In [1]:
```
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']

samples = 35393 # 2~35394
training_samples = 28317  # 2~28318 (Training)
validation_samples = 3541 # 28319~31859 (PublicTest)
test_samples = 3535       # 31860~35394 (PrivateTest)
expw_samples = 91793

image_path = "./dataset/images.npy"
emotion_path = "./dataset/emotions_multi.npy"
image_path_expw = "./AffectNet/images.npy"
emotion_path_expw = "./AffectNet/emotions.npy"
```

In [2]:
```
images = np.load(image_path)
emotions = np.load(emotion_path)
images_expw = np.load(image_path_expw)
emotions_expw = np.load(emotion_path_expw)
print(images.shape)
print(emotions.shape)
print(images_expw.shape)
print(emotions_expw.shape)
```

```
(35393, 48, 48, 1)
(35393, 8)
(291648, 48, 48, 3)
(291648, 8)
```

In [3]:
```
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 [4]:

```
images_expw = tf.convert_to_tensor(images_expw)
images = tf.image.grayscale_to_rgb(tf.convert_to_tensor(images))
images = tf.cast(images, tf.uint8)
```

In [5]:

```
print(images.shape)
print(emotions.shape)
print(images_expw.shape)
print(emotions_expw.shape)
```

```
(35393, 48, 48, 3)
(35393, 8)
(291648, 48, 48, 3)
(291648, 8)
```

In [6]:

```
from tensorflow.python.keras.applications import vgg16, resnet_v2
from tensorflow.python.keras import optimizers
from tensorflow.python.keras.optimizer_v2 import adam
import matplotlib.pyplot as plt

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

In [7]:

```
training_size = training_samples + validation_samples
print(images[:training_size].shape)
print(emotions[:training_size].shape)
print(images[training_size:].shape)
print(emotions[training_size:].shape)
```

```
(31858, 48, 48, 3)
```

```
(31858, 8)
(3535, 48, 48, 3)
(3535, 8)
```

In [8]:

```
base_model = vgg16.VGG16(include_top=False,
                         weights=None,
                         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-5),
              loss=mse,
              metrics = [model_acc])
model.fit(x=images_expw,
          y=emotions_expw,
          batch_size=32,
          epochs=40)
```

```
C:\Users\Darkl\anaconda3\lib\site-packages\tensorflow\python\data\ops\dataset_ops.py:3703: UserWarning: Even though the `tf.config.experimental_run_functions_eagerly` option is set, this option does not apply to tf.data functions. To force eager execution of tf.data functions, please use `tf.data.experimental.enable.debug_mode()`.
  warnings.warn(
Epoch 1/40
9114/9114 [==============================] - 626s 68ms/step - loss: 0.0627 - model_acc: 0.6271
Epoch 2/40
9114/9114 [==============================] - 867s 95ms/step - loss: 0.0549 - model_acc: 0.6788
Epoch 3/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0512 - model_acc: 0.7039
Epoch 4/40
9114/9114 [==============================] - 612s 67ms/step - loss: 0.0486 - model_acc: 0.7214
Epoch 5/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0463 - model_acc: 0.7373
Epoch 6/40
9114/9114 [==============================] - 608s 67ms/step - loss: 0.0439 - model_acc: 0.7536
Epoch 7/40
9114/9114 [==============================] - 608s 67ms/step - loss: 0.0415 - model_acc: 0.7703
Epoch 8/40
```

```
9114/9114 [==============================] - 608s 67ms/step - loss: 0.0388 - model_acc: 0.7869
Epoch 9/40
9114/9114 [==============================] - 608s 67ms/step - loss: 0.0361 - model_acc: 0.8046
Epoch 10/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0335 - model_acc: 0.8206
Epoch 11/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0310 - model_acc: 0.8354
Epoch 12/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0286 - model_acc: 0.8493
Epoch 13/40
9114/9114 [==============================] - 608s 67ms/step - loss: 0.0266 - model_acc: 0.8606
Epoch 14/40
9114/9114 [==============================] - 607s 67ms/step - loss: 0.0248 - model_acc: 0.8710
Epoch 15/40
9114/9114 [==============================] - 608s 67ms/step - loss: 0.0233 - model_acc: 0.8798
Epoch 16/40
9114/9114 [==============================] - 607s 67ms/step - loss: 0.0219 - model_acc: 0.8869
Epoch 17/40
9114/9114 [==============================] - 610s 67ms/step - loss: 0.0207 - model_acc: 0.8935
Epoch 18/40
9114/9114 [==============================] - 611s 67ms/step - loss: 0.0196 - model_acc: 0.8993
Epoch 19/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0186 - model_acc: 0.9044
Epoch 20/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0178 - model_acc: 0.9090
Epoch 21/40
9114/9114 [==============================] - 608s 67ms/step - loss: 0.0168 - model_acc: 0.9138
Epoch 22/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0163 - model_acc: 0.9164
Epoch 23/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0155 - model_acc: 0.9207
Epoch 24/40
9114/9114 [==============================] - 611s 67ms/step - loss: 0.0149 - model_acc: 0.9238
Epoch 25/40
9114/9114 [==============================] - 611s 67ms/step - loss: 0.0144 - model_acc: 0.9269
Epoch 26/40
9114/9114 [==============================] - 610s 67ms/step - loss: 0.0139 - model_acc: 0.9294
Epoch 27/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0133 - model_acc: 0.9324
Epoch 28/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0128 - model_acc: 0.9351
Epoch 29/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0124 - model_acc: 0.9377
Epoch 30/40
```

```
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0120 - model_acc: 0.9393
Epoch 31/40
9114/9114 [==============================] - 611s 67ms/step - loss: 0.0116 - model_acc: 0.9414
Epoch 32/40
9114/9114 [==============================] - 610s 67ms/step - loss: 0.0113 - model_acc: 0.9434
Epoch 33/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0109 - model_acc: 0.9455
Epoch 34/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0107 - model_acc: 0.9466
Epoch 35/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0103 - model_acc: 0.9480
Epoch 36/40
9114/9114 [==============================] - 608s 67ms/step - loss: 0.0101 - model_acc: 0.9494
Epoch 37/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0099 - model_acc: 0.9509
Epoch 38/40
9114/9114 [==============================] - 610s 67ms/step - loss: 0.0096 - model_acc: 0.9524
Epoch 39/40
9114/9114 [==============================] - 610s 67ms/step - loss: 0.0093 - model_acc: 0.9536
Epoch 40/40
9114/9114 [==============================] - 609s 67ms/step - loss: 0.0091 - model_acc: 0.9551
```

Out[8]:
```
<tensorflow.python.keras.callbacks.History at 0x15000855a60>
```

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

model.fit(x=images[:training_samples],
          y=emotions[:training_samples],
          batch_size=32,
          epochs=10,
          validation_data=(images[training_samples:], emotions[training_samples:]))
```

```
Epoch 1/10
885/885 [==============================] - 69s 78ms/step - loss: 0.0298 - model_acc: 0.6766 - val_loss: 0.0259 - val_model_acc: 0.
7155
Epoch 2/10
885/885 [==============================] - 68s 77ms/step - loss: 0.0222 - model_acc: 0.7453 - val_loss: 0.0229 - val_model_acc: 0.
7396
Epoch 3/10
885/885 [==============================] - 67s 76ms/step - loss: 0.0182 - model_acc: 0.7840 - val_loss: 0.0217 - val_model_acc: 0.
7596
```

