In [1]:

```
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow.python.keras.applications import vgg16, resnet
from tensorflow.python.keras.layers import Dense, GlobalAveragePooling2D
from tensorflow.python.keras.models import Model
from tensorflow.python.keras import layers, Sequential
from tensorflow.python.keras import losses, metrics
from tensorflow.python.keras.optimizer_v2 import adam

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]:

```
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 [3]:

```
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 = tf.image.resize(images, [224,224])
# print("images shape:", images.shape)

from tensorflow.python.keras import layers
# choose one method:
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)
```

```
images shape: (35393, 48, 48, 3)
emotions shape: (35393, 8)
training_images shape: (31858, 48, 48, 3)
training_emotions shape: (31858, 8)
test_images shape: (3535, 48, 48, 3)
test_emotions shape: (3535, 8)
```

In [4]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])
#model.summary()

from tensorflow.python.keras import losses, metrics
from tensorflow.python.keras.optimizer_v2 import adam
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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
C:\Users\Darkl\anaconda3\lib\site-packages\tensorflow\python\data\ops\dataset_ops.py:3703: UserWarning: Even though the `tf.config.experimental_run_functions_eag
erly` 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.debu
g_mode()`.
  warnings.warn(
Epoch 1/25
996/996 [==============================] - 68s 66ms/step - loss: 1.3678 - model_acc: 0.5054 - val_loss: 1.3199 - val_model_acc: 0.5335
Epoch 2/25
996/996 [==============================] - 66s 66ms/step - loss: 1.2571 - model_acc: 0.5530 - val_loss: 1.2914 - val_model_acc: 0.5459
Epoch 3/25
996/996 [==============================] - 65s 65ms/step - loss: 1.2055 - model_acc: 0.5692 - val_loss: 1.2686 - val_model_acc: 0.5527
Epoch 4/25
996/996 [==============================] - 65s 65ms/step - loss: 1.1629 - model_acc: 0.5893 - val_loss: 1.2409 - val_model_acc: 0.5603
Epoch 5/25
996/996 [==============================] - 63s 64ms/step - loss: 1.1263 - model_acc: 0.6037 - val_loss: 1.2349 - val_model_acc: 0.5659
Epoch 6/25
996/996 [==============================] - 63s 63ms/step - loss: 1.0853 - model_acc: 0.6238 - val_loss: 1.2145 - val_model_acc: 0.5743
Epoch 7/25
996/996 [==============================] - 65s 65ms/step - loss: 1.0495 - model_acc: 0.6370 - val_loss: 1.2028 - val_model_acc: 0.5743
Epoch 8/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0133 - model_acc: 0.6541 - val_loss: 1.2099 - val_model_acc: 0.5729
Epoch 9/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9798 - model_acc: 0.6671 - val_loss: 1.1870 - val_model_acc: 0.5799
Epoch 10/25
996/996 [==============================] - 63s 64ms/step - loss: 0.9430 - model_acc: 0.6855 - val_loss: 1.1739 - val_model_acc: 0.5898
Epoch 11/25
996/996 [==============================] - 63s 64ms/step - loss: 0.9099 - model_acc: 0.6955 - val_loss: 1.1823 - val_model_acc: 0.5887
Epoch 12/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8756 - model_acc: 0.7141 - val_loss: 1.1633 - val_model_acc: 0.5929
Epoch 13/25
```

```
996/996 [==============================] - 63s 63ms/step - loss: 0.8442 - model_acc: 0.7271 - val_loss: 1.1632 - val_model_acc: 0.5979
Epoch 14/25
996/996 [==============================] - 61s 62ms/step - loss: 0.8114 - model_acc: 0.7389 - val_loss: 1.1564 - val_model_acc: 0.5965
Epoch 15/25
996/996 [==============================] - 61s 62ms/step - loss: 0.7816 - model_acc: 0.7558 - val_loss: 1.1635 - val_model_acc: 0.6050
Epoch 16/25
996/996 [==============================] - 64s 64ms/step - loss: 0.7513 - model_acc: 0.7655 - val_loss: 1.1672 - val_model_acc: 0.6064
Epoch 17/25
996/996 [==============================] - 64s 64ms/step - loss: 0.7208 - model_acc: 0.7804 - val_loss: 1.1557 - val_model_acc: 0.6098
Epoch 18/25
996/996 [==============================] - 63s 63ms/step - loss: 0.6936 - model_acc: 0.7921 - val_loss: 1.1616 - val_model_acc: 0.6123
Epoch 19/25
996/996 [==============================] - 63s 63ms/step - loss: 0.6657 - model_acc: 0.8024 - val_loss: 1.1579 - val_model_acc: 0.6087
Epoch 20/25
996/996 [==============================] - 63s 63ms/step - loss: 0.6415 - model_acc: 0.8099 - val_loss: 1.1730 - val_model_acc: 0.6148
Epoch 21/25
996/996 [==============================] - 63s 63ms/step - loss: 0.6146 - model_acc: 0.8231 - val_loss: 1.1839 - val_model_acc: 0.6171
Epoch 22/25
996/996 [==============================] - 62s 62ms/step - loss: 0.5888 - model_acc: 0.8314 - val_loss: 1.1779 - val_model_acc: 0.6095
Epoch 23/25
996/996 [==============================] - 62s 62ms/step - loss: 0.5643 - model_acc: 0.8420 - val_loss: 1.2058 - val_model_acc: 0.6098
Epoch 24/25
996/996 [==============================] - 63s 63ms/step - loss: 0.5424 - model_acc: 0.8500 - val_loss: 1.1995 - val_model_acc: 0.6106
Epoch 25/25
996/996 [==============================] - 64s 64ms/step - loss: 0.5206 - model_acc: 0.8583 - val_loss: 1.2069 - val_model_acc: 0.6120
```

Out[4]:

```
<tensorflow.python.keras.callbacks.History at 0x208f01b3be0>
```

In [5]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 64s 64ms/step - loss: 1.5208 - model_acc: 0.4418 - val_loss: 1.4468 - val_model_acc: 0.4772
Epoch 2/25
996/996 [==============================] - 63s 63ms/step - loss: 1.3900 - model_acc: 0.5035 - val_loss: 1.3949 - val_model_acc: 0.5093
Epoch 3/25
996/996 [==============================] - 63s 63ms/step - loss: 1.3479 - model_acc: 0.5211 - val_loss: 1.3681 - val_model_acc: 0.5178
Epoch 4/25
996/996 [==============================] - 63s 63ms/step - loss: 1.3220 - model_acc: 0.5308 - val_loss: 1.3517 - val_model_acc: 0.5217
Epoch 5/25
996/996 [==============================] - 63s 63ms/step - loss: 1.3024 - model_acc: 0.5387 - val_loss: 1.3385 - val_model_acc: 0.5316
Epoch 6/25
996/996 [==============================] - 62s 62ms/step - loss: 1.2868 - model_acc: 0.5443 - val_loss: 1.3257 - val_model_acc: 0.5363
Epoch 7/25
996/996 [==============================] - 62s 62ms/step - loss: 1.2740 - model_acc: 0.5495 - val_loss: 1.3170 - val_model_acc: 0.5377
Epoch 8/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2625 - model_acc: 0.5539 - val_loss: 1.3087 - val_model_acc: 0.5406
Epoch 9/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2528 - model_acc: 0.5584 - val_loss: 1.3022 - val_model_acc: 0.5484
Epoch 10/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2436 - model_acc: 0.5624 - val_loss: 1.2967 - val_model_acc: 0.5493
Epoch 11/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2352 - model_acc: 0.5652 - val_loss: 1.2928 - val_model_acc: 0.5507
Epoch 12/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2274 - model_acc: 0.5667 - val_loss: 1.2858 - val_model_acc: 0.5498
Epoch 13/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2200 - model_acc: 0.5681 - val_loss: 1.2831 - val_model_acc: 0.5496
Epoch 14/25
996/996 [==============================] - 62s 62ms/step - loss: 1.2133 - model_acc: 0.5720 - val_loss: 1.2788 - val_model_acc: 0.5538
Epoch 15/25
996/996 [==============================] - 61s 62ms/step - loss: 1.2071 - model_acc: 0.5737 - val_loss: 1.2742 - val_model_acc: 0.5482
Epoch 16/25
996/996 [==============================] - 62s 62ms/step - loss: 1.2003 - model_acc: 0.5768 - val_loss: 1.2722 - val_model_acc: 0.5518
Epoch 17/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1946 - model_acc: 0.5783 - val_loss: 1.2669 - val_model_acc: 0.5538
```

```
Epoch 18/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1888 - model_acc: 0.5825 - val_loss: 1.2658 - val_model_acc: 0.5566
Epoch 19/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1833 - model_acc: 0.5842 - val_loss: 1.2615 - val_model_acc: 0.5549
Epoch 20/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1778 - model_acc: 0.5859 - val_loss: 1.2586 - val_model_acc: 0.5555
Epoch 21/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1725 - model_acc: 0.5895 - val_loss: 1.2601 - val_model_acc: 0.5555
Epoch 22/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1676 - model_acc: 0.5917 - val_loss: 1.2542 - val_model_acc: 0.5558
Epoch 23/25
996/996 [==============================] - 62s 62ms/step - loss: 1.1626 - model_acc: 0.5926 - val_loss: 1.2526 - val_model_acc: 0.5535
Epoch 24/25
996/996 [==============================] - 62s 62ms/step - loss: 1.1574 - model_acc: 0.5944 - val_loss: 1.2493 - val_model_acc: 0.5549
Epoch 25/25
996/996 [==============================] - 63s 64ms/step - loss: 1.1527 - model_acc: 0.5970 - val_loss: 1.2476 - val_model_acc: 0.5642
```

Out[5]:

```
<tensorflow.python.keras.callbacks.History at 0x2092d428040>
```

In [6]:

```python
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=5e-5), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3963 - model_acc: 0.4959 - val_loss: 1.3511 - val_model_acc: 0.5225
Epoch 2/25
996/996 [==============================] - 63s 64ms/step - loss: 1.2863 - model_acc: 0.5409 - val_loss: 1.3162 - val_model_acc: 0.5338
Epoch 3/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2432 - model_acc: 0.5593 - val_loss: 1.2923 - val_model_acc: 0.5397
Epoch 4/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2105 - model_acc: 0.5744 - val_loss: 1.2822 - val_model_acc: 0.5406
Epoch 5/25
996/996 [==============================] - 63s 64ms/step - loss: 1.1849 - model_acc: 0.5808 - val_loss: 1.2560 - val_model_acc: 0.5563
Epoch 6/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1624 - model_acc: 0.5916 - val_loss: 1.2529 - val_model_acc: 0.5549
Epoch 7/25
996/996 [==============================] - 62s 62ms/step - loss: 1.1385 - model_acc: 0.6018 - val_loss: 1.2379 - val_model_acc: 0.5673
Epoch 8/25
996/996 [==============================] - 62s 62ms/step - loss: 1.1174 - model_acc: 0.6105 - val_loss: 1.2209 - val_model_acc: 0.5650
Epoch 9/25
996/996 [==============================] - 64s 65ms/step - loss: 1.0972 - model_acc: 0.6193 - val_loss: 1.2142 - val_model_acc: 0.5698
Epoch 10/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0778 - model_acc: 0.6280 - val_loss: 1.2083 - val_model_acc: 0.5746
Epoch 11/25
996/996 [==============================] - 63s 64ms/step - loss: 1.0578 - model_acc: 0.6376 - val_loss: 1.2052 - val_model_acc: 0.5791
Epoch 12/25
996/996 [==============================] - 63s 64ms/step - loss: 1.0372 - model_acc: 0.6450 - val_loss: 1.1952 - val_model_acc: 0.5836
Epoch 13/25
996/996 [==============================] - 63s 64ms/step - loss: 1.0179 - model_acc: 0.6514 - val_loss: 1.1961 - val_model_acc: 0.5774
Epoch 14/25
996/996 [==============================] - 63s 63ms/step - loss: 0.9989 - model_acc: 0.6634 - val_loss: 1.1930 - val_model_acc: 0.5780
Epoch 15/25
996/996 [==============================] - 62s 62ms/step - loss: 0.9801 - model_acc: 0.6687 - val_loss: 1.1820 - val_model_acc: 0.5883
Epoch 16/25
996/996 [==============================] - 62s 62ms/step - loss: 0.9620 - model_acc: 0.6805 - val_loss: 1.1798 - val_model_acc: 0.5889
Epoch 17/25
996/996 [==============================] - 63s 63ms/step - loss: 0.9433 - model_acc: 0.6867 - val_loss: 1.1690 - val_model_acc: 0.5873
Epoch 18/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9239 - model_acc: 0.6948 - val_loss: 1.1688 - val_model_acc: 0.5898
Epoch 19/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9062 - model_acc: 0.7042 - val_loss: 1.1663 - val_model_acc: 0.5971
Epoch 20/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8898 - model_acc: 0.7112 - val_loss: 1.1662 - val_model_acc: 0.5913
Epoch 21/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8712 - model_acc: 0.7188 - val_loss: 1.1583 - val_model_acc: 0.5949
Epoch 22/25
```

```
996/996 [==============================] - 63s 63ms/step - loss: 0.8545 - model_acc: 0.7277 - val_loss: 1.1632 - val_model_acc: 0.6002
Epoch 23/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8369 - model_acc: 0.7353 - val_loss: 1.1560 - val_model_acc: 0.5904
Epoch 24/25
996/996 [==============================] - 62s 62ms/step - loss: 0.8196 - model_acc: 0.7425 - val_loss: 1.1617 - val_model_acc: 0.5904
Epoch 25/25
996/996 [==============================] - 62s 62ms/step - loss: 0.8037 - model_acc: 0.7494 - val_loss: 1.1540 - val_model_acc: 0.6041
```

Out[6]:

```
<tensorflow.python.keras.callbacks.History at 0x20b3b0a72e0>
```

In [7]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3653 - model_acc: 0.5069 - val_loss: 1.3199 - val_model_acc: 0.5273
Epoch 2/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2565 - model_acc: 0.5518 - val_loss: 1.2849 - val_model_acc: 0.5490
Epoch 3/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2061 - model_acc: 0.5711 - val_loss: 1.2535 - val_model_acc: 0.5558
```

```
Epoch 4/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1647 - model_acc: 0.5887 - val_loss: 1.2526 - val_model_acc: 0.5468
Epoch 5/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1253 - model_acc: 0.6043 - val_loss: 1.2286 - val_model_acc: 0.5704
Epoch 6/25
996/996 [==============================] - 63s 64ms/step - loss: 1.0883 - model_acc: 0.6196 - val_loss: 1.2096 - val_model_acc: 0.5693
Epoch 7/25
996/996 [==============================] - 62s 63ms/step - loss: 1.0509 - model_acc: 0.6353 - val_loss: 1.2029 - val_model_acc: 0.5774
Epoch 8/25
996/996 [==============================] - 62s 62ms/step - loss: 1.0136 - model_acc: 0.6523 - val_loss: 1.1864 - val_model_acc: 0.5796
Epoch 9/25
996/996 [==============================] - 63s 63ms/step - loss: 0.9807 - model_acc: 0.6650 - val_loss: 1.1788 - val_model_acc: 0.5850
Epoch 10/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9469 - model_acc: 0.6825 - val_loss: 1.1695 - val_model_acc: 0.5875
Epoch 11/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9124 - model_acc: 0.6977 - val_loss: 1.1617 - val_model_acc: 0.5878
Epoch 12/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8788 - model_acc: 0.7106 - val_loss: 1.1657 - val_model_acc: 0.5943
Epoch 13/25
996/996 [==============================] - 63s 64ms/step - loss: 0.8468 - model_acc: 0.7240 - val_loss: 1.1554 - val_model_acc: 0.5949
Epoch 14/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8172 - model_acc: 0.7368 - val_loss: 1.1535 - val_model_acc: 0.5996
Epoch 15/25
996/996 [==============================] - 63s 63ms/step - loss: 0.7836 - model_acc: 0.7527 - val_loss: 1.1738 - val_model_acc: 0.5962
Epoch 16/25
996/996 [==============================] - 61s 62ms/step - loss: 0.7548 - model_acc: 0.7640 - val_loss: 1.1566 - val_model_acc: 0.6078
Epoch 17/25
996/996 [==============================] - 62s 62ms/step - loss: 0.7255 - model_acc: 0.7760 - val_loss: 1.1616 - val_model_acc: 0.6100
Epoch 18/25
996/996 [==============================] - 64s 64ms/step - loss: 0.6960 - model_acc: 0.7901 - val_loss: 1.1630 - val_model_acc: 0.6092
Epoch 19/25
996/996 [==============================] - 64s 64ms/step - loss: 0.6691 - model_acc: 0.7987 - val_loss: 1.1734 - val_model_acc: 0.6064
Epoch 20/25
996/996 [==============================] - 63s 64ms/step - loss: 0.6435 - model_acc: 0.8102 - val_loss: 1.1615 - val_model_acc: 0.6171
Epoch 21/25
996/996 [==============================] - 63s 63ms/step - loss: 0.6168 - model_acc: 0.8210 - val_loss: 1.1886 - val_model_acc: 0.5943
Epoch 22/25
996/996 [==============================] - 63s 63ms/step - loss: 0.5925 - model_acc: 0.8310 - val_loss: 1.1987 - val_model_acc: 0.6087
Epoch 23/25
996/996 [==============================] - 63s 63ms/step - loss: 0.5686 - model_acc: 0.8398 - val_loss: 1.2075 - val_model_acc: 0.6021
Epoch 24/25
996/996 [==============================] - 62s 63ms/step - loss: 0.5445 - model_acc: 0.8480 - val_loss: 1.1988 - val_model_acc: 0.6126
Epoch 25/25
996/996 [==============================] - 62s 62ms/step - loss: 0.5214 - model_acc: 0.8579 - val_loss: 1.2066 - val_model_acc: 0.6103
```

Out[7]:

