

In [1]: *# data augmentation test: rotate different degree (pay attention to adjustable filename etc.)*

```
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow.python.keras.layers import Dense, GlobalAveragePooling2D
from tensorflow.python.keras.models import Model
from tensorflow.python.keras import layers, Sequential, losses, metrics

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

# !!! change sample size
samples = 99109 # 2~99110
training_samples = 28317*3 # (Training)
validation_samples = 3541*3 # (PublicTest)
test_samples = 3535 # (PrivateTest)

# !!! change npy folder name
image_path = "./dataset_r30/images.npy"
emotion_multi_path = "./dataset_r30/emotions_multi.npy"
emotion_single_path = "./dataset_r30/emotions_single.npy"
images = np.load(image_path)
emotions_multi = np.load(emotion_multi_path)
emotions_single = np.load(emotion_single_path)

# !!! change s/m dataset
#emotions = emotions_single
emotions = emotions_multi

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

2021-11-17 23:02:53.026029: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcudart.so.11.0

(99109, 48, 48, 1)

(99109, 8)

(99109, 8)

In [2]: 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 [3]:

```

images = tf.convert_to_tensor(images)
#images = tf.image.grayscale_to_rgb(images)
emotions = tf.convert_to_tensor(emotions)
#images = tf.image.resize(images, [224,224])
images = layers.Rescaling(1./127.5, offset= -1)(images)

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)

```

```

2021-11-17 23:02:58.664073: I tensorflow/compiler/jit/xla_cpu_device.cc:41] Not creating XLA devices, tf_xla_enable_xla_d
evices not set
2021-11-17 23:02:58.667490: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcuda.so.1
2021-11-17 23:02:58.725208: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from Sy
sFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-11-17 23:02:58.726009: 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
2021-11-17 23:02:58.726134: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from Sy
sFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero

```

```
2021-11-17 23:02:58.726839: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1720] Found device 1 with properties:
pciBusID: 0000:06:00.0 name: GeForce RTX 2080 Ti computeCapability: 7.5
coreClock: 1.545GHz coreCount: 68 deviceMemorySize: 10.76GiB deviceMemoryBandwidth: 573.69GiB/s
2021-11-17 23:02:58.726891: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcudart.so.11.0
2021-11-17 23:02:58.827940: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcublas.so.11
2021-11-17 23:02:58.828099: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcublasLt.so.11
2021-11-17 23:02:58.882143: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcufft.so.10
2021-11-17 23:02:58.960905: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcurand.so.10
2021-11-17 23:02:59.051870: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcusolver.so.10
2021-11-17 23:02:59.107698: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcusparse.so.11
2021-11-17 23:02:59.112673: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcudnn.so.8
2021-11-17 23:02:59.112914: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from Sy
sFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-11-17 23:02:59.113750: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from Sy
sFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-11-17 23:02:59.114481: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from Sy
sFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-11-17 23:02:59.115329: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from Sy
sFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-11-17 23:02:59.116022: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862] Adding visible gpu devices: 0, 1
2021-11-17 23:02:59.118335: I tensorflow/core/platform/cpu_feature_guard.cc:142] This TensorFlow binary is optimized with
oneAPI Deep Neural Network Library (oneDNN) to use the following CPU instructions in performance-critical operations: AV
X2 AVX512F FMA
To enable them in other operations, rebuild TensorFlow with the appropriate compiler flags.
2021-11-17 23:02:59.119538: I tensorflow/compiler/jit/xla_gpu_device.cc:99] Not creating XLA devices, tf_xla_enable_xla_d
evices not set
2021-11-17 23:02:59.461115: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from Sy
sFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-11-17 23:02:59.461853: 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
2021-11-17 23:02:59.461960: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from Sy
sFS had negative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-11-17 23:02:59.462624: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1720] Found device 1 with properties:
pciBusID: 0000:06:00.0 name: GeForce RTX 2080 Ti computeCapability: 7.5
coreClock: 1.545GHz coreCount: 68 deviceMemorySize: 10.76GiB deviceMemoryBandwidth: 573.69GiB/s
2021-11-17 23:02:59.462684: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcudart.so.11.0
```

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2021-11-17 23:02:59.462721: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcublas.so.11
2021-11-17 23:02:59.462739: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcublasLt.so.11
2021-11-17 23:02:59.462756: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcufft.so.10
2021-11-17 23:02:59.462772: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcurand.so.10
2021-11-17 23:02:59.462788: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcusolver.so.10
2021-11-17 23:02:59.462803: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcusparse.so.11
2021-11-17 23:02:59.462820: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcudnn.so.8
2021-11-17 23:02:59.462889: 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
2021-11-17 23:02:59.463597: 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
2021-11-17 23:02:59.464268: 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
2021-11-17 23:02:59.464932: 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
2021-11-17 23:02:59.465555: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862] Adding visible gpu devices: 0, 1
2021-11-17 23:02:59.465676: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcudart.so.11.0