```
Epoch 4/10
885/885 [==============================] - 67s 76ms/step - loss: 0.0153 - model_acc: 0.8148 - val_loss: 0.0216 - val_model_acc: 0.
7535
Epoch 5/10
885/885 [==============================] - 68s 77ms/step - loss: 0.0129 - model_acc: 0.8408 - val_loss: 0.0211 - val_model_acc: 0.
7627
Epoch 6/10
885/885 [==============================] - 69s 78ms/step - loss: 0.0110 - model_acc: 0.8639 - val_loss: 0.0194 - val_model_acc: 0.
7798
Epoch 7/10
885/885 [==============================] - 69s 78ms/step - loss: 0.0096 - model_acc: 0.8825 - val_loss: 0.0185 - val_model_acc: 0.
7910
Epoch 8/10
885/885 [==============================] - 69s 78ms/step - loss: 0.0079 - model_acc: 0.9039 - val_loss: 0.0194 - val_model_acc: 0.
7791
Epoch 9/10
885/885 [==============================] - 69s 78ms/step - loss: 0.0071 - model_acc: 0.9146 - val_loss: 0.0192 - val_model_acc: 0.
7762
Epoch 10/10
885/885 [==============================] - 68s 77ms/step - loss: 0.0068 - model_acc: 0.9152 - val_loss: 0.0189 - val_model_acc: 0.
7846
```

Out[9]: `<tensorflow.python.keras.callbacks.History at 0x14fa9951610>`

In [10]:

```
model.compile(optimizer=adam.Adam(learning_rate=1e-5),
                  loss=mse,
                  metrics = [model_acc])

model.fit(x=images[:training_samples],
          y=emotions[:training_samples],
          batch_size=32,
          epochs=30,
          validation_data=(images[training_samples:], emotions[training_samples:]))
```

```
Epoch 1/30
885/885 [==============================] - 68s 77ms/step - loss: 0.0046 - model_acc: 0.9438 - val_loss: 0.0165 - val_model_acc: 0.
8079
Epoch 2/30
885/885 [==============================] - 68s 77ms/step - loss: 0.0034 - model_acc: 0.9644 - val_loss: 0.0163 - val_model_acc: 0.
8069
Epoch 3/30
885/885 [==============================] - 67s 76ms/step - loss: 0.0028 - model_acc: 0.9765 - val_loss: 0.0162 - val_model_acc: 0.
8101
```

```
Epoch 4/30
885/885 [==============================] - 68s 76ms/step - loss: 0.0023 - model_acc: 0.9835 - val_loss: 0.0162 - val_model_acc: 0.
8105
Epoch 5/30
885/885 [==============================] - 69s 77ms/step - loss: 0.0020 - model_acc: 0.9880 - val_loss: 0.0163 - val_model_acc: 0.
8118
Epoch 6/30
885/885 [==============================] - 69s 78ms/step - loss: 0.0018 - model_acc: 0.9899 - val_loss: 0.0163 - val_model_acc: 0.
8112
Epoch 7/30
885/885 [==============================] - 69s 78ms/step - loss: 0.0016 - model_acc: 0.9923 - val_loss: 0.0163 - val_model_acc: 0.
8101
Epoch 8/30
885/885 [==============================] - 69s 78ms/step - loss: 0.0015 - model_acc: 0.9927 - val_loss: 0.0163 - val_model_acc: 0.
8118
Epoch 9/30
885/885 [==============================] - 69s 78ms/step - loss: 0.0013 - model_acc: 0.9935 - val_loss: 0.0164 - val_model_acc: 0.
8112
Epoch 10/30
885/885 [==============================] - 68s 77ms/step - loss: 0.0012 - model_acc: 0.9940 - val_loss: 0.0164 - val_model_acc: 0.
8140
Epoch 11/30
885/885 [==============================] - 69s 78ms/step - loss: 0.0011 - model_acc: 0.9951 - val_loss: 0.0163 - val_model_acc: 0.
8135
Epoch 12/30
885/885 [==============================] - 68s 77ms/step - loss: 0.0011 - model_acc: 0.9951 - val_loss: 0.0164 - val_model_acc: 0.
8105
Epoch 13/30
885/885 [==============================] - 67s 76ms/step - loss: 9.8978e-04 - model_acc: 0.9954 - val_loss: 0.0164 - val_model_ac
c: 0.8118
Epoch 14/30
885/885 [==============================] - 68s 76ms/step - loss: 9.3159e-04 - model_acc: 0.9954 - val_loss: 0.0165 - val_model_ac
c: 0.8102
Epoch 15/30
885/885 [==============================] - 69s 78ms/step - loss: 8.7639e-04 - model_acc: 0.9960 - val_loss: 0.0165 - val_model_ac
c: 0.8122
Epoch 16/30
885/885 [==============================] - 69s 78ms/step - loss: 8.2446e-04 - model_acc: 0.9957 - val_loss: 0.0164 - val_model_ac
c: 0.8128
Epoch 17/30
885/885 [==============================] - 69s 78ms/step - loss: 7.7488e-04 - model_acc: 0.9970 - val_loss: 0.0165 - val_model_ac
c: 0.8121
Epoch 18/30
885/885 [==============================] - 69s 78ms/step - loss: 7.3014e-04 - model_acc: 0.9966 - val_loss: 0.0164 - val_model_ac
```

```
c: 0.8114
Epoch 19/30
885/885 [==============================] - 69s 77ms/step - loss: 6.9869e-04 - model_acc: 0.9968 - val_loss: 0.0165 - val_model_ac
c: 0.8121
Epoch 20/30
885/885 [==============================] - 68s 77ms/step - loss: 6.6918e-04 - model_acc: 0.9966 - val_loss: 0.0165 - val_model_ac
c: 0.8125
Epoch 21/30
885/885 [==============================] - 68s 77ms/step - loss: 6.3120e-04 - model_acc: 0.9981 - val_loss: 0.0164 - val_model_ac
c: 0.8115
Epoch 22/30
885/885 [==============================] - 67s 76ms/step - loss: 5.9946e-04 - model_acc: 0.9974 - val_loss: 0.0165 - val_model_ac
c: 0.8124
Epoch 23/30
885/885 [==============================] - 67s 76ms/step - loss: 5.7767e-04 - model_acc: 0.9973 - val_loss: 0.0165 - val_model_ac
c: 0.8126
Epoch 24/30
885/885 [==============================] - 68s 76ms/step - loss: 5.5656e-04 - model_acc: 0.9974 - val_loss: 0.0164 - val_model_ac
c: 0.8122
Epoch 25/30
885/885 [==============================] - 69s 78ms/step - loss: 5.2809e-04 - model_acc: 0.9971 - val_loss: 0.0164 - val_model_ac
c: 0.8108
Epoch 26/30
885/885 [==============================] - 69s 78ms/step - loss: 5.0339e-04 - model_acc: 0.9976 - val_loss: 0.0165 - val_model_ac
c: 0.8111
Epoch 27/30
885/885 [==============================] - 69s 78ms/step - loss: 4.8556e-04 - model_acc: 0.9982 - val_loss: 0.0165 - val_model_ac
c: 0.8080
Epoch 28/30
885/885 [==============================] - 69s 78ms/step - loss: 4.6691e-04 - model_acc: 0.9976 - val_loss: 0.0165 - val_model_ac
c: 0.8115
Epoch 29/30
885/885 [==============================] - 69s 77ms/step - loss: 4.5114e-04 - model_acc: 0.9980 - val_loss: 0.0164 - val_model_ac
c: 0.8122
Epoch 30/30
885/885 [==============================] - 68s 77ms/step - loss: 4.3890e-04 - model_acc: 0.9982 - val_loss: 0.0164 - val_model_ac
c: 0.8140
```

Out[10]: <tensorflow.python.keras.callbacks.History at 0x15000f691f0>

In [11]:
```
# data augmentation: mirror and rotate +-25 degree (use read_dataset3, dataset3)
# data augmentation test: rotate different degree (pay attention to adjustable filename etc.)
import os
```