```
<tensorflow.python.keras.callbacks.History at 0x20b4ca9a490>
```

In [8]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=5e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 63s 63ms/step - loss: 1.3391 - model_acc: 0.5148 - val_loss: 1.3041 - val_model_acc: 0.5363
Epoch 2/25
996/996 [==============================] - 64s 65ms/step - loss: 1.2169 - model_acc: 0.5628 - val_loss: 1.2581 - val_model_acc: 0.5566
Epoch 3/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1421 - model_acc: 0.5945 - val_loss: 1.2117 - val_model_acc: 0.5695
Epoch 4/25
996/996 [==============================] - 63s 63ms/step - loss: 1.0741 - model_acc: 0.6215 - val_loss: 1.2071 - val_model_acc: 0.5755
Epoch 5/25
996/996 [==============================] - 63s 63ms/step - loss: 0.9997 - model_acc: 0.6526 - val_loss: 1.2014 - val_model_acc: 0.5777
Epoch 6/25
996/996 [==============================] - 63s 63ms/step - loss: 0.9265 - model_acc: 0.6793 - val_loss: 1.2297 - val_model_acc: 0.5594
Epoch 7/25
996/996 [==============================] - 63s 64ms/step - loss: 0.8524 - model_acc: 0.7093 - val_loss: 1.2182 - val_model_acc: 0.5878
Epoch 8/25
996/996 [==============================] - 62s 62ms/step - loss: 0.7813 - model_acc: 0.7368 - val_loss: 1.2054 - val_model_acc: 0.5946
```

```
Epoch 9/25
996/996 [==============================] - 62s 62ms/step - loss: 0.7095 - model_acc: 0.7661 - val_loss: 1.2705 - val_model_acc: 0.6016
Epoch 10/25
996/996 [==============================] - 63s 64ms/step - loss: 0.6455 - model_acc: 0.7933 - val_loss: 1.2790 - val_model_acc: 0.5911
Epoch 11/25
996/996 [==============================] - 64s 64ms/step - loss: 0.5833 - model_acc: 0.8175 - val_loss: 1.2882 - val_model_acc: 0.6145
Epoch 12/25
996/996 [==============================] - 63s 64ms/step - loss: 0.5272 - model_acc: 0.8409 - val_loss: 1.3512 - val_model_acc: 0.6134
Epoch 13/25
996/996 [==============================] - 63s 63ms/step - loss: 0.4797 - model_acc: 0.8569 - val_loss: 1.3620 - val_model_acc: 0.6016
Epoch 14/25
996/996 [==============================] - 63s 63ms/step - loss: 0.4349 - model_acc: 0.8740 - val_loss: 1.3931 - val_model_acc: 0.5962
Epoch 15/25
996/996 [==============================] - 63s 63ms/step - loss: 0.3948 - model_acc: 0.8897 - val_loss: 1.4667 - val_model_acc: 0.6104
Epoch 16/25
996/996 [==============================] - 62s 63ms/step - loss: 0.3611 - model_acc: 0.9029 - val_loss: 1.4824 - val_model_acc: 0.5931
Epoch 17/25
996/996 [==============================] - 61s 62ms/step - loss: 0.3297 - model_acc: 0.9159 - val_loss: 1.5014 - val_model_acc: 0.6066
Epoch 18/25
996/996 [==============================] - 62s 62ms/step - loss: 0.3032 - model_acc: 0.9236 - val_loss: 1.6282 - val_model_acc: 0.6118
Epoch 19/25
996/996 [==============================] - 64s 65ms/step - loss: 0.2821 - model_acc: 0.9316 - val_loss: 1.5990 - val_model_acc: 0.6207
Epoch 20/25
996/996 [==============================] - 64s 64ms/step - loss: 0.2605 - model_acc: 0.9397 - val_loss: 1.6475 - val_model_acc: 0.6112
Epoch 21/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2424 - model_acc: 0.9463 - val_loss: 1.6893 - val_model_acc: 0.6075
Epoch 22/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2252 - model_acc: 0.9514 - val_loss: 1.7400 - val_model_acc: 0.6067
Epoch 23/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2181 - model_acc: 0.9530 - val_loss: 1.7772 - val_model_acc: 0.6035
Epoch 24/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2099 - model_acc: 0.9570 - val_loss: 1.7950 - val_model_acc: 0.6094
Epoch 25/25
996/996 [==============================] - 62s 62ms/step - loss: 0.1948 - model_acc: 0.9610 - val_loss: 1.8656 - val_model_acc: 0.6041
```

Out[8]:

```
<tensorflow.python.keras.callbacks.History at 0x20b4d605c70>
```

In [9]:

```python
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-3), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 62s 62ms/step - loss: 1.3440 - model_acc: 0.5124 - val_loss: 1.2905 - val_model_acc: 0.5422
Epoch 2/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2255 - model_acc: 0.5588 - val_loss: 1.2819 - val_model_acc: 0.5484
Epoch 3/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1558 - model_acc: 0.5894 - val_loss: 1.2174 - val_model_acc: 0.5673
Epoch 4/25
996/996 [==============================] - 63s 64ms/step - loss: 1.0837 - model_acc: 0.6164 - val_loss: 1.2045 - val_model_acc: 0.5681
Epoch 5/25
996/996 [==============================] - 63s 63ms/step - loss: 1.0106 - model_acc: 0.6467 - val_loss: 1.2183 - val_model_acc: 0.5752
Epoch 6/25
996/996 [==============================] - 63s 63ms/step - loss: 0.9355 - model_acc: 0.6730 - val_loss: 1.2135 - val_model_acc: 0.5780
Epoch 7/25
996/996 [==============================] - 63s 64ms/step - loss: 0.8618 - model_acc: 0.7017 - val_loss: 1.2395 - val_model_acc: 0.5912
Epoch 8/25
996/996 [==============================] - 63s 63ms/step - loss: 0.7858 - model_acc: 0.7334 - val_loss: 1.2583 - val_model_acc: 0.5830
Epoch 9/25
996/996 [==============================] - 62s 62ms/step - loss: 0.7171 - model_acc: 0.7599 - val_loss: 1.3096 - val_model_acc: 0.5802
Epoch 10/25
996/996 [==============================] - 62s 62ms/step - loss: 0.6487 - model_acc: 0.7889 - val_loss: 1.3611 - val_model_acc: 0.5962
Epoch 11/25
996/996 [==============================] - 64s 64ms/step - loss: 0.5880 - model_acc: 0.8108 - val_loss: 1.3871 - val_model_acc: 0.6015
Epoch 12/25
996/996 [==============================] - 64s 64ms/step - loss: 0.5322 - model_acc: 0.8331 - val_loss: 1.4113 - val_model_acc: 0.5998
Epoch 13/25
```

```
996/996 [==============================] - 63s 64ms/step - loss: 0.4873 - model_acc: 0.8513 - val_loss: 1.4526 - val_model_acc: 0.6035
Epoch 14/25
996/996 [==============================] - 63s 63ms/step - loss: 0.4402 - model_acc: 0.8685 - val_loss: 1.4831 - val_model_acc: 0.5945
Epoch 15/25
996/996 [==============================] - 63s 63ms/step - loss: 0.3969 - model_acc: 0.8863 - val_loss: 1.6099 - val_model_acc: 0.6016
Epoch 16/25
996/996 [==============================] - 63s 63ms/step - loss: 0.3697 - model_acc: 0.8969 - val_loss: 1.6237 - val_model_acc: 0.6103
Epoch 17/25
996/996 [==============================] - 62s 62ms/step - loss: 0.3437 - model_acc: 0.9058 - val_loss: 1.7144 - val_model_acc: 0.6016
Epoch 18/25
996/996 [==============================] - 61s 62ms/step - loss: 0.3118 - model_acc: 0.9195 - val_loss: 1.7338 - val_model_acc: 0.6065
Epoch 19/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2943 - model_acc: 0.9228 - val_loss: 1.7697 - val_model_acc: 0.5951
Epoch 20/25
996/996 [==============================] - 64s 65ms/step - loss: 0.2734 - model_acc: 0.9313 - val_loss: 1.7957 - val_model_acc: 0.6017
Epoch 21/25
996/996 [==============================] - 64s 64ms/step - loss: 0.2569 - model_acc: 0.9393 - val_loss: 1.9191 - val_model_acc: 0.5900
Epoch 22/25
996/996 [==============================] - 63s 64ms/step - loss: 0.2398 - model_acc: 0.9434 - val_loss: 1.9051 - val_model_acc: 0.6089
Epoch 23/25
996/996 [==============================] - 66s 66ms/step - loss: 0.2321 - model_acc: 0.9463 - val_loss: 1.9627 - val_model_acc: 0.6100
Epoch 24/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2202 - model_acc: 0.9513 - val_loss: 2.0915 - val_model_acc: 0.6050
Epoch 25/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2086 - model_acc: 0.9564 - val_loss: 2.0272 - val_model_acc: 0.6064
```

Out[9]:

```
<tensorflow.python.keras.callbacks.History at 0x208ef3a2340>
```

In [10]:

```python
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=16,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
1992/1992 [==============================] - 82s 41ms/step - loss: 1.3530 - model_acc: 0.5130 - val_loss: 1.3283 - val_model_acc: 0.5103
Epoch 2/25
1992/1992 [==============================] - 81s 41ms/step - loss: 1.2420 - model_acc: 0.5539 - val_loss: 1.2867 - val_model_acc: 0.5437
Epoch 3/25
1992/1992 [==============================] - 84s 42ms/step - loss: 1.1887 - model_acc: 0.5756 - val_loss: 1.2451 - val_model_acc: 0.5570
Epoch 4/25
1992/1992 [==============================] - 84s 42ms/step - loss: 1.1365 - model_acc: 0.6002 - val_loss: 1.2210 - val_model_acc: 0.5722
Epoch 5/25
1992/1992 [==============================] - 83s 42ms/step - loss: 1.0870 - model_acc: 0.6195 - val_loss: 1.2136 - val_model_acc: 0.5770
Epoch 6/25
1992/1992 [==============================] - 83s 42ms/step - loss: 1.0414 - model_acc: 0.6397 - val_loss: 1.2009 - val_model_acc: 0.5754
Epoch 7/25
1992/1992 [==============================] - 83s 42ms/step - loss: 0.9986 - model_acc: 0.6576 - val_loss: 1.1812 - val_model_acc: 0.5895
Epoch 8/25
1992/1992 [==============================] - 83s 42ms/step - loss: 0.9515 - model_acc: 0.6773 - val_loss: 1.1701 - val_model_acc: 0.5824
Epoch 9/25
1992/1992 [==============================] - 82s 41ms/step - loss: 0.9093 - model_acc: 0.6957 - val_loss: 1.1569 - val_model_acc: 0.5974
Epoch 10/25
1992/1992 [==============================] - 82s 41ms/step - loss: 0.8653 - model_acc: 0.7119 - val_loss: 1.1609 - val_model_acc: 0.6028
Epoch 11/25
1992/1992 [==============================] - 84s 42ms/step - loss: 0.8226 - model_acc: 0.7325 - val_loss: 1.1610 - val_model_acc: 0.5988
Epoch 12/25
1992/1992 [==============================] - 84s 42ms/step - loss: 0.7832 - model_acc: 0.7480 - val_loss: 1.1740 - val_model_acc: 0.5996
Epoch 13/25
1992/1992 [==============================] - 83s 42ms/step - loss: 0.7429 - model_acc: 0.7669 - val_loss: 1.1735 - val_model_acc: 0.5977
Epoch 14/25
1992/1992 [==============================] - 83s 42ms/step - loss: 0.7047 - model_acc: 0.7826 - val_loss: 1.1738 - val_model_acc: 0.6028
Epoch 15/25
1992/1992 [==============================] - 83s 42ms/step - loss: 0.6678 - model_acc: 0.7980 - val_loss: 1.1787 - val_model_acc: 0.6087
Epoch 16/25
1992/1992 [==============================] - 83s 41ms/step - loss: 0.6324 - model_acc: 0.8116 - val_loss: 1.1809 - val_model_acc: 0.6070
Epoch 17/25
1992/1992 [==============================] - 81s 41ms/step - loss: 0.5969 - model_acc: 0.8241 - val_loss: 1.2010 - val_model_acc: 0.6056
```

```
Epoch 18/25
1992/1992 [==============================] - 82s 41ms/step - loss: 0.5650 - model_acc: 0.8379 - val_loss: 1.2313 - val_model_acc: 0.5963
Epoch 19/25
1992/1992 [==============================] - 84s 42ms/step - loss: 0.5336 - model_acc: 0.8491 - val_loss: 1.1998 - val_model_acc: 0.6192
Epoch 20/25
1992/1992 [==============================] - 84s 42ms/step - loss: 0.5046 - model_acc: 0.8606 - val_loss: 1.2280 - val_model_acc: 0.6067
Epoch 21/25
1992/1992 [==============================] - 83s 42ms/step - loss: 0.4779 - model_acc: 0.8704 - val_loss: 1.2427 - val_model_acc: 0.6061
Epoch 22/25
1992/1992 [==============================] - 83s 42ms/step - loss: 0.4499 - model_acc: 0.8814 - val_loss: 1.2797 - val_model_acc: 0.6178
Epoch 23/25
1992/1992 [==============================] - 83s 42ms/step - loss: 0.4252 - model_acc: 0.8901 - val_loss: 1.3108 - val_model_acc: 0.6186
Epoch 24/25
1992/1992 [==============================] - 83s 41ms/step - loss: 0.4025 - model_acc: 0.8974 - val_loss: 1.2808 - val_model_acc: 0.6200
Epoch 25/25
1992/1992 [==============================] - 82s 41ms/step - loss: 0.3818 - model_acc: 0.9032 - val_loss: 1.3080 - val_model_acc: 0.6172
Out[10]: <tensorflow.python.keras.callbacks.History at 0x20b4d720f10>
```

In [11]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=8,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
3983/3983 [==============================] - 130s 32ms/step - loss: 1.3464 - model_acc: 0.5159 - val_loss: 1.3108 - val_model_acc: 0.5369
Epoch 2/25
3983/3983 [==============================] - 130s 33ms/step - loss: 1.2291 - model_acc: 0.5591 - val_loss: 1.3112 - val_model_acc: 0.5267
Epoch 3/25
3983/3983 [==============================] - 130s 33ms/step - loss: 1.1636 - model_acc: 0.5895 - val_loss: 1.2266 - val_model_acc: 0.5716
Epoch 4/25
3983/3983 [==============================] - 129s 33ms/step - loss: 1.1025 - model_acc: 0.6131 - val_loss: 1.2316 - val_model_acc: 0.5465
Epoch 5/25
3983/3983 [==============================] - 129s 32ms/step - loss: 1.0439 - model_acc: 0.6372 - val_loss: 1.2063 - val_model_acc: 0.5818
Epoch 6/25
3983/3983 [==============================] - 129s 32ms/step - loss: 0.9886 - model_acc: 0.6600 - val_loss: 1.1719 - val_model_acc: 0.5841
Epoch 7/25
3983/3983 [==============================] - 128s 32ms/step - loss: 0.9302 - model_acc: 0.6828 - val_loss: 1.1692 - val_model_acc: 0.5903
Epoch 8/25
3983/3983 [==============================] - 129s 32ms/step - loss: 0.8775 - model_acc: 0.7068 - val_loss: 1.2073 - val_model_acc: 0.5810
Epoch 9/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.8223 - model_acc: 0.7290 - val_loss: 1.1840 - val_model_acc: 0.5920
Epoch 10/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.7723 - model_acc: 0.7469 - val_loss: 1.1778 - val_model_acc: 0.6008
Epoch 11/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.7203 - model_acc: 0.7710 - val_loss: 1.1761 - val_model_acc: 0.6065
Epoch 12/25
3983/3983 [==============================] - 129s 32ms/step - loss: 0.6725 - model_acc: 0.7884 - val_loss: 1.1949 - val_model_acc: 0.6113
Epoch 13/25
3983/3983 [==============================] - 129s 32ms/step - loss: 0.6270 - model_acc: 0.8100 - val_loss: 1.2551 - val_model_acc: 0.5973
Epoch 14/25
3983/3983 [==============================] - 128s 32ms/step - loss: 0.5835 - model_acc: 0.8258 - val_loss: 1.2306 - val_model_acc: 0.6005
Epoch 15/25
3983/3983 [==============================] - 129s 32ms/step - loss: 0.5444 - model_acc: 0.8412 - val_loss: 1.2301 - val_model_acc: 0.6107
Epoch 16/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.5055 - model_acc: 0.8552 - val_loss: 1.2438 - val_model_acc: 0.6081
Epoch 17/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.4680 - model_acc: 0.8691 - val_loss: 1.3174 - val_model_acc: 0.6194
Epoch 18/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.4361 - model_acc: 0.8810 - val_loss: 1.3080 - val_model_acc: 0.6126
Epoch 19/25
3983/3983 [==============================] - 129s 32ms/step - loss: 0.4046 - model_acc: 0.8918 - val_loss: 1.3344 - val_model_acc: 0.6130
Epoch 20/25
3983/3983 [==============================] - 129s 32ms/step - loss: 0.3755 - model_acc: 0.9029 - val_loss: 1.3401 - val_model_acc: 0.6095
Epoch 21/25
3983/3983 [==============================] - 128s 32ms/step - loss: 0.3518 - model_acc: 0.9124 - val_loss: 1.3838 - val_model_acc: 0.6251
Epoch 22/25
```

```
3983/3983 [==============================] - 130s 33ms/step - loss: 0.3275 - model_acc: 0.9197 - val_loss: 1.4253 - val_model_acc: 0.6007
Epoch 23/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.3079 - model_acc: 0.9258 - val_loss: 1.4461 - val_model_acc: 0.6003
Epoch 24/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.2855 - model_acc: 0.9343 - val_loss: 1.5149 - val_model_acc: 0.6126
Epoch 25/25
3983/3983 [==============================] - 130s 33ms/step - loss: 0.2703 - model_acc: 0.9409 - val_loss: 1.4826 - val_model_acc: 0.6124
```

Out[11]:

```
<tensorflow.python.keras.callbacks.History at 0x20b50248700>
```

In [12]:

```python
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(2048, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 63s 64ms/step - loss: 1.3772 - model_acc: 0.5005 - val_loss: 1.3272 - val_model_acc: 0.5293
Epoch 2/25
996/996 [==============================] - 63s 63ms/step - loss: 1.2697 - model_acc: 0.5464 - val_loss: 1.2933 - val_model_acc: 0.5394
Epoch 3/25
996/996 [==============================] - 62s 62ms/step - loss: 1.2248 - model_acc: 0.5643 - val_loss: 1.2630 - val_model_acc: 0.5575
```

```
Epoch 4/25
996/996 [==============================] - 62s 62ms/step - loss: 1.1910 - model_acc: 0.5792 - val_loss: 1.2529 - val_model_acc: 0.5530
Epoch 5/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1588 - model_acc: 0.5918 - val_loss: 1.2393 - val_model_acc: 0.5591
Epoch 6/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1297 - model_acc: 0.6033 - val_loss: 1.2208 - val_model_acc: 0.5639
Epoch 7/25
996/996 [==============================] - 63s 64ms/step - loss: 1.1028 - model_acc: 0.6163 - val_loss: 1.2104 - val_model_acc: 0.5670
Epoch 8/25
996/996 [==============================] - 63s 63ms/step - loss: 1.0751 - model_acc: 0.6275 - val_loss: 1.2090 - val_model_acc: 0.5690
Epoch 9/25
996/996 [==============================] - 63s 63ms/step - loss: 1.0481 - model_acc: 0.6374 - val_loss: 1.1985 - val_model_acc: 0.5780
Epoch 10/25
996/996 [==============================] - 63s 64ms/step - loss: 1.0222 - model_acc: 0.6526 - val_loss: 1.2231 - val_model_acc: 0.5717
Epoch 11/25
996/996 [==============================] - 62s 63ms/step - loss: 0.9978 - model_acc: 0.6608 - val_loss: 1.1822 - val_model_acc: 0.5858
Epoch 12/25
996/996 [==============================] - 62s 62ms/step - loss: 0.9719 - model_acc: 0.6726 - val_loss: 1.1782 - val_model_acc: 0.5873
Epoch 13/25
996/996 [==============================] - 62s 62ms/step - loss: 0.9471 - model_acc: 0.6810 - val_loss: 1.1761 - val_model_acc: 0.5909
Epoch 14/25
996/996 [==============================] - 64s 65ms/step - loss: 0.9228 - model_acc: 0.6947 - val_loss: 1.1656 - val_model_acc: 0.5892
Epoch 15/25
996/996 [==============================] - 64s 64ms/step - loss: 0.8974 - model_acc: 0.7040 - val_loss: 1.1615 - val_model_acc: 0.5986
Epoch 16/25
996/996 [==============================] - 63s 64ms/step - loss: 0.8751 - model_acc: 0.7150 - val_loss: 1.1608 - val_model_acc: 0.5934
Epoch 17/25
996/996 [==============================] - 63s 64ms/step - loss: 0.8513 - model_acc: 0.7243 - val_loss: 1.1667 - val_model_acc: 0.5977
Epoch 18/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8283 - model_acc: 0.7345 - val_loss: 1.1633 - val_model_acc: 0.6030
Epoch 19/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8055 - model_acc: 0.7453 - val_loss: 1.1662 - val_model_acc: 0.5920
Epoch 20/25
996/996 [==============================] - 62s 62ms/step - loss: 0.7842 - model_acc: 0.7551 - val_loss: 1.1599 - val_model_acc: 0.6084
Epoch 21/25
996/996 [==============================] - 62s 62ms/step - loss: 0.7618 - model_acc: 0.7640 - val_loss: 1.1633 - val_model_acc: 0.6002
Epoch 22/25
996/996 [==============================] - 63s 64ms/step - loss: 0.7407 - model_acc: 0.7712 - val_loss: 1.1621 - val_model_acc: 0.6058
Epoch 23/25
996/996 [==============================] - 64s 64ms/step - loss: 0.7217 - model_acc: 0.7800 - val_loss: 1.1720 - val_model_acc: 0.6053
Epoch 24/25
996/996 [==============================] - 63s 64ms/step - loss: 0.7013 - model_acc: 0.7910 - val_loss: 1.1584 - val_model_acc: 0.6120
Epoch 25/25
996/996 [==============================] - 63s 63ms/step - loss: 0.6825 - model_acc: 0.7970 - val_loss: 1.1735 - val_model_acc: 0.6148
```

Out[12]:

```
<tensorflow.python.keras.callbacks.History at 0x20b4ca6fe20>
```

In [13]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(2048, activation='relu'),
    layers.Dense(2048, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3525 - model_acc: 0.5101 - val_loss: 1.2981 - val_model_acc: 0.5326
Epoch 2/25
996/996 [==============================] - 64s 65ms/step - loss: 1.2221 - model_acc: 0.5664 - val_loss: 1.2450 - val_model_acc: 0.5552
Epoch 3/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1401 - model_acc: 0.5967 - val_loss: 1.2273 - val_model_acc: 0.5655
Epoch 4/25
996/996 [==============================] - 63s 63ms/step - loss: 1.0620 - model_acc: 0.6335 - val_loss: 1.1949 - val_model_acc: 0.5816
Epoch 5/25
996/996 [==============================] - 63s 63ms/step - loss: 0.9817 - model_acc: 0.6629 - val_loss: 1.2060 - val_model_acc: 0.5729
Epoch 6/25
996/996 [==============================] - 65s 66ms/step - loss: 0.8971 - model_acc: 0.6970 - val_loss: 1.1885 - val_model_acc: 0.5855
Epoch 7/25
996/996 [==============================] - 65s 65ms/step - loss: 0.8171 - model_acc: 0.7285 - val_loss: 1.1746 - val_model_acc: 0.5941
Epoch 8/25
```

```
996/996 [==============================] - 64s 65ms/step - loss: 0.7352 - model_acc: 0.7614 - val_loss: 1.2249 - val_model_acc: 0.5867
Epoch 9/25
996/996 [==============================] - 64s 65ms/step - loss: 0.6562 - model_acc: 0.7950 - val_loss: 1.2825 - val_model_acc: 0.5829
Epoch 10/25
996/996 [==============================] - 64s 64ms/step - loss: 0.5876 - model_acc: 0.8193 - val_loss: 1.2931 - val_model_acc: 0.5943
Epoch 11/25
996/996 [==============================] - 64s 65ms/step - loss: 0.5245 - model_acc: 0.8438 - val_loss: 1.3468 - val_model_acc: 0.6123
Epoch 12/25
996/996 [==============================] - 63s 63ms/step - loss: 0.4692 - model_acc: 0.8626 - val_loss: 1.4205 - val_model_acc: 0.6083
Epoch 13/25
996/996 [==============================] - 63s 63ms/step - loss: 0.4186 - model_acc: 0.8805 - val_loss: 1.4122 - val_model_acc: 0.6100
Epoch 14/25
996/996 [==============================] - 64s 64ms/step - loss: 0.3700 - model_acc: 0.8989 - val_loss: 1.5361 - val_model_acc: 0.6005
Epoch 15/25
996/996 [==============================] - 65s 66ms/step - loss: 0.3392 - model_acc: 0.9093 - val_loss: 1.6066 - val_model_acc: 0.5968
Epoch 16/25
996/996 [==============================] - 65s 65ms/step - loss: 0.3054 - model_acc: 0.9222 - val_loss: 1.6529 - val_model_acc: 0.6022
Epoch 17/25
996/996 [==============================] - 64s 65ms/step - loss: 0.2816 - model_acc: 0.9308 - val_loss: 1.6659 - val_model_acc: 0.6151
Epoch 18/25
996/996 [==============================] - 64s 65ms/step - loss: 0.2537 - model_acc: 0.9406 - val_loss: 1.7049 - val_model_acc: 0.6177
Epoch 19/25
996/996 [==============================] - 64s 65ms/step - loss: 0.2345 - model_acc: 0.9475 - val_loss: 1.7670 - val_model_acc: 0.6151
Epoch 20/25
996/996 [==============================] - 64s 64ms/step - loss: 0.2261 - model_acc: 0.9490 - val_loss: 1.8428 - val_model_acc: 0.6132
Epoch 21/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2017 - model_acc: 0.9581 - val_loss: 1.8345 - val_model_acc: 0.6118
Epoch 22/25
996/996 [==============================] - 63s 63ms/step - loss: 0.1935 - model_acc: 0.9613 - val_loss: 1.8708 - val_model_acc: 0.6137
Epoch 23/25
996/996 [==============================] - 65s 66ms/step - loss: 0.1811 - model_acc: 0.9647 - val_loss: 1.9378 - val_model_acc: 0.6199
Epoch 24/25
996/996 [==============================] - 65s 65ms/step - loss: 0.1708 - model_acc: 0.9694 - val_loss: 1.9353 - val_model_acc: 0.6222
Epoch 25/25
996/996 [==============================] - 64s 65ms/step - loss: 0.1618 - model_acc: 0.9723 - val_loss: 1.9516 - val_model_acc: 0.6170
```

Out[13]:

```
<tensorflow.python.keras.callbacks.History at 0x20b539874c0>
```

In [14]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(256, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3551 - model_acc: 0.5085 - val_loss: 1.3092 - val_model_acc: 0.5256
Epoch 2/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2325 - model_acc: 0.5610 - val_loss: 1.2495 - val_model_acc: 0.5625
Epoch 3/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1629 - model_acc: 0.5906 - val_loss: 1.2209 - val_model_acc: 0.5611
Epoch 4/25
996/996 [==============================] - 63s 63ms/step - loss: 1.0973 - model_acc: 0.6148 - val_loss: 1.2428 - val_model_acc: 0.5554
Epoch 5/25
996/996 [==============================] - 63s 63ms/step - loss: 1.0341 - model_acc: 0.6423 - val_loss: 1.1783 - val_model_acc: 0.5830
Epoch 6/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9658 - model_acc: 0.6702 - val_loss: 1.1685 - val_model_acc: 0.5876
Epoch 7/25
996/996 [==============================] - 65s 65ms/step - loss: 0.9002 - model_acc: 0.6962 - val_loss: 1.1704 - val_model_acc: 0.5886
Epoch 8/25
996/996 [==============================] - 64s 65ms/step - loss: 0.8278 - model_acc: 0.7227 - val_loss: 1.1764 - val_model_acc: 0.5917
Epoch 9/25
996/996 [==============================] - 64s 64ms/step - loss: 0.7589 - model_acc: 0.7554 - val_loss: 1.2208 - val_model_acc: 0.5856
Epoch 10/25
996/996 [==============================] - 64s 64ms/step - loss: 0.6933 - model_acc: 0.7800 - val_loss: 1.1887 - val_model_acc: 0.6032
Epoch 11/25
996/996 [==============================] - 64s 64ms/step - loss: 0.6319 - model_acc: 0.8048 - val_loss: 1.2583 - val_model_acc: 0.6088
Epoch 12/25
```

```
996/996 [==============================] - 64s 64ms/step - loss: 0.5706 - model_acc: 0.8280 - val_loss: 1.3097 - val_model_acc: 0.5836
Epoch 13/25
996/996 [==============================] - 62s 63ms/step - loss: 0.5139 - model_acc: 0.8504 - val_loss: 1.2945 - val_model_acc: 0.6095
Epoch 14/25
996/996 [==============================] - 62s 63ms/step - loss: 0.4708 - model_acc: 0.8648 - val_loss: 1.4183 - val_model_acc: 0.5889
Epoch 15/25
996/996 [==============================] - 65s 65ms/step - loss: 0.4234 - model_acc: 0.8824 - val_loss: 1.3568 - val_model_acc: 0.6200
Epoch 16/25
996/996 [==============================] - 65s 65ms/step - loss: 0.3854 - model_acc: 0.8954 - val_loss: 1.4353 - val_model_acc: 0.6216
Epoch 17/25
996/996 [==============================] - 64s 64ms/step - loss: 0.3508 - model_acc: 0.9086 - val_loss: 1.4697 - val_model_acc: 0.6134
Epoch 18/25
996/996 [==============================] - 64s 64ms/step - loss: 0.3189 - model_acc: 0.9184 - val_loss: 1.5681 - val_model_acc: 0.5999
Epoch 19/25
996/996 [==============================] - 64s 64ms/step - loss: 0.2936 - model_acc: 0.9284 - val_loss: 1.5852 - val_model_acc: 0.6064
Epoch 20/25
996/996 [==============================] - 64s 64ms/step - loss: 0.2729 - model_acc: 0.9362 - val_loss: 1.6727 - val_model_acc: 0.5987
Epoch 21/25
996/996 [==============================] - 63s 63ms/step - loss: 0.2533 - model_acc: 0.9412 - val_loss: 1.6852 - val_model_acc: 0.6174
Epoch 22/25
996/996 [==============================] - 62s 63ms/step - loss: 0.2363 - model_acc: 0.9468 - val_loss: 1.7741 - val_model_acc: 0.6140
Epoch 23/25
996/996 [==============================] - 63s 64ms/step - loss: 0.2221 - model_acc: 0.9533 - val_loss: 1.7651 - val_model_acc: 0.6174
Epoch 24/25
996/996 [==============================] - 65s 65ms/step - loss: 0.2088 - model_acc: 0.9576 - val_loss: 1.8064 - val_model_acc: 0.6098
Epoch 25/25
996/996 [==============================] - 64s 64ms/step - loss: 0.1942 - model_acc: 0.9616 - val_loss: 1.8713 - val_model_acc: 0.5908
```

Out[14]:

```
<tensorflow.python.keras.callbacks.History at 0x20b53a49430>
```

In [15]:

```
#multilabel
```

In [16]:

```
emotions = emotions_multi
emotions = tf.convert_to_tensor(emotions)

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, 3)
training_emotions shape: (31858, 8)
test_images shape: (3535, 48, 48, 3)
test_emotions shape: (3535, 8)
```

In [17]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 63s 63ms/step - loss: 1.4881 - model_acc: 0.5122 - val_loss: 1.4466 - val_model_acc: 0.5364
Epoch 2/25
996/996 [==============================] - 64s 64ms/step - loss: 1.4095 - model_acc: 0.5526 - val_loss: 1.4093 - val_model_acc: 0.5406
Epoch 3/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3733 - model_acc: 0.5741 - val_loss: 1.4356 - val_model_acc: 0.5287
Epoch 4/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3450 - model_acc: 0.5891 - val_loss: 1.3870 - val_model_acc: 0.5504
Epoch 5/25
996/996 [==============================] - 62s 62ms/step - loss: 1.3168 - model_acc: 0.6039 - val_loss: 1.3632 - val_model_acc: 0.5752
Epoch 6/25
```

```
996/996 [==============================] - 62s 63ms/step - loss: 1.2894 - model_acc: 0.6223 - val_loss: 1.3447 - val_model_acc: 0.5881
Epoch 7/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2666 - model_acc: 0.6349 - val_loss: 1.3427 - val_model_acc: 0.5810
Epoch 8/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2404 - model_acc: 0.6501 - val_loss: 1.3337 - val_model_acc: 0.5861
Epoch 9/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2177 - model_acc: 0.6661 - val_loss: 1.3227 - val_model_acc: 0.5901
Epoch 10/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1922 - model_acc: 0.6812 - val_loss: 1.3228 - val_model_acc: 0.5870
Epoch 11/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1694 - model_acc: 0.6937 - val_loss: 1.3170 - val_model_acc: 0.5934
Epoch 12/25
996/996 [==============================] - 64s 64ms/step - loss: 1.1465 - model_acc: 0.7071 - val_loss: 1.3200 - val_model_acc: 0.5918
Epoch 13/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1254 - model_acc: 0.7201 - val_loss: 1.3023 - val_model_acc: 0.6016
Epoch 14/25
996/996 [==============================] - 62s 62ms/step - loss: 1.1049 - model_acc: 0.7328 - val_loss: 1.3050 - val_model_acc: 0.5976
Epoch 15/25
996/996 [==============================] - 62s 63ms/step - loss: 1.0843 - model_acc: 0.7433 - val_loss: 1.3036 - val_model_acc: 0.6061
Epoch 16/25
996/996 [==============================] - 65s 65ms/step - loss: 1.0640 - model_acc: 0.7564 - val_loss: 1.3060 - val_model_acc: 0.6005
Epoch 17/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0465 - model_acc: 0.7669 - val_loss: 1.3119 - val_model_acc: 0.5998
Epoch 18/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0281 - model_acc: 0.7787 - val_loss: 1.3178 - val_model_acc: 0.6029
Epoch 19/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0101 - model_acc: 0.7892 - val_loss: 1.3319 - val_model_acc: 0.6016
Epoch 20/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9949 - model_acc: 0.7957 - val_loss: 1.3257 - val_model_acc: 0.6092
Epoch 21/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9773 - model_acc: 0.8057 - val_loss: 1.3127 - val_model_acc: 0.6125
Epoch 22/25
996/996 [==============================] - 62s 62ms/step - loss: 0.9630 - model_acc: 0.8126 - val_loss: 1.3143 - val_model_acc: 0.6024
Epoch 23/25
996/996 [==============================] - 62s 62ms/step - loss: 0.9475 - model_acc: 0.8224 - val_loss: 1.3081 - val_model_acc: 0.6160
Epoch 24/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9326 - model_acc: 0.8319 - val_loss: 1.3328 - val_model_acc: 0.6108
Epoch 25/25
996/996 [==============================] - 64s 65ms/step - loss: 0.9193 - model_acc: 0.8388 - val_loss: 1.3114 - val_model_acc: 0.6055
```

Out[17]:

```
<tensorflow.python.keras.callbacks.History at 0x20b4d71d760>
```

In [18]:

```python
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
```

```
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 64s 64ms/step - loss: 1.6119 - model_acc: 0.4510 - val_loss: 1.5461 - val_model_acc: 0.4837
Epoch 2/25
996/996 [==============================] - 63s 64ms/step - loss: 1.5103 - model_acc: 0.5092 - val_loss: 1.5045 - val_model_acc: 0.5076
Epoch 3/25
996/996 [==============================] - 64s 64ms/step - loss: 1.4777 - model_acc: 0.5230 - val_loss: 1.4827 - val_model_acc: 0.5166
Epoch 4/25
996/996 [==============================] - 64s 64ms/step - loss: 1.4577 - model_acc: 0.5328 - val_loss: 1.4694 - val_model_acc: 0.5248
Epoch 5/25
996/996 [==============================] - 63s 63ms/step - loss: 1.4434 - model_acc: 0.5393 - val_loss: 1.4592 - val_model_acc: 0.5358
Epoch 6/25
996/996 [==============================] - 62s 62ms/step - loss: 1.4321 - model_acc: 0.5454 - val_loss: 1.4482 - val_model_acc: 0.5344
Epoch 7/25
996/996 [==============================] - 62s 63ms/step - loss: 1.4227 - model_acc: 0.5491 - val_loss: 1.4424 - val_model_acc: 0.5394
Epoch 8/25
996/996 [==============================] - 64s 65ms/step - loss: 1.4149 - model_acc: 0.5525 - val_loss: 1.4356 - val_model_acc: 0.5462
Epoch 9/25
996/996 [==============================] - 64s 64ms/step - loss: 1.4076 - model_acc: 0.5560 - val_loss: 1.4314 - val_model_acc: 0.5453
Epoch 10/25
996/996 [==============================] - 64s 64ms/step - loss: 1.4015 - model_acc: 0.5605 - val_loss: 1.4269 - val_model_acc: 0.5493
```

```
Epoch 11/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3955 - model_acc: 0.5637 - val_loss: 1.4224 - val_model_acc: 0.5524
Epoch 12/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3900 - model_acc: 0.5670 - val_loss: 1.4184 - val_model_acc: 0.5479
Epoch 13/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3850 - model_acc: 0.5692 - val_loss: 1.4149 - val_model_acc: 0.5510
Epoch 14/25
996/996 [==============================] - 62s 62ms/step - loss: 1.3804 - model_acc: 0.5709 - val_loss: 1.4116 - val_model_acc: 0.5484
Epoch 15/25
996/996 [==============================] - 62s 62ms/step - loss: 1.3759 - model_acc: 0.5722 - val_loss: 1.4089 - val_model_acc: 0.5563
Epoch 16/25
996/996 [==============================] - 63s 64ms/step - loss: 1.3719 - model_acc: 0.5757 - val_loss: 1.4047 - val_model_acc: 0.5544
Epoch 17/25
996/996 [==============================] - 64s 65ms/step - loss: 1.3675 - model_acc: 0.5786 - val_loss: 1.4029 - val_model_acc: 0.5538
Epoch 18/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3635 - model_acc: 0.5804 - val_loss: 1.4006 - val_model_acc: 0.5529
Epoch 19/25
996/996 [==============================] - 63s 64ms/step - loss: 1.3597 - model_acc: 0.5832 - val_loss: 1.3978 - val_model_acc: 0.5555
Epoch 20/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3558 - model_acc: 0.5844 - val_loss: 1.3961 - val_model_acc: 0.5555
Epoch 21/25
996/996 [==============================] - 63s 64ms/step - loss: 1.3520 - model_acc: 0.5867 - val_loss: 1.3941 - val_model_acc: 0.5552
Epoch 22/25
996/996 [==============================] - 63s 63ms/step - loss: 1.3485 - model_acc: 0.5892 - val_loss: 1.3914 - val_model_acc: 0.5611
Epoch 23/25
996/996 [==============================] - 62s 62ms/step - loss: 1.3447 - model_acc: 0.5912 - val_loss: 1.3924 - val_model_acc: 0.5574
Epoch 24/25
996/996 [==============================] - 62s 62ms/step - loss: 1.3415 - model_acc: 0.5932 - val_loss: 1.3875 - val_model_acc: 0.5597
Epoch 25/25
996/996 [==============================] - 65s 65ms/step - loss: 1.3380 - model_acc: 0.5930 - val_loss: 1.3864 - val_model_acc: 0.5585
```

Out[18]:

```
<tensorflow.python.keras.callbacks.History at 0x20b902eedc0>
```

In [19]:

```
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-3), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 64s 65ms/step - loss: 1.4758 - model_acc: 0.5137 - val_loss: 1.4800 - val_model_acc: 0.5130
Epoch 2/25
996/996 [==============================] - 63s 64ms/step - loss: 1.3902 - model_acc: 0.5622 - val_loss: 1.3908 - val_model_acc: 0.5465
Epoch 3/25
996/996 [==============================] - 63s 64ms/step - loss: 1.3400 - model_acc: 0.5896 - val_loss: 1.3656 - val_model_acc: 0.5608
Epoch 4/25
996/996 [==============================] - 63s 64ms/step - loss: 1.2922 - model_acc: 0.6163 - val_loss: 1.3609 - val_model_acc: 0.5760
Epoch 5/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2476 - model_acc: 0.6412 - val_loss: 1.3620 - val_model_acc: 0.5810
Epoch 6/25
996/996 [==============================] - 62s 63ms/step - loss: 1.2031 - model_acc: 0.6658 - val_loss: 1.3415 - val_model_acc: 0.5876
Epoch 7/25
996/996 [==============================] - 62s 62ms/step - loss: 1.1590 - model_acc: 0.6883 - val_loss: 1.3631 - val_model_acc: 0.5827
Epoch 8/25
996/996 [==============================] - 63s 63ms/step - loss: 1.1150 - model_acc: 0.7154 - val_loss: 1.3561 - val_model_acc: 0.5960
Epoch 9/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0752 - model_acc: 0.7369 - val_loss: 1.3604 - val_model_acc: 0.5940
Epoch 10/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0384 - model_acc: 0.7579 - val_loss: 1.3660 - val_model_acc: 0.5959
Epoch 11/25
996/996 [==============================] - 63s 64ms/step - loss: 1.0036 - model_acc: 0.7761 - val_loss: 1.3814 - val_model_acc: 0.5939
Epoch 12/25
996/996 [==============================] - 63s 64ms/step - loss: 0.9686 - model_acc: 0.7956 - val_loss: 1.4234 - val_model_acc: 0.5959
Epoch 13/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9441 - model_acc: 0.8071 - val_loss: 1.4110 - val_model_acc: 0.6056
Epoch 14/25
996/996 [==============================] - 63s 63ms/step - loss: 0.9167 - model_acc: 0.8193 - val_loss: 1.4209 - val_model_acc: 0.6044
Epoch 15/25
```

```
996/996 [==============================] - 62s 62ms/step - loss: 0.8930 - model_acc: 0.8335 - val_loss: 1.4596 - val_model_acc: 0.6039
Epoch 16/25
996/996 [==============================] - 62s 62ms/step - loss: 0.8733 - model_acc: 0.8453 - val_loss: 1.4442 - val_model_acc: 0.6185
Epoch 17/25
996/996 [==============================] - 64s 64ms/step - loss: 0.8549 - model_acc: 0.8518 - val_loss: 1.4499 - val_model_acc: 0.6033
Epoch 18/25
996/996 [==============================] - 64s 64ms/step - loss: 0.8413 - model_acc: 0.8567 - val_loss: 1.4697 - val_model_acc: 0.6216
Epoch 19/25
996/996 [==============================] - 64s 64ms/step - loss: 0.8213 - model_acc: 0.8688 - val_loss: 1.4790 - val_model_acc: 0.6002
Epoch 20/25
996/996 [==============================] - 63s 64ms/step - loss: 0.8097 - model_acc: 0.8714 - val_loss: 1.4668 - val_model_acc: 0.6089
Epoch 21/25
996/996 [==============================] - 63s 64ms/step - loss: 0.7960 - model_acc: 0.8782 - val_loss: 1.5142 - val_model_acc: 0.6140
Epoch 22/25
996/996 [==============================] - 63s 64ms/step - loss: 0.7848 - model_acc: 0.8831 - val_loss: 1.5420 - val_model_acc: 0.6002
Epoch 23/25
996/996 [==============================] - 63s 63ms/step - loss: 0.7756 - model_acc: 0.8856 - val_loss: 1.5428 - val_model_acc: 0.5926
Epoch 24/25
996/996 [==============================] - 62s 62ms/step - loss: 0.7668 - model_acc: 0.8876 - val_loss: 1.5256 - val_model_acc: 0.6033
Epoch 25/25
996/996 [==============================] - 63s 63ms/step - loss: 0.7578 - model_acc: 0.8926 - val_loss: 1.5331 - val_model_acc: 0.6135
```

Out[19]:

```
<tensorflow.python.keras.callbacks.History at 0x20b90e3ff10>
```

In [20]:

```python
base_model = vgg16.VGG16(include_top=False, weights="imagenet", input_shape=(48,48,3))
#base_model = resnet.ResNet50(include_top=False, weights="imagenet", input_shape=(48,48,3))
base_model.trainable=False
model = Sequential([
    base_model,
    layers.GlobalAveragePooling2D(),
    layers.Dense(4096, activation='relu'),
    layers.Dense(256, activation='relu'),
    layers.Dense(emotions_count, activation='softmax'),
])

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
model.compile(optimizer=adam.Adam(learning_rate=1e-4), loss=losses.CategoricalCrossentropy(), metrics = [model_acc])

model.fit(x=training_images,
          y=training_emotions,
          batch_size=32,
          epochs=25,
          validation_data=(test_images, test_emotions))
```

```
Epoch 1/25
996/996 [==============================] - 65s 65ms/step - loss: 1.4817 - model_acc: 0.5118 - val_loss: 1.4379 - val_model_acc: 0.5408
Epoch 2/25
996/996 [==============================] - 64s 65ms/step - loss: 1.3948 - model_acc: 0.5588 - val_loss: 1.3986 - val_model_acc: 0.5467
Epoch 3/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3468 - model_acc: 0.5835 - val_loss: 1.3597 - val_model_acc: 0.5667
Epoch 4/25
996/996 [==============================] - 64s 64ms/step - loss: 1.3032 - model_acc: 0.6104 - val_loss: 1.3485 - val_model_acc: 0.5743
Epoch 5/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2626 - model_acc: 0.6365 - val_loss: 1.3495 - val_model_acc: 0.5762
Epoch 6/25
996/996 [==============================] - 64s 64ms/step - loss: 1.2188 - model_acc: 0.6589 - val_loss: 1.3255 - val_model_acc: 0.5828
Epoch 7/25
996/996 [==============================] - 62s 63ms/step - loss: 1.1755 - model_acc: 0.6853 - val_loss: 1.3166 - val_model_acc: 0.6013
Epoch 8/25
996/996 [==============================] - 62s 63ms/step - loss: 1.1313 - model_acc: 0.7133 - val_loss: 1.3294 - val_model_acc: 0.5917
Epoch 9/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0886 - model_acc: 0.7360 - val_loss: 1.3246 - val_model_acc: 0.5988
Epoch 10/25
996/996 [==============================] - 65s 65ms/step - loss: 1.0479 - model_acc: 0.7594 - val_loss: 1.3228 - val_model_acc: 0.6089
Epoch 11/25
996/996 [==============================] - 64s 64ms/step - loss: 1.0120 - model_acc: 0.7816 - val_loss: 1.3148 - val_model_acc: 0.6139
Epoch 12/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9743 - model_acc: 0.8010 - val_loss: 1.3324 - val_model_acc: 0.6162
Epoch 13/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9442 - model_acc: 0.8156 - val_loss: 1.3495 - val_model_acc: 0.5982
Epoch 14/25
996/996 [==============================] - 64s 64ms/step - loss: 0.9139 - model_acc: 0.8329 - val_loss: 1.3449 - val_model_acc: 0.6187
Epoch 15/25
996/996 [==============================] - 63s 63ms/step - loss: 0.8882 - model_acc: 0.8450 - val_loss: 1.3579 - val_model_acc: 0.6105
Epoch 16/25
996/996 [==============================] - 62s 62ms/step - loss: 0.8637 - model_acc: 0.8562 - val_loss: 1.3803 - val_model_acc: 0.6137
Epoch 17/25
996/996 [==============================] - 64s 64ms/step - loss: 0.8403 - model_acc: 0.8691 - val_loss: 1.3901 - val_model_acc: 0.6060
Epoch 18/25
996/996 [==============================] - 66s 67ms/step - loss: 0.8235 - model_acc: 0.8761 - val_loss: 1.4071 - val_model_acc: 0.6122
Epoch 19/25
```

```
996/996 [==============================] - 67s 68ms/step - loss: 0.8059 - model_acc: 0.8853 - val_loss: 1.4024 - val_model_acc: 0.6171
Epoch 20/25
996/996 [==============================] - 66s 66ms/step - loss: 0.7871 - model_acc: 0.8925 - val_loss: 1.3994 - val_model_acc: 0.6188
Epoch 21/25
996/996 [==============================] - 66s 67ms/step - loss: 0.7735 - model_acc: 0.8964 - val_loss: 1.4091 - val_model_acc: 0.6128
Epoch 22/25
996/996 [==============================] - 66s 66ms/step - loss: 0.7587 - model_acc: 0.9031 - val_loss: 1.4166 - val_model_acc: 0.6235
Epoch 23/25
996/996 [==============================] - 67s 67ms/step - loss: 0.7493 - model_acc: 0.9060 - val_loss: 1.4309 - val_model_acc: 0.6163
Epoch 24/25
996/996 [==============================] - 66s 67ms/step - loss: 0.7396 - model_acc: 0.9090 - val_loss: 1.4381 - val_model_acc: 0.6225
Epoch 25/25
996/996 [==============================] - 65s 65ms/step - loss: 0.7282 - model_acc: 0.9153 - val_loss: 1.4488 - val_model_acc: 0.6236
```

```
Out[20]: <tensorflow.python.keras.callbacks.History at 0x20b919efc40>
```