2021-11-17 23:03:01.260443: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1261] Device interconnect StreamExecutor with strength 1 edge matrix:
2021-11-17 23:03:01.260495: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1267]      0 1
2021-11-17 23:03:01.260504: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1280] 0:   N N
2021-11-17 23:03:01.260509: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1280] 1:   N N
2021-11-17 23:03:01.260869: 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
2021-11-17 23:03:01.261491: 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
2021-11-17 23:03:01.262055: 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
2021-11-17 23:03:01.262706: 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
2021-11-17 23:03:01.263337: 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)
2021-11-17 23:03:01.264323: 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
2021-11-17 23:03:01.264913: 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
2021-11-17 23:03:01.265453: 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)
```

```
lhost/replica:0/task:0/device:GPU:1 with 10071 MB memory) -> physical GPU (device: 1, name: GeForce RTX 2080 Ti, pci bus
id: 0000:06:00.0, compute capability: 7.5)
training_images shape: (95574, 48, 48, 1)
training_emotions shape: (95574, 8)
test_images shape: (3535, 48, 48, 1)
test_emotions shape: (3535, 8)
```

```
In [4]: from tensorflow.python.keras.applications import vgg16, resnet_v2
        from tensorflow.python.keras import optimizers
        from tensorflow.python.keras.optimizer_v2 import adam
```

```
In [5]: base_model = vgg16.VGG16(include_top=False,
                                weights="imagenet",
                                input_shape=(48,48,3))
        base_model.trainable=True
        model = Sequential([
            base_model,
            layers.GlobalAveragePooling2D(),
            layers.Dense(4096, activation='relu'),
            layers.Dense(4096, activation='relu'),
            layers.Dense(emotions_count, activation='softmax'),
        ])
        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=40,
                  validation_data=(tf.image.grayscale_to_rgb(test_images), test_emotions))
```

```
/userhome/cs/fym666/anaconda3/envs/tensorflow/lib/python3.8/site-packages/tensorflow/python/data/ops/dataset_ops.py:3503:
UserWarning: Even though the tf.config.experimental_run_functions_eagerly option is set, this option does not apply to t
f.data functions. tf.data functions are still traced and executed as graphs.
```

```
warnings.warn(
2021-11-17 23:03:06.042633: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:116] None of the MLIR optimization
passes are enabled (registered 2)
2021-11-17 23:03:06.043591: I tensorflow/core/platform/profile_utils/cpu_utils.cc:112] CPU Frequency: 2199920000 Hz
2021-11-17 23:03:06.081298: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic l
ibrary libcudnn.so.8
Epoch 1/40
```

```
2021-11-17 23:03:10.817360: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcublas.so.11
2021-11-17 23:03:11.856792: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcublasLt.so.11
2987/2987 [=====] - 265s 87ms/step - loss: 0.0363 - model_acc: 0.6148 - val_loss: 0.0204 - val_model_acc: 0.7675
Epoch 2/40
2987/2987 [=====] - 259s 87ms/step - loss: 0.0180 - model_acc: 0.7852 - val_loss: 0.0167 - val_model_acc: 0.7968
Epoch 3/40
2987/2987 [=====] - 256s 86ms/step - loss: 0.0136 - model_acc: 0.8300 - val_loss: 0.0148 - val_model_acc: 0.8106
Epoch 4/40
2987/2987 [=====] - 257s 86ms/step - loss: 0.0111 - model_acc: 0.8592 - val_loss: 0.0134 - val_model_acc: 0.8337
Epoch 5/40
2987/2987 [=====] - 258s 86ms/step - loss: 0.0087 - model_acc: 0.8883 - val_loss: 0.0134 - val_model_acc: 0.8239
Epoch 6/40
2987/2987 [=====] - 257s 86ms/step - loss: 0.0074 - model_acc: 0.9062 - val_loss: 0.0132 - val_model_acc: 0.8312
Epoch 7/40
2987/2987 [=====] - 256s 86ms/step - loss: 0.0062 - model_acc: 0.9209 - val_loss: 0.0133 - val_model_acc: 0.8357
Epoch 8/40
2987/2987 [=====] - 257s 86ms/step - loss: 0.0056 - model_acc: 0.9283 - val_loss: 0.0130 - val_model_acc: 0.8354
Epoch 9/40
2987/2987 [=====] - 256s 86ms/step - loss: 0.0047 - model_acc: 0.9394 - val_loss: 0.0128 - val_model_acc: 0.8326
Epoch 10/40
2987/2987 [=====] - 257s 86ms/step - loss: 0.0042 - model_acc: 0.9456 - val_loss: 0.0125 - val_model_acc: 0.8408
Epoch 11/40
2987/2987 [=====] - 255s 85ms/step - loss: 0.0037 - model_acc: 0.9533 - val_loss: 0.0127 - val_model_acc: 0.8346
Epoch 12/40
2987/2987 [=====] - 256s 86ms/step - loss: 0.0036 - model_acc: 0.9523 - val_loss: 0.0129 - val_model_acc: 0.8343
Epoch 13/40
2987/2987 [=====] - 256s 86ms/step - loss: 0.0033 - model_acc: 0.9559 - val_loss: 0.0127 - val_model_acc: 0.8371
Epoch 14/40
2987/2987 [=====] - 254s 85ms/step - loss: 0.0030 - model_acc: 0.9599 - val_loss: 0.0121 - val_model_acc: 0.8456
Epoch 15/40
```

```
2987/2987 [=====] - 255s 85ms/step - loss: 0.0025 - model_acc: 0.9665 - val_loss: 0.0125 - val_m
odel_acc: 0.8427
Epoch 16/40
2987/2987 [=====] - 249s 83ms/step - loss: 0.0026 - model_acc: 0.9656 - val_loss: 0.0120 - val_m
odel_acc: 0.8405
Epoch 17/40
2987/2987 [=====] - 256s 86ms/step - loss: 0.0023 - model_acc: 0.9687 - val_loss: 0.0124 - val_m
odel_acc: 0.8385
Epoch 18/40
2987/2987 [=====] - 256s 86ms/step - loss: 0.0021 - model_acc: 0.9714 - val_loss: 0.0121 - val_m
odel_acc: 0.8478
Epoch 19/40
2987/2987 [=====] - 255s 85ms/step - loss: 0.0019 - model_acc: 0.9753 - val_loss: 0.0121 - val_m
odel_acc: 0.8453
Epoch 20/40
2987/2987 [=====] - 255s 86ms/step - loss: 0.0018 - model_acc: 0.9752 - val_loss: 0.0127 - val_m
odel_acc: 0.8402
Epoch 21/40
2987/2987 [=====] - 254s 85ms/step - loss: 0.0019 - model_acc: 0.9734 - val_loss: 0.0120 - val_m
odel_acc: 0.8453
Epoch 22/40
2987/2987 [=====] - 254s 85ms/step - loss: 0.0015 - model_acc: 0.9816 - val_loss: 0.0121 - val_m
odel_acc: 0.8473
Epoch 23/40
2987/2987 [=====] - 254s 85ms/step - loss: 0.0019 - model_acc: 0.9722 - val_loss: 0.0120 - val_m
odel_acc: 0.8461
Epoch 24/40
2987/2987 [=====] - 250s 84ms/step - loss: 0.0015 - model_acc: 0.9809 - val_loss: 0.0121 - val_m
odel_acc: 0.8407
Epoch 25/40
2987/2987 [=====] - 252s 84ms/step - loss: 0.0015 - model_acc: 0.9796 - val_loss: 0.0126 - val_m
odel_acc: 0.8388
Epoch 26/40
2987/2987 [=====] - 254s 85ms/step - loss: 0.0013 - model_acc: 0.9811 - val_loss: 0.0123 - val_m
odel_acc: 0.8442
Epoch 27/40
2987/2987 [=====] - 253s 85ms/step - loss: 0.0013 - model_acc: 0.9807 - val_loss: 0.0121 - val_m
odel_acc: 0.8464
Epoch 28/40
2987/2987 [=====] - 254s 85ms/step - loss: 0.0011 - model_acc: 0.9850 - val_loss: 0.0119 - val_m
odel_acc: 0.8498
Epoch 29/40
2987/2987 [=====] - 248s 83ms/step - loss: 0.0011 - model_acc: 0.9841 - val_loss: 0.0119 - val_m
odel_acc: 0.8464
Epoch 30/40
2987/2987 [=====] - 254s 85ms/step - loss: 0.0014 - model_acc: 0.9801 - val_loss: 0.0124 - val_m
```

```

odel_acc: 0.8417
Epoch 31/40
2987/2987 [=====] - 254s 85ms/step - loss: 9.0761e-04 - model_acc: 0.9881 - val_loss: 0.0121 - v
al_model_acc: 0.8455
Epoch 32/40
2987/2987 [=====] - 253s 85ms/step - loss: 8.1179e-04 - model_acc: 0.9902 - val_loss: 0.0122 - v
al_model_acc: 0.8473
Epoch 33/40
2987/2987 [=====] - 250s 84ms/step - loss: 0.0010 - model_acc: 0.9855 - val_loss: 0.0122 - val_m
odel_acc: 0.8475
Epoch 34/40
2987/2987 [=====] - 255s 85ms/step - loss: 8.5676e-04 - model_acc: 0.9879 - val_loss: 0.0123 - v
al_model_acc: 0.8444
Epoch 35/40
2987/2987 [=====] - 253s 85ms/step - loss: 8.7212e-04 - model_acc: 0.9873 - val_loss: 0.0127 - v
al_model_acc: 0.8366
Epoch 36/40
2987/2987 [=====] - 255s 85ms/step - loss: 0.0012 - model_acc: 0.9824 - val_loss: 0.0127 - val_m
odel_acc: 0.8436
Epoch 37/40
2987/2987 [=====] - 253s 85ms/step - loss: 8.7267e-04 - model_acc: 0.9896 - val_loss: 0.0123 - v
al_model_acc: 0.8425
Epoch 38/40
2987/2987 [=====] - 254s 85ms/step - loss: 6.3090e-04 - model_acc: 0.9931 - val_loss: 0.0121 - v
al_model_acc: 0.8515
Epoch 39/40
2987/2987 [=====] - 253s 85ms/step - loss: 6.4730e-04 - model_acc: 0.9920 - val_loss: 0.0126 - v
al_model_acc: 0.8405
Epoch 40/40
2987/2987 [=====] - 253s 85ms/step - loss: 6.8897e-04 - model_acc: 0.9909 - val_loss: 0.0124 - v
al_model_acc: 0.8414

```

Out[5]: <tensorflow.python.keras.callbacks.History at 0x14aaac6ba1f0>

In []: