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', 'fear', 'contempt']

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, Input, Conv2D, Flatten
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
```

```
2021-12-25 17:42:18.539787: I tensorflow/stream_executor/platform/default/dso_loader.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)
```

```
2021-12-25 17:42:22.631774: I tensorflow/compiler/jit/xla_cpu_device.cc:41] Not creating XLA devices, tf_xla_enable_xla_devices no
t set
2021-12-25 17:42:22.633957: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcuda.so.1
2021-12-25 17:42:22.691448: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:22.692103: 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
2021-12-25 17:42:22.692151: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcudart.so.11.0
2021-12-25 17:42:22.697785: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcublas.so.11
2021-12-25 17:42:22.697883: I tensorflow/stream_executor/platfo
images shape: (35393, 48, 48, 1)
emotions shape: (35393, 8)
rm/default/dso_loader.cc:49] Successfully opened dynamic library libcublasLt.so.11
2021-12-25 17:42:22.700752: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcufft.so.10
2021-12-25 17:42:22.702097: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcurand.so.10
2021-12-25 17:42:22.708080: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcusolver.so.10
2021-12-25 17:42:22.710010: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcusparse.so.11
2021-12-25 17:42:22.711086: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcudnn.so.8
2021-12-25 17:42:22.711255: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:22.711972: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:22.712594: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862] Adding visible gpu devices: 0
2021-12-25 17:42:22.716543: I tensorflow/core/platform/cpu_feature_guard.cc:142] This TensorFlow binary is optimized with oneAPI D
eep 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.
2021-12-25 17:42:22.716871: I tensorflow/compiler/jit/xla_gpu_device.cc:99] Not creating XLA devices, tf_xla_enable_xla_devices no
t set
2021-12-25 17:42:22.717120: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:22.717776: 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
2021-12-25 17:42:22.717810: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcudart.so.11.0
2021-12-25 17:42:22.717830: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcublas.so.11
2021-12-25 17:42:22.717844: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcublasLt.so.11
2021-12-25 17:42:22.717858: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcufft.so.10
2021-12-25 17:42:22.717872: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcurand.so.10
2021-12-25 17:42:22.717887: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcusolver.so.10
2021-12-25 17:42:22.717904: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcusparse.so.11
2021-12-25 17:42:22.717919: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcudnn.so.8
2021-12-25 17:42:22.717995: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:22.718647: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:22.719268: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1862] Adding visible gpu devices: 0
2021-12-25 17:42:22.719329: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library li
bcudart.so.11.0
2021-12-25 17:42:23.656871: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1261] Device interconnect StreamExecutor with stren
gth 1 edge matrix:
2021-12-25 17:42:23.656916: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1267]      0
2021-12-25 17:42:23.656925: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1280] 0:   N
2021-12-25 17:42:23.657172: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:23.657703: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:23.658180: I tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:941] successful NUMA node read from SysFS had n
egative value (-1), but there must be at least one NUMA node, so returning NUMA node zero
2021-12-25 17:42:23.658632: I tensorflow/core/common_runtime/gpu/gpu_device.cc:1406] Created TensorFlow device (/job:localhost/rep
lica: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 [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, efficientnet
from tensorflow.python.keras.layers import Dense, GlobalAveragePooling2D, MaxPool2D, Input, Conv2D, Flatten, Concatenate, Dropout
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_layer)
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(0.8)(x)
x = Dense(units=4096, activation='relu')(x)
x = Dropout(0.8)(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/tensorflow/python/data/ops/dataset_ops.py:3503: UserWarn
ing: Even though the tf.config.experimental_run_functions_eagerly option is set, this option does not apply to tf.data functions.
tf.data functions are still traced and executed as graphs.
  warnings.warn(
2021-12-25 17:42:25.489932: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:116] None of the MLIR optimization passes a
re enabled (registered 2)
2021-12-25 17:42:25.490586: I tensorflow/core/platform/profile_utils/cpu_utils.cc:112] CPU Frequency: 2199715000 Hz
```

```
2021-12-25 17:42:25.517462: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcudnn.so.8
Epoch 1/30
2021-12-25 17:42:28.369497: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcublas.so.11
2021-12-25 17:42:29.000372: I tensorflow/stream_executor/platform/default/dso_loader.cc:49] Successfully opened dynamic library libcublasLt.so.11
996/996 [==============================] - 95s 90ms/step - loss: 0.0599 - model_acc: 0.3500 - val_loss: 0.0582 - val_model_acc: 0.3757
Epoch 2/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0528 - model_acc: 0.4371 - val_loss: 0.0354 - val_model_acc: 0.6329
Epoch 3/30
996/996 [==============================] - 87s 88ms/step - loss: 0.0315 - model_acc: 0.6694 - val_loss: 0.0274 - val_model_acc: 0.6962
Epoch 4/30
996/996 [==============================] - 84s 84ms/step - loss: 0.0249 - model_acc: 0.7250 - val_loss: 0.0231 - val_model_acc: 0.7345
Epoch 5/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0203 - model_acc: 0.7687 - val_loss: 0.0207 - val_model_acc: 0.7506
Epoch 6/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0171 - model_acc: 0.7958 - val_loss: 0.0205 - val_model_acc: 0.7588
Epoch 7/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0148 - model_acc: 0.8236 - val_loss: 0.0181 - val_model_acc: 0.7787
Epoch 8/30
996/996 [==============================] - 87s 88ms/step - loss: 0.0125 - model_acc: 0.8481 - val_loss: 0.0165 - val_model_acc: 0.8000
Epoch 9/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0108 - model_acc: 0.8639 - val_loss: 0.0169 - val_model_acc: 0.7980
Epoch 10/30
996/996 [==============================] - 84s 85ms/step - loss: 0.0097 - model_acc: 0.8806 - val_loss: 0.0159 - val_model_acc: 0.7994
Epoch 11/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0084 - model_acc: 0.8922 - val_loss: 0.0158 - val_model_acc: 0.8071
Epoch 12/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0075 - model_acc: 0.9077 - val_loss: 0.0154 - val_model_acc: 0.8171
Epoch 13/30
```

```
996/996 [==============================] - 85s 86ms/step - loss: 0.0069 - model_acc: 0.9129 - val_loss: 0.0166 - val_model_acc: 0.
8070
Epoch 14/30
996/996 [==============================] - 87s 88ms/step - loss: 0.0064 - model_acc: 0.9220 - val_loss: 0.0157 - val_model_acc: 0.
8154
Epoch 15/30
996/996 [==============================] - 84s 84ms/step - loss: 0.0060 - model_acc: 0.9244 - val_loss: 0.0162 - val_model_acc: 0.
7881
Epoch 16/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0055 - model_acc: 0.9324 - val_loss: 0.0160 - val_model_acc: 0.
8010
Epoch 17/30
996/996 [==============================] - 84s 85ms/step - loss: 0.0053 - model_acc: 0.9339 - val_loss: 0.0163 - val_model_acc: 0.
7977
Epoch 18/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0050 - model_acc: 0.9340 - val_loss: 0.0149 - val_model_acc: 0.
8151
Epoch 19/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0046 - model_acc: 0.9425 - val_loss: 0.0151 - val_model_acc: 0.
8148
Epoch 20/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0044 - model_acc: 0.9435 - val_loss: 0.0148 - val_model_acc: 0.
8146
Epoch 21/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0041 - model_acc: 0.9469 - val_loss: 0.0148 - val_model_acc: 0.
8140
Epoch 22/30
996/996 [==============================] - 87s 88ms/step - loss: 0.0041 - model_acc: 0.9491 - val_loss: 0.0144 - val_model_acc: 0.
8244
Epoch 23/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0038 - model_acc: 0.9491 - val_loss: 0.0146 - val_model_acc: 0.
8210
Epoch 24/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0037 - model_acc: 0.9537 - val_loss: 0.0144 - val_model_acc: 0.
8247
Epoch 25/30
996/996 [==============================] - 83s 84ms/step - loss: 0.0035 - model_acc: 0.9555 - val_loss: 0.0152 - val_model_acc: 0.
8081
Epoch 26/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0034 - model_acc: 0.9556 - val_loss: 0.0145 - val_model_acc: 0.
8244
Epoch 27/30
996/996 [==============================] - 84s 84ms/step - loss: 0.0032 - model_acc: 0.9583 - val_loss: 0.0144 - val_model_acc: 0.
8216
```

```
Epoch 28/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0032 - model_acc: 0.9586 - val_loss: 0.0146 - val_model_acc: 0.
8165
Epoch 29/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0030 - model_acc: 0.9598 - val_loss: 0.0148 - val_model_acc: 0.
8098
Epoch 30/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0030 - model_acc: 0.9585 - val_loss: 0.0145 - val_model_acc: 0.
8152
```

Out[8]:
```
<tensorflow.python.keras.callbacks.History at 0x151f056b0be0>
```

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 [==============================] - 85s 85ms/step - loss: 0.0026 - model_acc: 0.9653 - val_loss: 0.0140 - val_model_acc: 0.
8236
Epoch 2/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0021 - model_acc: 0.9760 - val_loss: 0.0143 - val_model_acc: 0.
8255
Epoch 3/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0020 - model_acc: 0.9792 - val_loss: 0.0141 - val_model_acc: 0.
8253
Epoch 4/30
996/996 [==============================] - 84s 85ms/step - loss: 0.0020 - model_acc: 0.9779 - val_loss: 0.0142 - val_model_acc: 0.
8256
Epoch 5/30
996/996 [==============================] - 85s 86ms/step - loss: 0.0018 - model_acc: 0.9788 - val_loss: 0.0140 - val_model_acc: 0.
8287
Epoch 6/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0018 - model_acc: 0.9797 - val_loss: 0.0143 - val_model_acc: 0.
8323
Epoch 7/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0018 - model_acc: 0.9780 - val_loss: 0.0140 - val_model_acc: 0.
8276
```

```
Epoch 8/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0017 - model_acc: 0.9792 - val_loss: 0.0142 - val_model_acc: 0.
8253
Epoch 9/30
996/996 [==============================] - 84s 85ms/step - loss: 0.0016 - model_acc: 0.9817 - val_loss: 0.0141 - val_model_acc: 0.
8301
Epoch 10/30
996/996 [==============================] - 85s 86ms/step - loss: 0.0016 - model_acc: 0.9822 - val_loss: 0.0141 - val_model_acc: 0.
8255
Epoch 11/30
996/996 [==============================] - 82s 83ms/step - loss: 0.0016 - model_acc: 0.9798 - val_loss: 0.0143 - val_model_acc: 0.
8267
Epoch 12/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0015 - model_acc: 0.9830 - val_loss: 0.0141 - val_model_acc: 0.
8284
Epoch 13/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0015 - model_acc: 0.9793 - val_loss: 0.0143 - val_model_acc: 0.
8270
Epoch 14/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0015 - model_acc: 0.9822 - val_loss: 0.0142 - val_model_acc: 0.
8239
Epoch 15/30
996/996 [==============================] - 84s 84ms/step - loss: 0.0014 - model_acc: 0.9826 - val_loss: 0.0141 - val_model_acc: 0.
8286
Epoch 16/30
996/996 [==============================] - 86s 87ms/step - loss: 0.0014 - model_acc: 0.9804 - val_loss: 0.0142 - val_model_acc: 0.
8238
Epoch 17/30
996/996 [==============================] - 84s 85ms/step - loss: 0.0014 - model_acc: 0.9834 - val_loss: 0.0142 - val_model_acc: 0.
8207
Epoch 18/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0014 - model_acc: 0.9828 - val_loss: 0.0141 - val_model_acc: 0.
8286
Epoch 19/30
996/996 [==============================] - 87s 88ms/step - loss: 0.0014 - model_acc: 0.9823 - val_loss: 0.0143 - val_model_acc: 0.
8289
Epoch 20/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0013 - model_acc: 0.9844 - val_loss: 0.0142 - val_model_acc: 0.
8309
Epoch 21/30
996/996 [==============================] - 83s 84ms/step - loss: 0.0013 - model_acc: 0.9832 - val_loss: 0.0143 - val_model_acc: 0.
8261
Epoch 22/30
996/996 [==============================] - 84s 84ms/step - loss: 0.0013 - model_acc: 0.9843 - val_loss: 0.0143 - val_model_acc: 0.
```

```
8323
Epoch 23/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0013 - model_acc: 0.9825 - val_loss: 0.0144 - val_model_acc: 0.
8258
Epoch 24/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0013 - model_acc: 0.9842 - val_loss: 0.0144 - val_model_acc: 0.
8295
Epoch 25/30
996/996 [==============================] - 88s 88ms/step - loss: 0.0013 - model_acc: 0.9842 - val_loss: 0.0142 - val_model_acc: 0.
8287
Epoch 26/30
996/996 [==============================] - 87s 87ms/step - loss: 0.0012 - model_acc: 0.9840 - val_loss: 0.0142 - val_model_acc: 0.
8309
Epoch 27/30
996/996 [==============================] - 85s 85ms/step - loss: 0.0012 - model_acc: 0.9853 - val_loss: 0.0143 - val_model_acc: 0.
8303
Epoch 28/30
996/996 [==============================] - 87s 88ms/step - loss: 0.0012 - model_acc: 0.9843 - val_loss: 0.0143 - val_model_acc: 0.
8295
Epoch 29/30
996/996 [==============================] - 87s 88ms/step - loss: 0.0012 - model_acc: 0.9840 - val_loss: 0.0141 - val_model_acc: 0.
8286
Epoch 30/30
996/996 [==============================] - 86s 86ms/step - loss: 0.0012 - model_acc: 0.9840 - val_loss: 0.0142 - val_model_acc: 0.
8287
```

Out[9]: <tensorflow.python.keras.callbacks.History at 0x151f05781820>

In [ ]: