In [1]:
```
import numpy as np
import matplotlib.pyplot as plt


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

samples = 35393 # 2~35394
training_samples = 28317  # 2~28318 (Training)
validation_samples = 3541 # 28319~31859 (PublicTest)
test_samples = 3535       # 31860~35394 (PrivateTest)
```

In [2]:
```
import tensorflow as tf
from tensorflow.python.keras.layers import Dense, GlobalAveragePooling2D, MaxPool2D,
from tensorflow.python.keras.models import Model
from tensorflow.python.keras import layers, Sequential,losses, metrics
from tensorflow.python.keras import optimizers, callbacks, models
from tensorflow.python.keras.optimizer_v2 import adam
```

```
2021-12-24 23:28:39.229442: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
```

In [3]:
```
image_path = "./dataset/images.npy"
emotion_multi_path = "./dataset/emotions_multi.npy"
emotion_single_path = "./dataset/emotions_single.npy"

images = np.load(image_path)
emotions_multi = np.load(emotion_multi_path)
emotions_single = np.load(emotion_single_path)

print(images.shape)
print(emotions_multi.shape)
print(emotions_single.shape)
```

```
(35393, 48, 48, 1)
(35393, 8)
(35393, 8)
```

In [4]:
```
#emotions = emotions_single
emotions = emotions_multi

images = tf.convert_to_tensor(images)
#images = tf.image.grayscale_to_rgb(images)
emotions = tf.convert_to_tensor(emotions)
print("images shape:", images.shape)
print("emotions shape:", emotions.shape)
```

```
images shape: (35393, 48, 48, 1)
emotions shape: (35393, 8)
2021-12-24 23:28:43.071714: I tensorflow/compiler/jit/xla_cpu_device.cc:41] Not crea
ting XLA devices, tf_xla_enable_xla_devices not set
2021-12-24 23:28:43.073410: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcuda.so.1
2021-12-24 23:28:43.762750: 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
2021-12-24 23:28:43.763407: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1720]
```

```
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
2021-12-24 23:28:43.787772: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862]
Adding visible gpu devices: 0
2021-12-24 23:28:43.787832: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudart.so.11.0
2021-12-24 23:28:44.610447: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1261]
Device interconnect StreamExecutor with strength 1 edge matrix:
2021-12-24 23:28:44.610493: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1267]
0
2021-12-24 23:28:44.610502: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1280]
0:   N
2021-12-24 23:28:44.610858: 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
2021-12-24 23:28:44.611440: 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
2021-12-24 23:28:44.611972: 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
2021-12-24 23:28:44.612450: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1406]
Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:0 with 10072 M
B memory) -> physical GPU (device: 0, name: GeForce RTX 2080 Ti, pci bus id: 0000:0
5:00.0, compute capability: 7.5)
```

In [5]:

```
from tensorflow.python.keras import layers
# choose one method:
images = layers.Rescaling(1./127.5, offset= -1)(images)
```

In [6]:

```
training_size = training_samples + validation_samples
test_size = test_samples

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

print("training_images shape:", training_images.shape)
print("training_emotions shape:", training_emotions.shape)
print("test_images shape:", test_images.shape)
print("test_emotions shape:", test_emotions.shape)
```

```
training_images shape: (31858, 48, 48, 1)
training_emotions shape: (31858, 8)
test_images shape: (3535, 48, 48, 1)
test_emotions shape: (3535, 8)
```

In [7]:

```
from tensorflow.python.keras import losses, metrics
from tensorflow.python.keras.optimizer_v2 import adam

cce = losses.CategoricalCrossentropy()
mse = losses.MeanSquaredError()

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 [8]:

```
from tensorflow.python.keras.applications import vgg16, resnet_v2, densenet, efficie
from tensorflow.python.keras.layers import Dense, GlobalAveragePooling2D, MaxPool2D,
from tensorflow.python.keras.models import Model
from tensorflow.python.keras import layers, Sequential

# VGG16 combined features
input_layer = Input(shape=(48,48,3))
print(input_layer.shape)
feat1 = GlobalAveragePooling2D()(input_layer)
print("feature1", feat1.shape)
x = Conv2D (filters=64, kernel_size=3, padding='same', activation='relu')(input_laye
x = Conv2D (filters=64, kernel_size=3, padding='same', activation='relu')(x)
x = MaxPool2D(pool_size=2, strides=2, padding='same')(x)
print(x.shape)
feat2 = GlobalAveragePooling2D()(x)
print("feature2", feat2.shape)
x = Conv2D (filters=128, kernel_size=3, padding='same', activation='relu')(x)
x = Conv2D (filters=128, kernel_size=3, padding='same', activation='relu')(x)
x = MaxPool2D(pool_size=2, strides=2, padding='same')(x)
print(x.shape)
feat3 = GlobalAveragePooling2D()(x)
print("feature3", feat3.shape)
x = Conv2D (filters=256, kernel_size=3, padding='same', activation='relu')(x)
x = Conv2D (filters=256, kernel_size=3, padding='same', activation='relu')(x)
x = Conv2D (filters=256, kernel_size=3, padding='same', activation='relu')(x)
x = MaxPool2D(pool_size=2, strides=2, padding='same')(x)
print(x.shape)
feat4 = GlobalAveragePooling2D()(x)
print("feature4", feat4.shape)
x = Conv2D (filters=512, kernel_size=3, padding='same', activation='relu')(x)
x = Conv2D (filters=512, kernel_size=3, padding='same', activation='relu')(x)
x = Conv2D (filters=512, kernel_size=3, padding='same', activation='relu')(x)
x = MaxPool2D(pool_size=2, strides=2, padding='same')(x)
print(x.shape)
feat5 = GlobalAveragePooling2D()(x)
print("feature5", feat5.shape)
x = Conv2D (filters=512, kernel_size=3, padding='same', activation='relu')(x)
x = Conv2D (filters=512, kernel_size=3, padding='same', activation='relu')(x)
x = Conv2D (filters=512, kernel_size=3, padding='same', activation='relu')(x)
x = MaxPool2D(pool_size=2, strides=2, padding='same')(x)
print(x.shape)
x = GlobalAveragePooling2D()(x)
print(x.shape)
feat6 = x
print("feature6", feat6.shape)

x = tf.concat([feat1, feat2, feat3, feat4, feat5, feat6], -1)
print("combined feature", x.shape)
x = Dense(units=4096, activation='relu')(x)
x = Dropout(0.5)(x)
x = Dense(units=4096, activation='relu')(x)
x = Dropout(0.5)(x)
output_layer = Dense(units=8, activation='softmax')(x)
model = Model(inputs=input_layer, outputs=output_layer)


model.compile(optimizer=adam.Adam(learning_rate=2e-4),
              loss=mse,
```

```
              metrics = [model_acc])

model.fit(x=tf.image.grayscale_to_rgb(training_images),
          y=training_emotions,
          batch_size=32,
          epochs=30,
          validation_data=(tf.image.grayscale_to_rgb(test_images), test_emotions))
```

```
(None, 48, 48, 3)
feature1 (None, 3)
(None, 24, 24, 64)
feature2 (None, 64)
(None, 12, 12, 128)
feature3 (None, 128)
(None, 6, 6, 256)
feature4 (None, 256)
(None, 3, 3, 512)
feature5 (None, 512)
(None, 2, 2, 512)
(None, 512)
feature6 (None, 512)
combined feature (None, 1475)
/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(
2021-12-24 23:28:46.191553: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.
cc:116] None of the MLIR optimization passes are enabled (registered 2)
2021-12-24 23:28:46.192149: I tensorflow/core/platform/profile_utils/cpu_utils.cc:11
2] CPU Frequency: 2199980000 Hz
2021-12-24 23:28:46.219851: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcudnn.so.8
Epoch 1/30
2021-12-24 23:28:48.664371: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublas.so.11
2021-12-24 23:28:49.291694: I tensorflow/stream_executor/platform/default/dso_loade
r.cc:49] Successfully opened dynamic library libcublasLt.so.11
996/996 [==============================] - 94s 90ms/step - loss: 0.0591 - model_acc:
0.3595 - val_loss: 0.0466 - val_model_acc: 0.5332
Epoch 2/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0391 - model_acc:
0.5941 - val_loss: 0.0291 - val_model_acc: 0.6873
Epoch 3/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0262 - model_acc:
0.7104 - val_loss: 0.0243 - val_model_acc: 0.7238
Epoch 4/30
996/996 [==============================] - 88s 89ms/step - loss: 0.0207 - model_acc:
0.7617 - val_loss: 0.0220 - val_model_acc: 0.7431
Epoch 5/30
996/996 [==============================] - 88s 89ms/step - loss: 0.0173 - model_acc:
0.7952 - val_loss: 0.0186 - val_model_acc: 0.7812
Epoch 6/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0144 - model_acc:
0.8262 - val_loss: 0.0183 - val_model_acc: 0.7898
Epoch 7/30
996/996 [==============================] - 89s 89ms/step - loss: 0.0120 - model_acc:
0.8501 - val_loss: 0.0180 - val_model_acc: 0.7799
Epoch 8/30
996/996 [==============================] - 90s 90ms/step - loss: 0.0100 - model_acc:
0.8766 - val_loss: 0.0162 - val_model_acc: 0.8060
Epoch 9/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0087 - model_acc:
```

```
0.8891 - val_loss: 0.0160 - val_model_acc: 0.8064
Epoch 10/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0077 - model_acc:
0.8986 - val_loss: 0.0160 - val_model_acc: 0.8038
Epoch 11/30
996/996 [==============================] - 85s 86ms/step - loss: 0.0068 - model_acc:
0.9134 - val_loss: 0.0152 - val_model_acc: 0.8115
Epoch 12/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0060 - model_acc:
0.9236 - val_loss: 0.0152 - val_model_acc: 0.8111
Epoch 13/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0054 - model_acc:
0.9343 - val_loss: 0.0151 - val_model_acc: 0.8066
Epoch 14/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0050 - model_acc:
0.9361 - val_loss: 0.0145 - val_model_acc: 0.8132
Epoch 15/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0046 - model_acc:
0.9411 - val_loss: 0.0147 - val_model_acc: 0.8163
Epoch 16/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0042 - model_acc:
0.9456 - val_loss: 0.0146 - val_model_acc: 0.8208
Epoch 17/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0040 - model_acc:
0.9449 - val_loss: 0.0148 - val_model_acc: 0.8208
Epoch 18/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0038 - model_acc:
0.9522 - val_loss: 0.0147 - val_model_acc: 0.8121
Epoch 19/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0036 - model_acc:
0.9531 - val_loss: 0.0140 - val_model_acc: 0.8281
Epoch 20/30
996/996 [==============================] - 88s 89ms/step - loss: 0.0034 - model_acc:
0.9550 - val_loss: 0.0139 - val_model_acc: 0.8290
Epoch 21/30
996/996 [==============================] - 81s 82ms/step - loss: 0.0031 - model_acc:
0.9600 - val_loss: 0.0143 - val_model_acc: 0.8278
Epoch 22/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0032 - model_acc:
0.9592 - val_loss: 0.0140 - val_model_acc: 0.8253
Epoch 23/30
996/996 [==============================] - 84s 84ms/step - loss: 0.0029 - model_acc:
0.9643 - val_loss: 0.0143 - val_model_acc: 0.8233
Epoch 24/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0027 - model_acc:
0.9639 - val_loss: 0.0145 - val_model_acc: 0.8177
Epoch 25/30
996/996 [==============================] - 84s 85ms/step - loss: 0.0028 - model_acc:
0.9621 - val_loss: 0.0137 - val_model_acc: 0.8284
Epoch 26/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0025 - model_acc:
0.9674 - val_loss: 0.0139 - val_model_acc: 0.8241
Epoch 27/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0024 - model_acc:
0.9662 - val_loss: 0.0139 - val_model_acc: 0.8253
Epoch 28/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0023 - model_acc:
0.9727 - val_loss: 0.0142 - val_model_acc: 0.8166
Epoch 29/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0023 - model_acc:
0.9648 - val_loss: 0.0137 - val_model_acc: 0.8259
Epoch 30/30
996/996 [==============================] - 83s 84ms/step - loss: 0.0023 - model_acc:
0.9706 - val_loss: 0.0137 - val_model_acc: 0.8230
```

Out[8]: <tensorflow.python.keras.callbacks.History at 0x14d315237af0>

In [9]:
```
model.compile(optimizer=adam.Adam(learning_rate=1e-4),
              loss=mse,
              metrics = [model_acc])

model.fit(x=tf.image.grayscale_to_rgb(training_images),
          y=training_emotions,
          batch_size=32,
          epochs=30,
          validation_data=(tf.image.grayscale_to_rgb(test_images), test_emotions))
```

```
Epoch 1/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0018 - model_acc:
0.9748 - val_loss: 0.0132 - val_model_acc: 0.8290
Epoch 2/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0014 - model_acc:
0.9856 - val_loss: 0.0133 - val_model_acc: 0.8275
Epoch 3/30
996/996 [==============================] - 82s 82ms/step - loss: 0.0013 - model_acc:
0.9883 - val_loss: 0.0131 - val_model_acc: 0.8352
Epoch 4/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0013 - model_acc:
0.9880 - val_loss: 0.0131 - val_model_acc: 0.8303
Epoch 5/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0012 - model_acc:
0.9875 - val_loss: 0.0133 - val_model_acc: 0.8270
Epoch 6/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0011 - model_acc:
0.9880 - val_loss: 0.0131 - val_model_acc: 0.8301
Epoch 7/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0011 - model_acc:
0.9859 - val_loss: 0.0131 - val_model_acc: 0.8349
Epoch 8/30
996/996 [==============================] - 88s 89ms/step - loss: 0.0010 - model_acc:
0.9895 - val_loss: 0.0132 - val_model_acc: 0.8304
Epoch 9/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0010 - model_acc:
0.9893 - val_loss: 0.0132 - val_model_acc: 0.8326
Epoch 10/30
996/996 [==============================] - 89s 90ms/step - loss: 9.8413e-04 - model_
acc: 0.9887 - val_loss: 0.0134 - val_model_acc: 0.8283
Epoch 11/30
996/996 [==============================] - 87s 87ms/step - loss: 9.6609e-04 - model_
acc: 0.9894 - val_loss: 0.0132 - val_model_acc: 0.8377
Epoch 12/30
996/996 [==============================] - 83s 83ms/step - loss: 9.3164e-04 - model_
acc: 0.9888 - val_loss: 0.0132 - val_model_acc: 0.8332
Epoch 13/30
996/996 [==============================] - 85s 86ms/step - loss: 9.0622e-04 - model_
acc: 0.9900 - val_loss: 0.0133 - val_model_acc: 0.8342
Epoch 14/30
996/996 [==============================] - 88s 88ms/step - loss: 8.8753e-04 - model_
acc: 0.9910 - val_loss: 0.0132 - val_model_acc: 0.8318
Epoch 15/30
996/996 [==============================] - 88s 89ms/step - loss: 8.6046e-04 - model_
acc: 0.9914 - val_loss: 0.0133 - val_model_acc: 0.8306
Epoch 16/30
996/996 [==============================] - 86s 86ms/step - loss: 8.2407e-04 - model_
acc: 0.9900 - val_loss: 0.0133 - val_model_acc: 0.8307
Epoch 17/30
996/996 [==============================] - 82s 82ms/step - loss: 8.3417e-04 - model_
acc: 0.9898 - val_loss: 0.0133 - val_model_acc: 0.8315
```

```
Epoch 18/30
996/996 [==============================] - 83s 83ms/step - loss: 8.0320e-04 - model_
acc: 0.9906 - val_loss: 0.0133 - val_model_acc: 0.8292
Epoch 19/30
996/996 [==============================] - 84s 84ms/step - loss: 7.7432e-04 - model_
acc: 0.9909 - val_loss: 0.0132 - val_model_acc: 0.8287
Epoch 20/30
996/996 [==============================] - 85s 85ms/step - loss: 7.5446e-04 - model_
acc: 0.9913 - val_loss: 0.0133 - val_model_acc: 0.8309
Epoch 21/30
996/996 [==============================] - 86s 87ms/step - loss: 7.3326e-04 - model_
acc: 0.9920 - val_loss: 0.0133 - val_model_acc: 0.8334
Epoch 22/30
996/996 [==============================] - 84s 85ms/step - loss: 7.2232e-04 - model_
acc: 0.9911 - val_loss: 0.0133 - val_model_acc: 0.8284
Epoch 23/30
996/996 [==============================] - 89s 89ms/step - loss: 7.1092e-04 - model_
acc: 0.9916 - val_loss: 0.0133 - val_model_acc: 0.8286
Epoch 24/30
996/996 [==============================] - 85s 85ms/step - loss: 6.9428e-04 - model_
acc: 0.9912 - val_loss: 0.0134 - val_model_acc: 0.8323
Epoch 25/30
996/996 [==============================] - 85s 86ms/step - loss: 6.6646e-04 - model_
acc: 0.9931 - val_loss: 0.0132 - val_model_acc: 0.8283
Epoch 26/30
996/996 [==============================] - 86s 87ms/step - loss: 6.5811e-04 - model_
acc: 0.9922 - val_loss: 0.0133 - val_model_acc: 0.8301
Epoch 27/30
996/996 [==============================] - 88s 89ms/step - loss: 6.4732e-04 - model_
acc: 0.9919 - val_loss: 0.0135 - val_model_acc: 0.8273
Epoch 28/30
996/996 [==============================] - 88s 88ms/step - loss: 6.4550e-04 - model_
acc: 0.9924 - val_loss: 0.0132 - val_model_acc: 0.8354
Epoch 29/30
996/996 [==============================] - 87s 88ms/step - loss: 6.3284e-04 - model_
acc: 0.9918 - val_loss: 0.0134 - val_model_acc: 0.8310
Epoch 30/30
996/996 [==============================] - 85s 85ms/step - loss: 6.1210e-04 - model_
acc: 0.9929 - val_loss: 0.0133 - val_model_acc: 0.8352
```

Out[9]: <tensorflow.python.keras.callbacks.History at 0x14d314b20ee0>

In [ ]: