 22:49:58.660851: 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 22:49:58.661596: 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 22:49:58.662257: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862]
Adding visible gpu devices: 0
2022-01-24 22:49:58.662311: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2022-01-24 22:49:59.531247: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1261]
Device interconnect StreamExecutor with strength 1 edge matrix:
2022-01-24 22:49:59.531288: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1267]
0
2022-01-24 22:49:59.531296: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1280]
0:   N
```

```
2022-01-24 22:49:59.531589: 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 22:49:59.532125: 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 22:49:59.532565: 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 22:49:59.532982: 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]:

```python
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]:

```python
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]:

```python
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_3.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 22:50:01.728745: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.
cc:116] None of the MLIR optimization passes are enabled (registered 2)
2022-01-24 22:50:01.729308: I tensorflow/core/platform/profile_utils/cpu_utils.cc:11
2] CPU Frequency: 2199880000 Hz
2022-01-24 22:50:01.753759: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
Epoch 1/50
2022-01-24 22:50:04.120712: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2022-01-24 22:50:04.700911: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
996/996 [==============================] - 103s 100ms/step - loss: 0.0526 - model_ac
c: 0.5465 - val_loss: 0.0321 - val_model_acc: 0.6808
Epoch 2/50
996/996 [==============================] - 92s 92ms/step - loss: 0.0248 - model_acc:
0.7330 - val_loss: 0.0235 - val_model_acc: 0.7270
Epoch 3/50
996/996 [==============================] - 89s 90ms/step - loss: 0.0197 - model_acc:
0.7769 - val_loss: 0.0224 - val_model_acc: 0.7487
Epoch 4/50
996/996 [==============================] - 99s 99ms/step - loss: 0.0169 - model_acc:
0.8061 - val_loss: 0.0212 - val_model_acc: 0.7617
Epoch 5/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0145 - model_acc:
0.8311 - val_loss: 0.0212 - val_model_acc: 0.7713
Epoch 6/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0124 - model_acc:
0.8548 - val_loss: 0.0174 - val_model_acc: 0.8017
Epoch 7/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0107 - model_acc:
0.8707 - val_loss: 0.0171 - val_model_acc: 0.7980
Epoch 8/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0095 - model_acc:
0.8835 - val_loss: 0.0163 - val_model_acc: 0.8132
Epoch 9/50
996/996 [==============================] - 91s 91ms/step - loss: 0.0086 - model_acc:
0.8967 - val_loss: 0.0162 - val_model_acc: 0.8101
Epoch 10/50
```

```
996/996 [==============================] - 91s 91ms/step - loss: 0.0074 - model_acc:
0.9124 - val_loss: 0.0152 - val_model_acc: 0.8160
Epoch 11/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0069 - model_acc:
0.9170 - val_loss: 0.0149 - val_model_acc: 0.8225
Epoch 12/50
996/996 [==============================] - 94s 95ms/step - loss: 0.0063 - model_acc:
0.9253 - val_loss: 0.0148 - val_model_acc: 0.8191
Epoch 13/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0057 - model_acc:
0.9330 - val_loss: 0.0150 - val_model_acc: 0.8278
Epoch 14/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0052 - model_acc:
0.9356 - val_loss: 0.0139 - val_model_acc: 0.8304
Epoch 15/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0048 - model_acc:
0.9396 - val_loss: 0.0154 - val_model_acc: 0.8171
Epoch 16/50
996/996 [==============================] - 89s 90ms/step - loss: 0.0047 - model_acc:
0.9397 - val_loss: 0.0154 - val_model_acc: 0.8247
Epoch 17/50
996/996 [==============================] - 89s 90ms/step - loss: 0.0043 - model_acc:
0.9427 - val_loss: 0.0138 - val_model_acc: 0.8288
Epoch 18/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0041 - model_acc:
0.9482 - val_loss: 0.0157 - val_model_acc: 0.8146
Epoch 19/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0039 - model_acc:
0.9466 - val_loss: 0.0136 - val_model_acc: 0.8309
Epoch 20/50
996/996 [==============================] - 93s 94ms/step - loss: 0.0036 - model_acc:
0.9516 - val_loss: 0.0138 - val_model_acc: 0.8287
Epoch 21/50
996/996 [==============================] - 91s 91ms/step - loss: 0.0034 - model_acc:
0.9538 - val_loss: 0.0130 - val_model_acc: 0.8352
Epoch 22/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0032 - model_acc:
0.9547 - val_loss: 0.0143 - val_model_acc: 0.8220
Epoch 23/50
996/996 [==============================] - 93s 94ms/step - loss: 0.0031 - model_acc:
0.9571 - val_loss: 0.0127 - val_model_acc: 0.8405
Epoch 24/50
996/996 [==============================] - 97s 97ms/step - loss: 0.0029 - model_acc:
0.9575 - val_loss: 0.0135 - val_model_acc: 0.8319
Epoch 25/50
996/996 [==============================] - 86s 86ms/step - loss: 0.0028 - model_acc:
0.9573 - val_loss: 0.0137 - val_model_acc: 0.8273
Epoch 26/50
996/996 [==============================] - 86s 87ms/step - loss: 0.0026 - model_acc:
0.9586 - val_loss: 0.0136 - val_model_acc: 0.8321
Epoch 27/50
996/996 [==============================] - 92s 92ms/step - loss: 0.0025 - model_acc:
0.9621 - val_loss: 0.0127 - val_model_acc: 0.8430
Epoch 28/50
996/996 [==============================] - 98s 98ms/step - loss: 0.0024 - model_acc:
0.9619 - val_loss: 0.0133 - val_model_acc: 0.8343
Epoch 29/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0023 - model_acc:
0.9656 - val_loss: 0.0132 - val_model_acc: 0.8284
Epoch 30/50
996/996 [==============================] - 90s 91ms/step - loss: 0.0022 - model_acc:
0.9659 - val_loss: 0.0130 - val_model_acc: 0.8379
Epoch 31/50
996/996 [==============================] - 90s 91ms/step - loss: 0.0022 - model_acc:
```

```
0.9617 - val_loss: 0.0129 - val_model_acc: 0.8309
Epoch 32/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0020 - model_acc:
0.9669 - val_loss: 0.0128 - val_model_acc: 0.8431
Epoch 33/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0020 - model_acc:
0.9681 - val_loss: 0.0122 - val_model_acc: 0.8464
Epoch 34/50
996/996 [==============================] - 91s 92ms/step - loss: 0.0019 - model_acc:
0.9677 - val_loss: 0.0126 - val_model_acc: 0.8433
Epoch 35/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0018 - model_acc:
0.9690 - val_loss: 0.0126 - val_model_acc: 0.8388
Epoch 36/50
996/996 [==============================] - 96s 97ms/step - loss: 0.0018 - model_acc:
0.9694 - val_loss: 0.0127 - val_model_acc: 0.8397
Epoch 37/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0017 - model_acc:
0.9712 - val_loss: 0.0124 - val_model_acc: 0.8422
Epoch 38/50
996/996 [==============================] - 90s 90ms/step - loss: 0.0017 - model_acc:
0.9732 - val_loss: 0.0127 - val_model_acc: 0.8346
Epoch 39/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0016 - model_acc:
0.9729 - val_loss: 0.0126 - val_model_acc: 0.8422
Epoch 40/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0015 - model_acc:
0.9715 - val_loss: 0.0126 - val_model_acc: 0.8383
Epoch 41/50
996/996 [==============================] - 94s 94ms/step - loss: 0.0015 - model_acc:
0.9738 - val_loss: 0.0127 - val_model_acc: 0.8408
Epoch 42/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0016 - model_acc:
0.9712 - val_loss: 0.0125 - val_model_acc: 0.8349
Epoch 43/50
996/996 [==============================] - 94s 95ms/step - loss: 0.0015 - model_acc:
0.9724 - val_loss: 0.0125 - val_model_acc: 0.8408
Epoch 44/50
996/996 [==============================] - 97s 98ms/step - loss: 0.0014 - model_acc:
0.9750 - val_loss: 0.0129 - val_model_acc: 0.8360
Epoch 45/50
996/996 [==============================] - 95s 95ms/step - loss: 0.0014 - model_acc:
0.9735 - val_loss: 0.0125 - val_model_acc: 0.8436
Epoch 46/50
996/996 [==============================] - 95s 96ms/step - loss: 0.0015 - model_acc:
0.9718 - val_loss: 0.0128 - val_model_acc: 0.8377
Epoch 47/50
996/996 [==============================] - 88s 88ms/step - loss: 0.0013 - model_acc:
0.9737 - val_loss: 0.0125 - val_model_acc: 0.8447
Epoch 48/50
996/996 [==============================] - 98s 98ms/step - loss: 0.0013 - model_acc:
0.9741 - val_loss: 0.0124 - val_model_acc: 0.8430
Epoch 49/50
996/996 [==============================] - 98s 99ms/step - loss: 0.0012 - model_acc:
0.9777 - val_loss: 0.0126 - val_model_acc: 0.8371
Epoch 50/50
996/996 [==============================] - 96s 96ms/step - loss: 0.0012 - model_acc:
0.9772 - val_loss: 0.0125 - val_model_acc: 0.8411
```

In [ ]: