Import frames and train, test, evaluate network on facial images

Importing Dependencies

```
from google.colab import drive
drive.mount('/content/drive', force_remount=True)
```

```
Mounted at /content/drive
```

```
PROJECT_FOLDER = '/content/drive/MyDrive/CNN_Emotion_Classification/'
```

```
# %cd /content/drive/MyDrive/CNN_Emotion_Classification/
```

```
# copy content in main folder
! cp -a {PROJECT_FOLDER}. ./
```

```
!pip install -r Requirements/pireqs_opencv_contrib_env.txt
```

Show hidden output

Double-click (or enter) to edit

```
# !pip install keras_applications
```

```
from display import pltDisplay
from pathlib import Path
from matplotlib.colors import ListedColormap
from sklearn.metrics import classification_report, roc_curve, auc, roc_auc_score
from sklearn.preprocessing import LabelBinarizer
from sklearn.model_selection import train_test_split
# from sorting import human_sort
from tensorflow.keras.layers import Input, Conv2D, MaxPooling2D, Dense, Flatten
from tensorflow.keras.layers import BatchNormalization, Dropout, Activation, ReLU, Softmax, GlobalAveragePooling2D
from tensorflow.keras.models import Model, Sequential
from tensorflow.keras.callbacks import ModelCheckpoint, EarlyStopping, ReduceLROnPlateau
from tensorflow.keras.regularizers import l2
```

```
# import IPython.display as ipd


import constants as const
import csv
import cv2
import json
import logging
import gc
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import random
import seaborn as sns
import tensorflow as tf
import subprocess
import tensorflow.keras.backend as K
import time
import utils

from keras_vggface.vggface import VGGFace
from tensorflow.keras.applications import EfficientNetB0
from tensorflow.keras.applications.vgg16 import VGG16
from tensorflow.keras.applications.vgg16 import preprocess_input as preprocess_imagenet
from keras_vggface.utils import preprocess_input as preprocess_vggface
```

```
print("Num GPUs Available: ", len(tf.config.list_physical_devices('GPU')))
```

```
Num GPUs Available:  1
```

```
gpus = tf.config.list_physical_devices('GPU')
if gpus:
  try:
    # Currently, memory growth needs to be the same across GPUs
    for gpu in gpus:
        print("Name:", gpu.name, "  Type:", gpu.device_type)
        print(tf.config.experimental.get_device_details(gpu))
        print(tf.config.experimental.get_memory_info('GPU:0'))
        # tf.config.experimental.set_memory_growth(gpu, True)
    logical_gpus = tf.config.list_logical_devices('GPU')
    print(len(gpus), "Physical GPUs,", len(logical_gpus), "Logical GPUs")
  except RuntimeError as e:
    # Memory growth must be set before GPUs have been initialized
    print(e)
```

```
Name: /physical_device:GPU:0   Type: GPU
{'compute_capability': (7, 5), 'device_name': 'Tesla T4'}
{'current': 0, 'peak': 0}
1 Physical GPUs, 1 Logical GPUs
```

```
# unzip archive in folder
!7z x Generated/Frames_300.zip -oGenerated/
```

```
7-Zip [64] 16.02 : Copyright (c) 1999-2016 Igor Pavlov : 2016-05-21
p7zip Version 16.02 (locale=en_US.UTF-8,Utf16=on,HugeFiles=on,64 bits,2 CPUs Intel(R) Xeon(R) CPU @ 2.00GHz (50653),ASM,AES-NI)

Scanning the drive for archives:
1 file, 4154172627 bytes (3962 MiB)

Extracting archive: Generated/Frames_300.zip
--
Path = Generated/Frames_300.zip
Type = zip
Physical Size = 4154172627
64-bit = +

Everything is Ok

Folders: 202
Files: 158556
Size:       4143561934
Compressed: 4154172627
```

```
utils.modules_info()
```

```
    OpenCV:
        Version: 4.8.0
    Tensorflow:
        Version: 2.15.0
```

```
log_file = Path(const.logs_path, 'FACER.log')
logging.basicConfig(
    format='%(asctime)s %(message)s',
    filemode='a',
    filename=log_file,
    encoding='utf-8',
    level=logging.INFO,
    force=True
)
```

Importing Dataset

```
data_df = pd.read_csv(Path(const.csv_path, 'dataset.csv'))
```

Frame

Preparing Data

Dataset Creation for ML

```
IMG_WIDTH = IMG_HEIGHT = 224
IMG_CHANNELS = 3
SEED = 42
BATCH_SIZE = 128
VALIDATION_SPLIT = 0.2
EMOTIONS_LABELS = const.EMOTIONS_LABELS  # RAVDESS emotion labels
```

```
EMOTIONS_LABELS
```

```
['neutral', 'calm', 'happy', 'sad', 'angry', 'fearful', 'disgust', 'surprised']
```

```
TOTAL_ELEMENTS = const.DATASET_TOTAL_ELEMENTS
label_names = const.EMOTIONS_LABELS_SORTED.copy()
# label_names.remove('neutral')
# label_names.remove('calm')
# label_names.remove('surprised')
```

```
label_names_gender = []
for em in label_names:
    label_names_gender.append(em + '_female')
    label_names_gender.append(em + '_male')
```

```
def get_gender(fname):

    gender = int(utils.get_actor(fname)) % 2
    gender_str = 'male' if (gender == 1) else 'female'
    return [gender, gender_str]
```

Dataset Creation - NEW

```
actors_labels = [f'{i:02d}' for i in range(1, 25)]
dist_idxs = {
    '1': [slice(0, 16), slice(16, 20), slice(20, 24)],
    '2': [slice(8, 24), slice(4, 8), slice(0, 4)],
    '3': [slice(4, 20), slice(20, 24), slice(0, 4)]
}
```

```
# Split actors in train, validation, test
dist_n = 1
train_idxs, val_idxs, test_idxs = [actors_labels[i] for i in dist_idxs[str(dist_n)]]

print(train_idxs, val_idxs, test_idxs)
```

```
['01', '02', '03', '04', '05', '06', '07', '08', '09', '10', '11', '12', '13', '14', '15', '16'] ['17', '18', '19', '20'] ['21', '22', '23', '24']
```

```
def make_dataset(path, actors_idx, talk_frame=False, acted_frame=False,
                 undersampling=False, preprocess_vgg=True, shuffle=False,
                 gender_classes=False, sampling=1):
    # gender classes -> create a men/woman category for each emotion
    def parse_image(filename):
        image = tf.io.read_file(filename)
        image = tf.image.decode_jpeg(image, channels=IMG_CHANNELS)
        image = tf.image.resize(image, [IMG_HEIGHT, IMG_WIDTH])
        if (preprocess_vgg == 'Imagenet'):
            image = preprocess_imagenet(image)
        elif (preprocess_vgg == 'VGGFace'):
            # function does not accept tensor
            # so convert to np and then to tensor
            # image = np.array(image)
            image = preprocess_vggface(image, version=2)
            # image = tf.convert_to_tensor(image)
        else:
            image = image / 255

        return image

    # label_names = label_names if gender_classes else label_names_gender

    filenames = []
    talk_regex = '*-01.jpg' if talk_frame else '*.jpg'
    acted_regex = '02' if acted_frame else '*'
    gen_regex = f'*-*-*-{acted_regex}-*-*-*-{talk_regex}'

    file_dict = dict()
    file_dict_gender = dict()

    for label in sorted(label_names):
        file_dict[label] = []

    for label in sorted(label_names_gender):
        file_dict_gender[label] = []


    for label in label_names:
        for actor in actors_idx:
            for file in Path(path, label, actor).glob(f'{gen_regex}'):
                gender = get_gender(str(file))[1]
                lab = label + f'_{gender}'
                file_dict_gender[lab].append(str(file))
                file_dict[label].append(str(file))

```

```
    if shuffle:
        for label, item in file_dict_gender.items():
            logging.info(f'Label: {label}')
            logging.info(f'Array len: {len(item)}')
            random.Random(SEED).shuffle(item)


    # NO GENDER


    arr_len = [len(arr) for arr in file_dict.values()]

    if undersampling:
        filenames = [arr[:min(arr_len)] for arr in file_dict.values()]
    else:
        filenames = [arr for arr in file_dict.values()]

    filenames = sum(filenames, [])

    if shuffle:
        random.Random(SEED).shuffle(filenames)

    labels = []

    if (gender_classes):

        for elem in filenames:
            cl = utils.get_class_string(str(elem))
            gender = get_gender(str(elem))[1]
            lab = cl + f'_{gender}'
            labels.append(label_names_gender.index(lab))
    else:
        labels = [
            label_names.index(EMOTIONS_LABELS[int(utils.get_class(elem)) - 1])
            for elem in filenames
        ]

    if (sampling < 1):
        filenames, _, labels, _ = train_test_split(
            filenames, labels, train_size=sampling, random_state=SEED
        )

    filenames_ds = tf.data.Dataset.from_tensor_slices(filenames)
    labels_ds = tf.data.Dataset.from_tensor_slices(labels)

    images_ds = filenames_ds.map(
```

```
        parse_image, num_parallel_calls=tf.data.experimental.AUTOTUNE
    )
    ds = tf.data.Dataset.zip((images_ds, labels_ds))

    return [ds, filenames]
```

```
sampling_rate = 1
gender_classes = False
talk_frame = True
acted_frame = False
preprocess_vgg = 'Imagenet'  # False, Imagenet or VGGFace
NUM_CLASSES = len(label_names_gender) if gender_classes else len(label_names)


train_ds, train_files = make_dataset(
    const.frames_path, train_idxs, talk_frame=talk_frame, acted_frame=acted_frame,
    preprocess_vgg=preprocess_vgg, shuffle=True, gender_classes=gender_classes,
    sampling=sampling_rate
)

val_ds, val_files = make_dataset(
    const.frames_path, val_idxs, talk_frame=talk_frame, acted_frame=acted_frame,
    preprocess_vgg=preprocess_vgg, gender_classes=gender_classes,
    sampling=sampling_rate
)

test_ds, test_files = make_dataset(
    const.frames_path, test_idxs, talk_frame=talk_frame, acted_frame=acted_frame,
    preprocess_vgg=preprocess_vgg, gender_classes=gender_classes,
    sampling=sampling_rate
)

labels = label_names if not gender_classes else label_names_gender
```

```
# train_ds = train_ds[:31882]
# train_files = train_files[:31882]

# val_ds = val_ds[:8426]
# val_files = val_files[:8426]

# test_ds = test_ds[:8301]
# test_files = test_files[:8301]
```

```
assert len(train_ds) == len(train_files), len(train_files)
assert len(val_ds) == len(val_files), len(val_files)
assert len(test_ds) == len(test_files), len(test_files)
```

```
train_ds_elements = len(train_ds)
test_ds_elements = len(test_ds)
val_ds_elements = len(val_ds)
```

```
print(f'train_ds samples: {train_ds_elements}')
print(f'test_ds samples: {test_ds_elements}')
print(f'val_ds samples: {val_ds_elements}')
```

```
train_ds samples: 67906
test_ds samples: 17994
val_ds samples: 17642
```

Build and train the model

Add operations to reduce read latency while training the model:

`ds.batch` Combines consecutive elements of the dataset into batches. The components of the resulting element will have an additional outer dimension, which will be *batch_size*

`ds.cache` Caches the elements in this dataset.

`ds.prefetch` Allows later elements to be prepared while the current element is being processed. This often improves latency and throughput, at the cost of using additional memory to store prefetched elements.

```
def configure_for_performance(ds, batch_size=BATCH_SIZE):
    ds = ds.batch(batch_size)
    # ds = ds.cache()
    # ds = ds.shuffle(buffer_size=1000)
    # ds = ds.repeat()
    ds = ds.prefetch(buffer_size=tf.data.AUTOTUNE)
    return ds
```

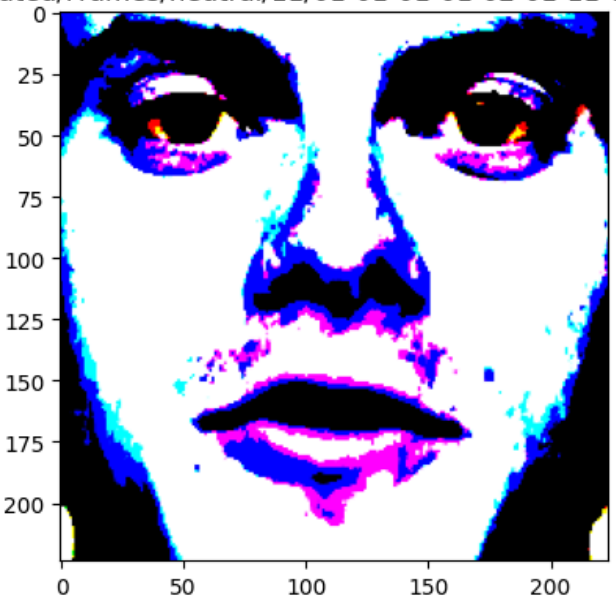
```
train_ds = configure_for_performance(train_ds)
val_ds = configure_for_performance(val_ds)
test_ds = configure_for_performance(test_ds)
```

```
for example_images, example_labels in train_ds.take(1):
    print(example_images.shape)
    print(example_labels.shape)
```

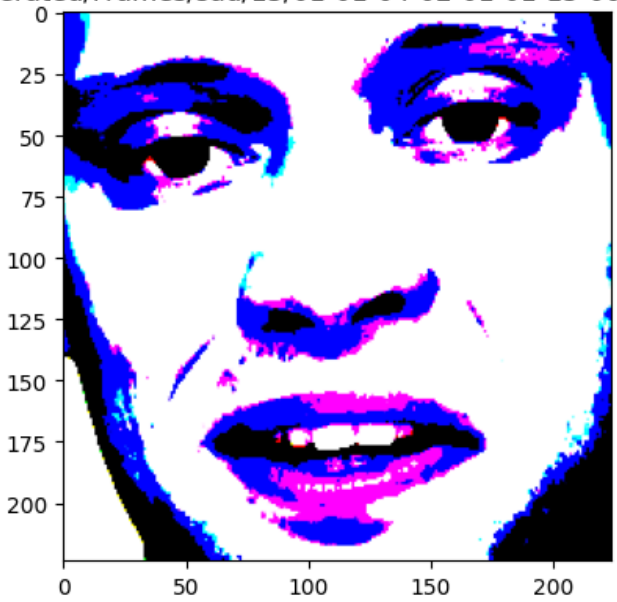
```
(128, 224, 224, 3)
(128,)
```

```
plt.figure(figsize=(16, 10))
rows = 2
cols = 2
n = rows * cols
for i in range(n):
    plt.subplot(rows, cols, i + 1)
    image = example_images[i]
    plt.imshow(image)  # 3 channels
    # plt.imshow(image * 255, cmap='gray', vmin=0, vmax=255)  # 1 channel
    plt.title(f'{label_names[example_labels[i]]}\n{train_files[i]}')
```

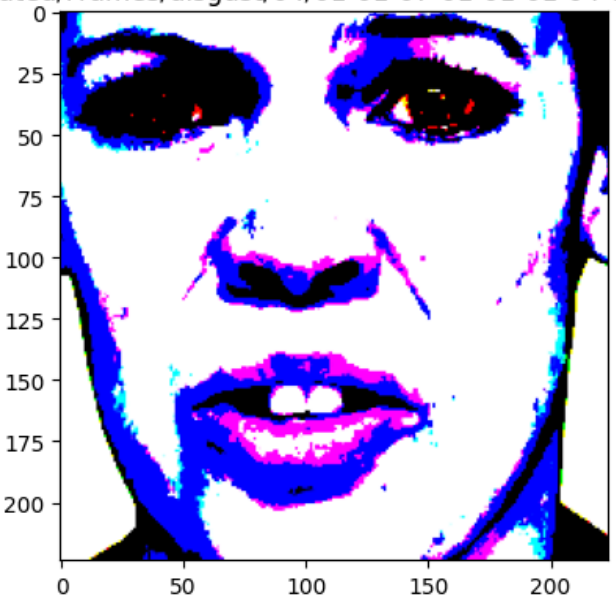
neutral
Generated/Frames/neutral/11/01-01-01-01-02-01-11-035-01.jpg



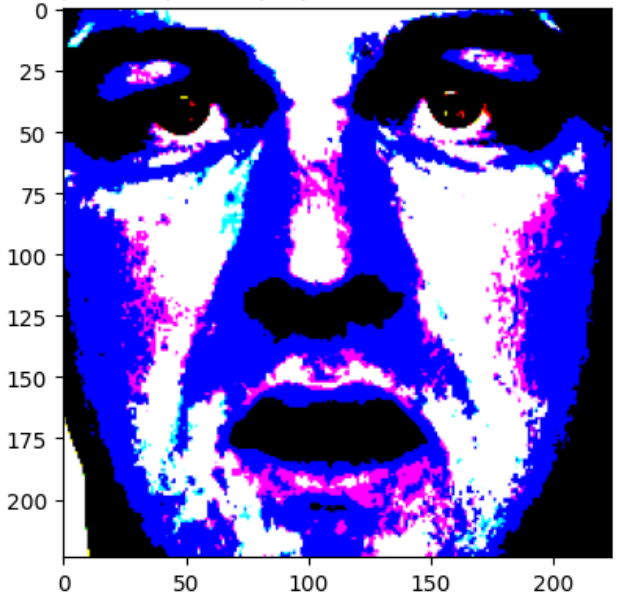
sad
Generated/Frames/sad/15/01-01-04-02-01-01-15-068-01.jpg



disgust
Generated/Frames/disgust/04/01-01-07-01-01-01-04-071-01.jpg



fearful
Generated/Frames/fearful/13/01-01-06-02-02-02-13-031-01.jpg



```
def create_Bilotti_CNN(name='Bilotti_CNN'):

    inputs = Input(shape=(IMG_HEIGHT, IMG_WIDTH, IMG_CHANNELS))

    conv1 = Conv2D(32, kernel_size=(3, 3), activation='relu')(inputs)
    conv2 = Conv2D(32, kernel_size=(3, 3), activation='relu')(conv1)
    pool1 = MaxPooling2D(pool_size=(2, 2))(conv2)

    conv3 = Conv2D(64, kernel_size=(3, 3), activation='relu')(pool1)
    conv4 = Conv2D(64, kernel_size=(3, 3), activation='relu')(conv3)
    pool2 = MaxPooling2D(pool_size=(2, 2))(conv4)

    conv4 = Conv2D(18, kernel_size=(3, 3), activation='relu')(pool2)
    conv5 = Conv2D(18, kernel_size=(3, 3), activation='relu')(conv4)
    conv6 = Conv2D(18, kernel_size=(3, 3), activation='relu')(conv5)
    pool3 = MaxPooling2D(pool_size=(2, 2))(conv6)

    conv7 = Conv2D(56, kernel_size=(3, 3), activation='relu')(pool3)
    conv8 = Conv2D(56, kernel_size=(3, 3), activation='relu')(conv7)
    conv9 = Conv2D(56, kernel_size=(3, 3), activation='relu')(conv8)
    pool4 = MaxPooling2D(pool_size=(2, 2))(conv9)

    conv10 = Conv2D(51, kernel_size=(3, 3), activation='relu')(pool4)
    conv11 = Conv2D(51, kernel_size=(3, 3), activation='relu')(conv10)
    conv12 = Conv2D(51, kernel_size=(3, 3), activation='relu')(conv11)
    pool5 = MaxPooling2D(pool_size=(2, 2))(conv12)

    flatten = Flatten()(pool5)

    dense1 = Dense(2048, activation='relu')(flatten)
    drop1 = Dropout(0.25)(dense1)

    dense2 = Dense(1024, activation='relu')(drop1)
    drop2 = Dropout(0.4)(dense2)

    output = Dense(NUM_CLASSES, activation='softmax')(drop2)

    model = Model(inputs, output)

    model._name = name

    return model
```

```
def create_VGG16_Imagenet(name='VGG16_Imagenet'):

    base_model = VGG16(
        weights='imagenet',
        include_top=False,
        input_shape=(IMG_WIDTH, IMG_HEIGHT, IMG_CHANNELS)
    )
    base_model.trainable = False  # Not trainable weights

    flatten_layer = Flatten()
    dense_layer_1 = Dense(2048, activation='relu')
    drop_1 = Dropout(0.4)
    dense_layer_2 = Dense(1024, activation='relu')
    drop_2 = Dropout(0.4)
    dense_layer_3 = Dense(512, activation='relu')
    drop_3 = Dropout(0.4)
    prediction_layer = Dense(NUM_CLASSES, activation='softmax')

    model = Sequential([
        base_model,
        flatten_layer,
        dense_layer_1,
        drop_1,
        dense_layer_2,
        drop_2,
        dense_layer_3,
        drop_3,
        prediction_layer
    ])

    model._name = name

    return model
```

```
def create_EfficientNetB0_Imagenet(name='EfficientNetB0_Imagenet'):

    nb_class = NUM_CLASSES

    inputs = Input(shape=(IMG_WIDTH, IMG_HEIGHT, IMG_CHANNELS))
    model = EfficientNetB0(
        include_top=False, input_tensor=inputs, weights="imagenet"
    )

    # Freeze the pretrained weights
    model.trainable = False

    # Rebuild top
    x = GlobalAveragePooling2D(name="avg_pool")(model.output)
    x = BatchNormalization()(x)

    top_dropout_rate = 0.2
    x = Dropout(top_dropout_rate, name="top_dropout")(x)
    outputs = Dense(nb_class, activation="softmax", name="pred")(x)

    model._name = name
    # Compile
    model = Model(inputs, outputs, name="EfficientNet")

    return model
```

```python
def create_VGG16_VGGFACE(name='VGG16_VGGFACE'):
    nb_class = NUM_CLASSES

    vgg_model = VGGFace(
        include_top=False, weights='vggface', input_shape=(IMG_WIDTH, IMG_HEIGHT, IMG_CHANNELS)
    )
    last_layer = vgg_model.get_layer('pool5').output
    x = Flatten(name='flatten')(last_layer)

    x = Dense(512, activation='relu', name='fc6')(x)
    x = Dropout(0.35)(x)
    x = Dense(256, activation='relu', name='fc7')(x)
    x = Dropout(0.35)(x)
    x = Dense(128, activation='relu', name='fc8')(x)
    x = Dropout(0.35)(x)

    out = Dense(nb_class, activation='softmax', name='fc9')(x)

    custom_vgg_model = Model(vgg_model.input, out)
    custom_vgg_model._name = name

    return custom_vgg_model
```

```python
tf.keras.backend.clear_session()  # clear all precedent models and sessions
```

```python
check_path = 'checkpoint.weights.h5'
checkpointer = ModelCheckpoint(
    check_path, monitor='val_accuracy', verbose=1, save_best_only=True,
    save_weights_only=False, mode='auto', save_freq='epoch'
)
```

```python
# model = create_cnn_model()
# model = medium_model()
# model = create_VGG16_Imagenet()
# model = create_VGG16_VGGFACE()
model = create_EfficientNetB0_Imagenet()
# model = create_grigorasi_model()
# model = create_Bilotti_CNN()
model.summary()
```

```
block6b_se_excite (Multipl  (None, 7, 7, 1152)          0         ['block6b_activation[0][0]',
y)                                                                  'block6b_se_expand[0][0]']
```

```
# Define training callbacks

class TimeHistory(tf.keras.callbacks.Callback):
    def on_train_begin(self, logs={}):
        self.times = []

    def on_epoch_begin(self, batch, logs={}):
        self.epoch_time_start = time.time()

    def on_epoch_end(self, batch, logs={}):
        self.times.append(time.time() - self.epoch_time_start)


early_stopping_callback = tf.keras.callbacks.EarlyStopping(
    verbose=1,
    patience=5,
    restore_best_weights=True
)

reduce_lr = ReduceLROnPlateau(monitor='val_loss', factor=0.2, verbose=1,
                              patience=3, min_lr=0)
```

```
METRICS = ['accuracy']
```

```
model.compile(
    optimizer=tf.keras.optimizers.Adam(
        learning_rate=1e-2
    ),
    # optimizer=tf.keras.optimizers.SGD(),  # for VGG16_VGGFACE
    loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=False),
    metrics=METRICS,
)
```

Train Model

```
EPOCHS = 100
time_callback = TimeHistory()
history = model.fit(
    x=train_ds,
    validation_data=val_ds,
    epochs=EPOCHS,
    callbacks=[time_callback, early_stopping_callback, reduce_lr]
)
```

```
Epoch 1/100
531/531 [==============================] - 367s 664ms/step - loss: 1.1273 - accuracy: 0.6550 - val_loss: 2.0916 - val_accuracy: 0.4065 - lr: 0.0100
Epoch 2/100
531/531 [==============================] - 323s 609ms/step - loss: 0.9074 - accuracy: 0.7043 - val_loss: 2.0951 - val_accuracy: 0.4336 - lr: 0.0100
Epoch 3/100
531/531 [==============================] - 330s 622ms/step - loss: 0.8689 - accuracy: 0.7105 - val_loss: 2.1393 - val_accuracy: 0.4371 - lr: 0.0100
Epoch 4/100
531/531 [==============================] - ETA: 0s - loss: 0.8555 - accuracy: 0.7128
Epoch 4: ReduceLROnPlateau reducing learning rate to 0.0019999999552965165.
531/531 [==============================] - 316s 595ms/step - loss: 0.8555 - accuracy: 0.7128 - val_loss: 2.0959 - val_accuracy: 0.4111 - lr: 0.0100
Epoch 5/100
531/531 [==============================] - 318s 599ms/step - loss: 0.7495 - accuracy: 0.7473 - val_loss: 1.8994 - val_accuracy: 0.4540 - lr: 0.0020
Epoch 6/100
531/531 [==============================] - 322s 606ms/step - loss: 0.7267 - accuracy: 0.7526 - val_loss: 1.8757 - val_accuracy: 0.4581 - lr: 0.0020
Epoch 7/100
531/531 [==============================] - 317s 598ms/step - loss: 0.7259 - accuracy: 0.7546 - val_loss: 1.8582 - val_accuracy: 0.4761 - lr: 0.0020
Epoch 8/100
531/531 [==============================] - 321s 604ms/step - loss: 0.7227 - accuracy: 0.7562 - val_loss: 1.8993 - val_accuracy: 0.4639 - lr: 0.0020
Epoch 9/100
531/531 [==============================] - 337s 635ms/step - loss: 0.7229 - accuracy: 0.7574 - val_loss: 1.8278 - val_accuracy: 0.4675 - lr: 0.0020
Epoch 10/100
531/531 [==============================] - 320s 603ms/step - loss: 0.7174 - accuracy: 0.7587 - val_loss: 1.8641 - val_accuracy: 0.4719 - lr: 0.0020
Epoch 11/100
531/531 [==============================] - 332s 626ms/step - loss: 0.7194 - accuracy: 0.7569 - val_loss: 1.9551 - val_accuracy: 0.4593 - lr: 0.0020
Epoch 12/100
531/531 [==============================] - ETA: 0s - loss: 0.7180 - accuracy: 0.7581
Epoch 12: ReduceLROnPlateau reducing learning rate to 0.0003999999724328518.
531/531 [==============================] - 318s 599ms/step - loss: 0.7180 - accuracy: 0.7581 - val_loss: 2.0049 - val_accuracy: 0.4496 - lr: 0.0020
Epoch 13/100
531/531 [==============================] - 330s 621ms/step - loss: 0.6904 - accuracy: 0.7662 - val_loss: 1.9980 - val_accuracy: 0.4525 - lr: 4.0000e-04
Epoch 14/100
531/531 [==============================] - ETA: 0s - loss: 0.6872 - accuracy: 0.7678Restoring model weights from the end of the best epoch: 9.
531/531 [==============================] - 319s 601ms/step - loss: 0.6872 - accuracy: 0.7678 - val_loss: 1.9956 - val_accuracy: 0.4503 - lr: 4.0000e-04
Epoch 14: early stopping
```

```
EPOCHS = len(time_callback.times)
```

```
# Create model path
model_path = Path(const.models_path, 'Frame', model._name)
run_folders = list(Path(const.models_path, 'Frame', model._name).glob('Run_*'))

if not run_folders:
    model_path = Path(model_path, 'Run_1')
else:
    last_run = run_folders.pop()
    last_run_idx = Path(last_run).name.split('_')[-1]
    model_path = Path(model_path, f'Run_{int(last_run_idx) + 1}')

model_path.mkdir(parents=True, exist_ok=False)
```

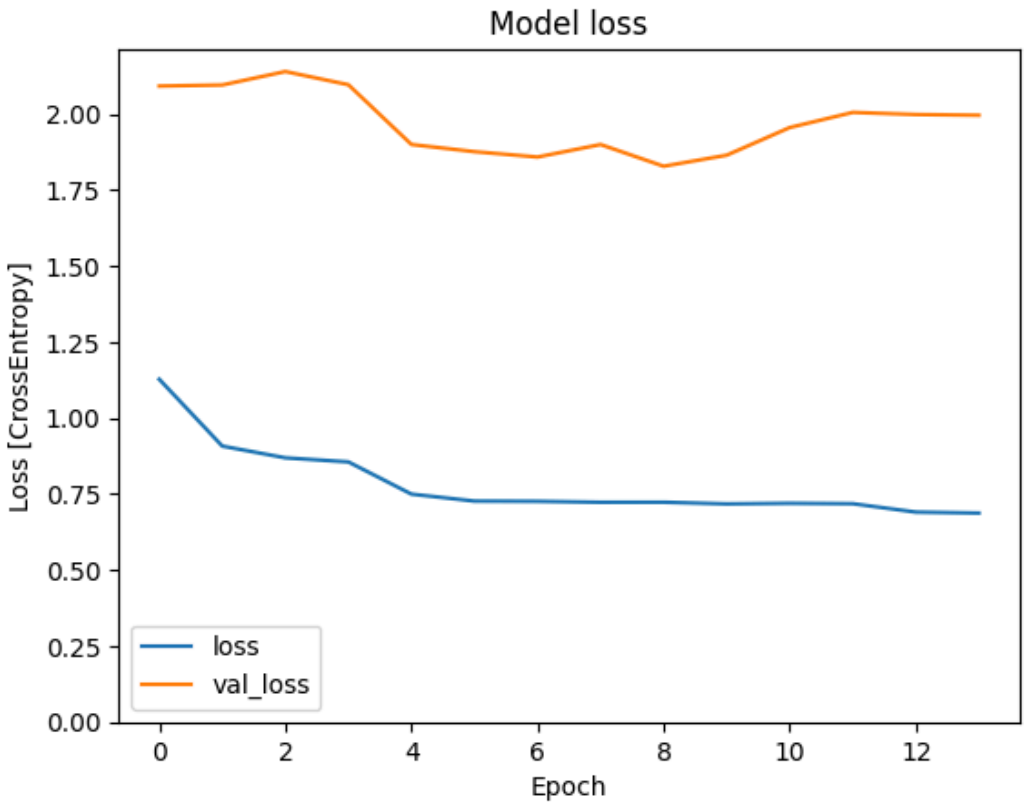
```
# Save info on the indexes used for train, val and test
ds_info_path = Path(model_path, f'{model._name}_dataset.txt')
with open(ds_info_path, 'w+', newline='') as res_file:
    res_file.write(f'Train indexes: {train_idxs}\n')
    res_file.write(f'Train files: {train_ds_elements}\n')
    res_file.write(f'Val indexes: {val_idxs}\n')
    res_file.write(f'Val files: {val_ds_elements}\n')
    res_file.write(f'Test indexes: {test_idxs}\n')
    res_file.write(f'Test files: {test_ds_elements}\n')
```

```
metrics = history.history
```

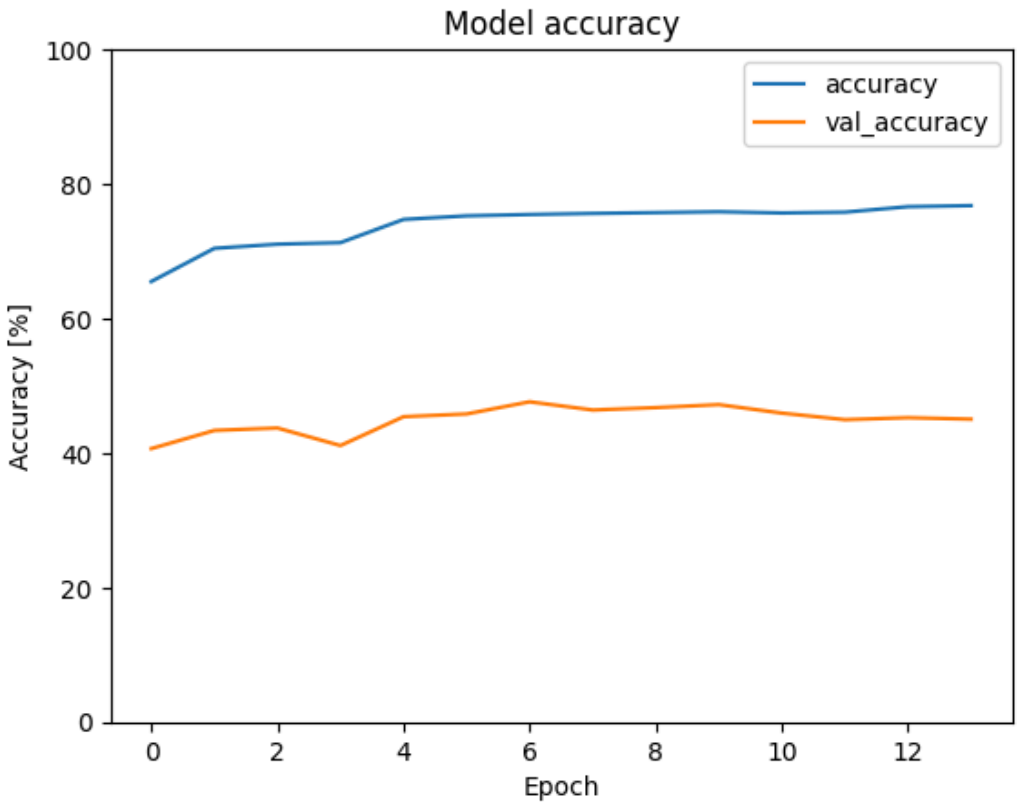
```
mod_loss = metrics['loss']
mod_val_loss = metrics['val_loss']
mod_accuracy = metrics['accuracy']
mod_val_accuracy = metrics['val_accuracy']
# mod_f1 = metrics['fBeta_score']
# mod_val_f1 = metrics['val_fBeta_score']

mod_mean_loss = np.mean(mod_loss)
mod_mean_val_loss = np.mean(mod_val_loss)
mod_mean_accuracy = np.mean(mod_accuracy)
mod_mean_val_accuracy = np.mean(mod_val_accuracy)
# mod_mean_f1 = np.mean(mod_f1)
# mod_mean_val_f1 = np.mean(mod_val_f1)
```

```
# Save Loss
plt.title('Model loss')
plt.plot(history.epoch, mod_loss, mod_val_loss)
plt.legend(['loss', 'val_loss'])
plt.ylim([0, max(plt.ylim())])
plt.xlabel('Epoch')
plt.ylabel('Loss [CrossEntropy]')
plt.savefig(Path(model_path, 'loss.png'))
```



```
# Save Accuracy
plt.title('Model accuracy')
plt.plot(
    history.epoch,
    100 * np.array(mod_accuracy),
    100 * np.array(mod_val_accuracy)
)
plt.legend(['accuracy', 'val_accuracy'])
plt.ylim([0, 100])
plt.xlabel('Epoch')
plt.ylabel('Accuracy [%]')
plt.savefig(Path(model_path, 'accuracy.png'))
```



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Evaluate Model

```
model_eval = model.evaluate(test_ds, return_dict=True)
```

```
141/141 [==============================] - 71s 497ms/step - loss: 1.8451 - accuracy: 0.4229
```

```
# Save model
model.save(Path(model_path, f'{model._name}.keras'), overwrite=False)
# Save history
np.save(Path(model_path, f'{model._name}_history.npy'), history)
# Save model image
model_img = tf.keras.utils.plot_model(
    model, Path(model_path, f'{model._name}.png'), show_shapes=True,
    show_layer_names=True, show_layer_activations=True
)
```

```
model_eval
```

```
{'loss': 1.8450863361358643, 'accuracy': 0.4228631854057312}
```

```
test_loss = model_eval['loss']
test_accuracy = model_eval['accuracy']
# test_f1 = model_eval['fBeta_score']
mean_epoch_time = np.mean(time_callback.times)
```

```
# Salvataggio informazioni modello
model_save_path = Path(model_path, f'{model._name}_result.txt')
with open(model_save_path, 'w+', newline='') as res_file:
    res_file.write(f'BATCH: {BATCH_SIZE}\n')
    res_file.write(f'Train loss: {str(mod_loss)}\n')
    res_file.write(f'val_loss: {str(mod_val_loss)}\n')
    res_file.write(f'Train accuracy: {str(mod_accuracy)}\n')
    res_file.write(f'Train val_accuracy: {str(mod_val_accuracy)}\n')
    # res_file.write(f'Train f1_score: {str(mod_f1)}\n')
    # res_file.write(f'Train val_f1_score: {str(mod_val_f1)}\n')
    res_file.write(f'Test loss: {str(test_loss)}\n')
    res_file.write(f'Test accuracy: {str(test_accuracy)}\n')
    # res_file.write(f'Test f1_score: {str(test_f1)}\n')
    res_file.write(f'Mean epoch time: {str(mean_epoch_time)}')
```

```
# Salvataggio informazioni generali modelli
```

```
with open(Path(const.models_path, 'Frame', 'models.csv'), 'a+') as csvfile:
    filewriter = csv.writer(
        csvfile, delimiter=';', quotechar='|', quoting=csv.QUOTE_MINIMAL
    )

    # filewriter.writerow(
    #     ["Model Name", "Epochs", "% Validation", "% Test set",
    #      "Train loss", "Train accuracy", "Val loss", "Val accuracy",
    #      "Test loss", "Test accuracy", "Mean epoch time", "Note"]
    # )
    test_ds_perc = utils.trunc((test_ds_elements * 100) / TOTAL_ELEMENTS, 2)
    val_ds_perc = utils.trunc((val_ds_elements * 100) / TOTAL_ELEMENTS, 2)
    full_path = str(Path(model._name, model_path.name))
    filewriter.writerow(
        [full_path, EPOCHS, val_ds_perc, test_ds_perc,
         mod_loss, mod_accuracy, mod_val_loss, mod_val_accuracy,
         test_loss, test_accuracy, mean_epoch_time, '']
    )
```

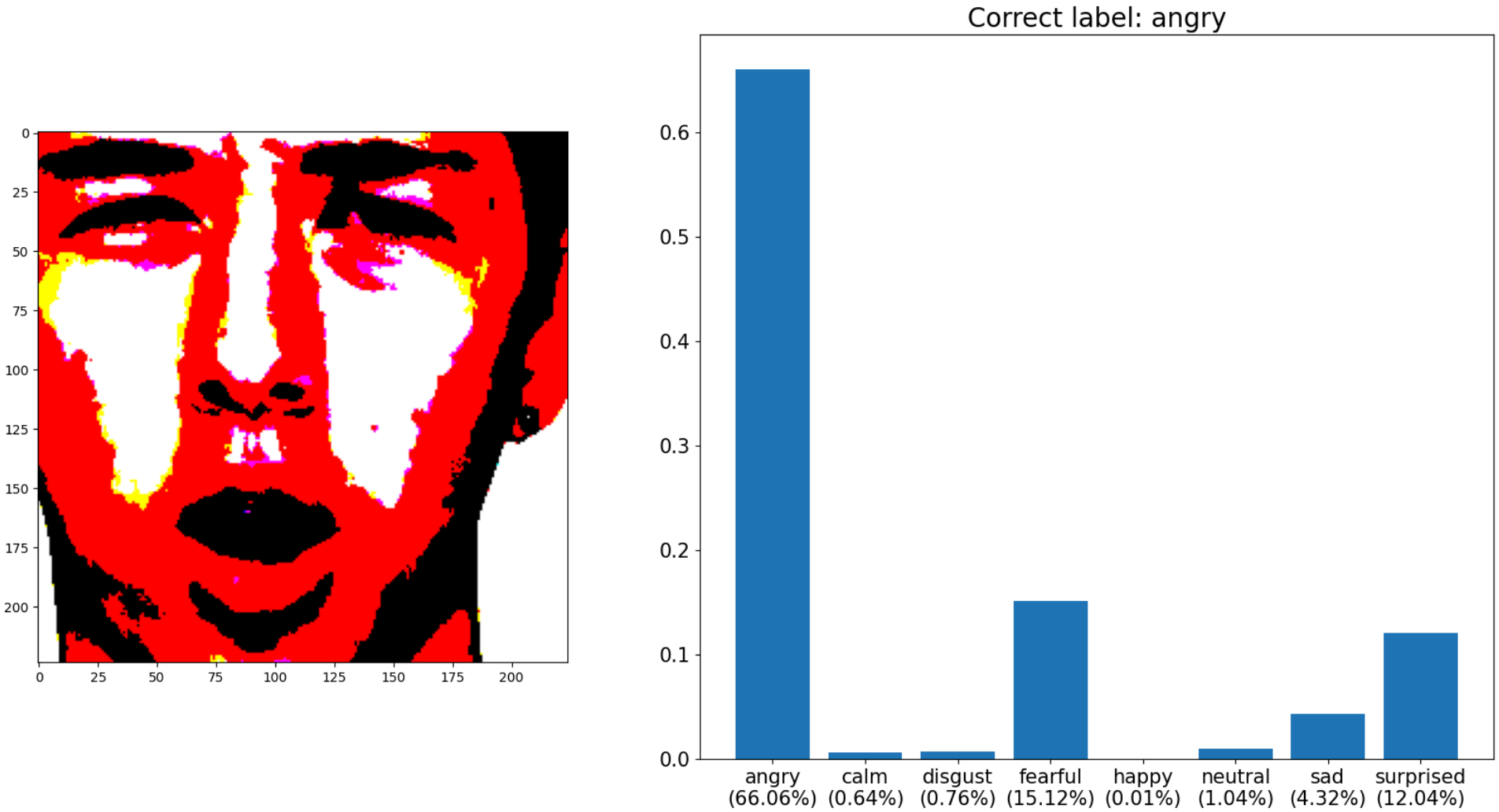
```
for test_images, test_labels in test_ds.take(1):
    print(test_images.shape)
    print(test_labels.shape)
```

```
(128, 224, 224, 3)
(128,)
```

```
gen = np.random.default_rng(seed=None)
idx = gen.integers(0, len(test_images))
print(test_files[idx])

image = test_images[idx]
label = test_labels[idx]

net_input = utils.extend_tensor(image, 0)
prediction = model(net_input)
prediction = prediction[0].numpy()

valued_arr = []

for idx, name in enumerate(label_names):
    valued_arr.append(f'{name}\n({prediction[idx]:.2%})')

fig, ax = plt.subplots(
    nrows=1, ncols=2, width_ratios=[0.4, 0.6], figsize=(20, 10)
)
```

```
20
21 pltDisplay(image * 255, ax=ax[0])  # 1 channel
22 # pltDisplay(image, ax=ax[0])
23
24 ax[1].bar(valued_arr, prediction)
25 plt.xticks(fontsize=15)
26 plt.yticks(fontsize=15)
27 plt.title(f'Correct label: {label_names[label]}', fontsize=20)
28 # plt.xlabel('Predicted class')
29 # plt.ylabel('Percentage')
30 plt.show()
```

```
Generated/Frames/angry/21/01-01-05-01-01-02-21-087-01.jpg
```



Display a confusion matrix

Use a [confusion matrix](#) to check how well the model did classifying each of the commands in the test set:

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```
y_pred = model.predict(test_ds)
```

```
141/141 [==============================] - 76s 510ms/step
```

```
y_pred = tf.argmax(y_pred, axis=1, output_type=tf.int32)
```

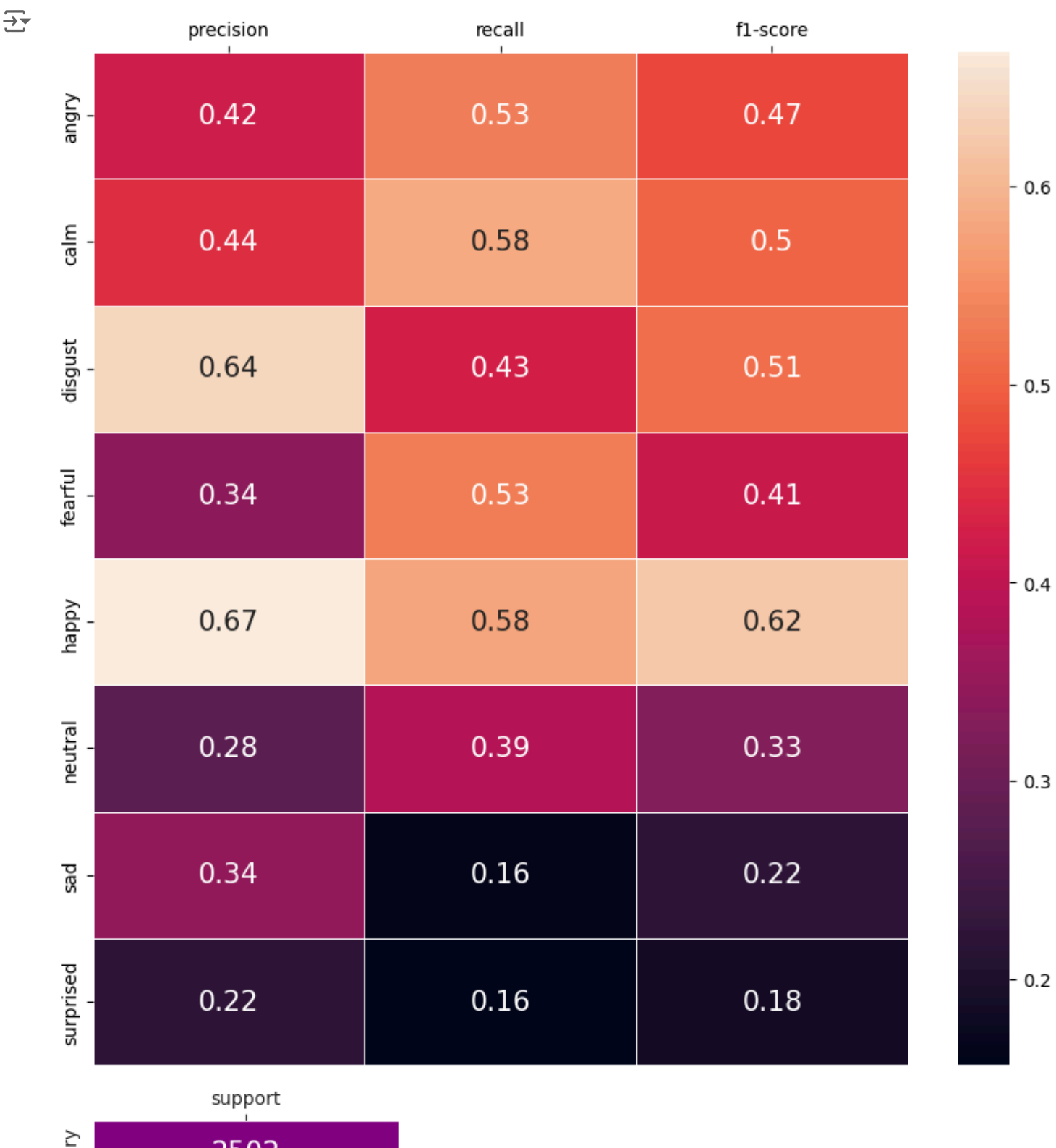
```
y_true = tf.concat(list(test_ds.map(lambda _, lab: lab)), axis=0)
```

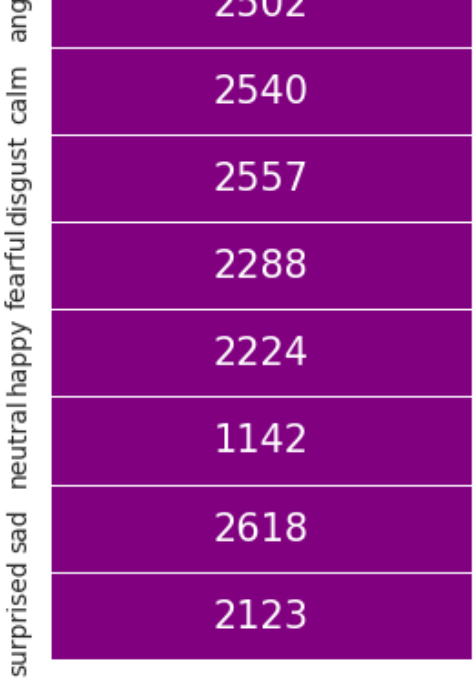
```
report = classification_report(
    y_true, y_pred, target_names=label_names,
    output_dict=True, zero_division='warn'
)
```

```
rep_to_csv = pd.DataFrame(data=report).transpose()
```

```
fig, ax = plt.subplots(figsize=(10, 10))
ax.xaxis.tick_top()
sns.heatmap(rep_to_csv.iloc[:NUM_CLASSES, :3],
            cbar=True,
            square=False,
            annot=True,
            annot_kws={'size': 15},
            fmt='.2g',
            linewidths=0.5)
plt.savefig(Path(model_path, f'{model._name}_f1_score.png'))
plt.show()


with sns.axes_style('white'):
    fig, ax = plt.subplots(figsize=(3, 5))
    ax.xaxis.tick_top()
    sns.heatmap(rep_to_csv.iloc[:NUM_CLASSES, 3:],
                cbar=False,
                square=False,
                annot=True,
                annot_kws={'size': 15},
                fmt='.4g',
                cmap=ListedColormap([('purple')]),
                linewidths=0.5)
    plt.savefig(Path(model_path, f'{model._name}_support.png'))
    plt.show()
```


precision
recall
f1-score
angry
calm
disgust
fearful
happy
neutral
sad
surprised
0.42
0.53
0.47
0.44
0.58
0.5
0.64
0.43
0.51
0.34
0.53
0.41
0.67
0.58
0.62
0.28
0.39
0.33
0.34
0.16
0.22
0.22
0.16
0.18
0.6
0.5
0.4
0.3
0.2
support




```
report_save_path = Path(model_path, f'{model._name}_report.csv')
rep_to_csv.to_csv(report_save_path)
```

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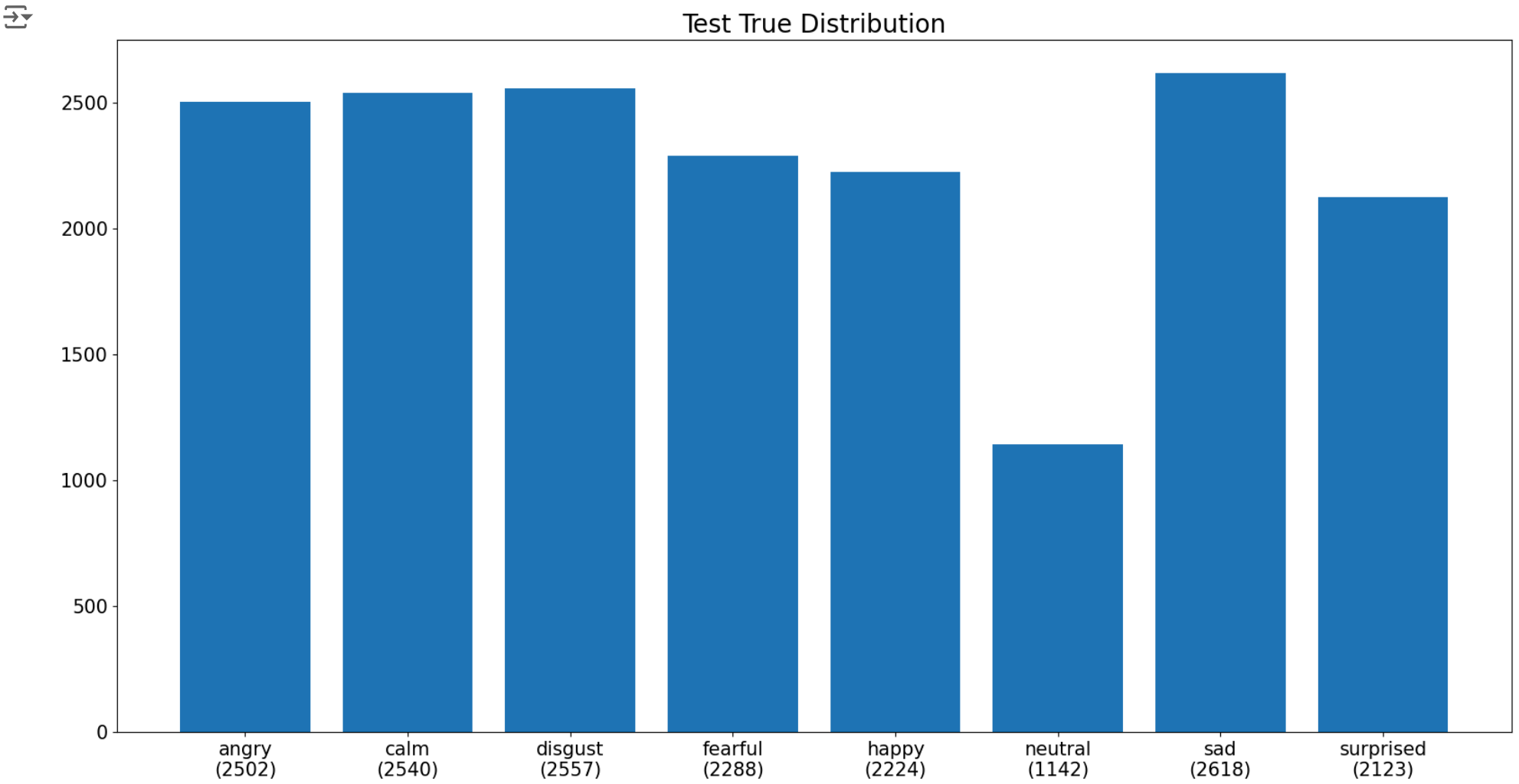
```
np.mean([report[c]['f1-score'] for c in list(report)[:NUM_CLASSES]])
```

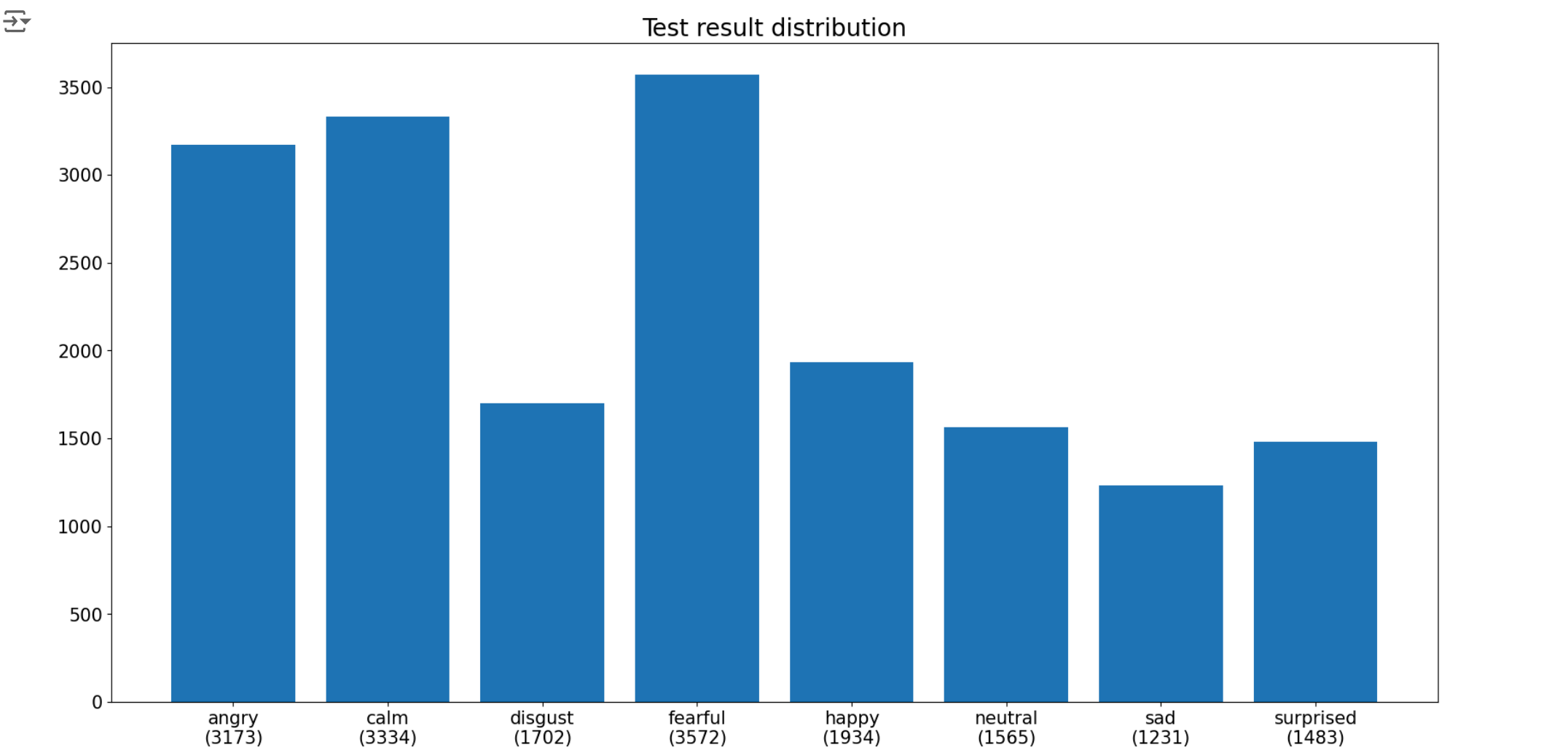
```
0.4066562185019181
```

```
# True Test Distribution
# unique, counts = np.unique(y_true, return_counts=True)
# collections.Counter(y_true)
counts = [np.count_nonzero(y_true == idx) for idx in range(len(label_names))]
valued_arr = []
# for i in range(len(label_names)):
for idx, name in enumerate(label_names):
    count = counts[idx]
    valued_arr.append(f'{name}\n({count})')

fig = plt.subplots(figsize=(20, 10))
plt.bar(valued_arr, counts)
plt.xticks(fontsize=15)
```

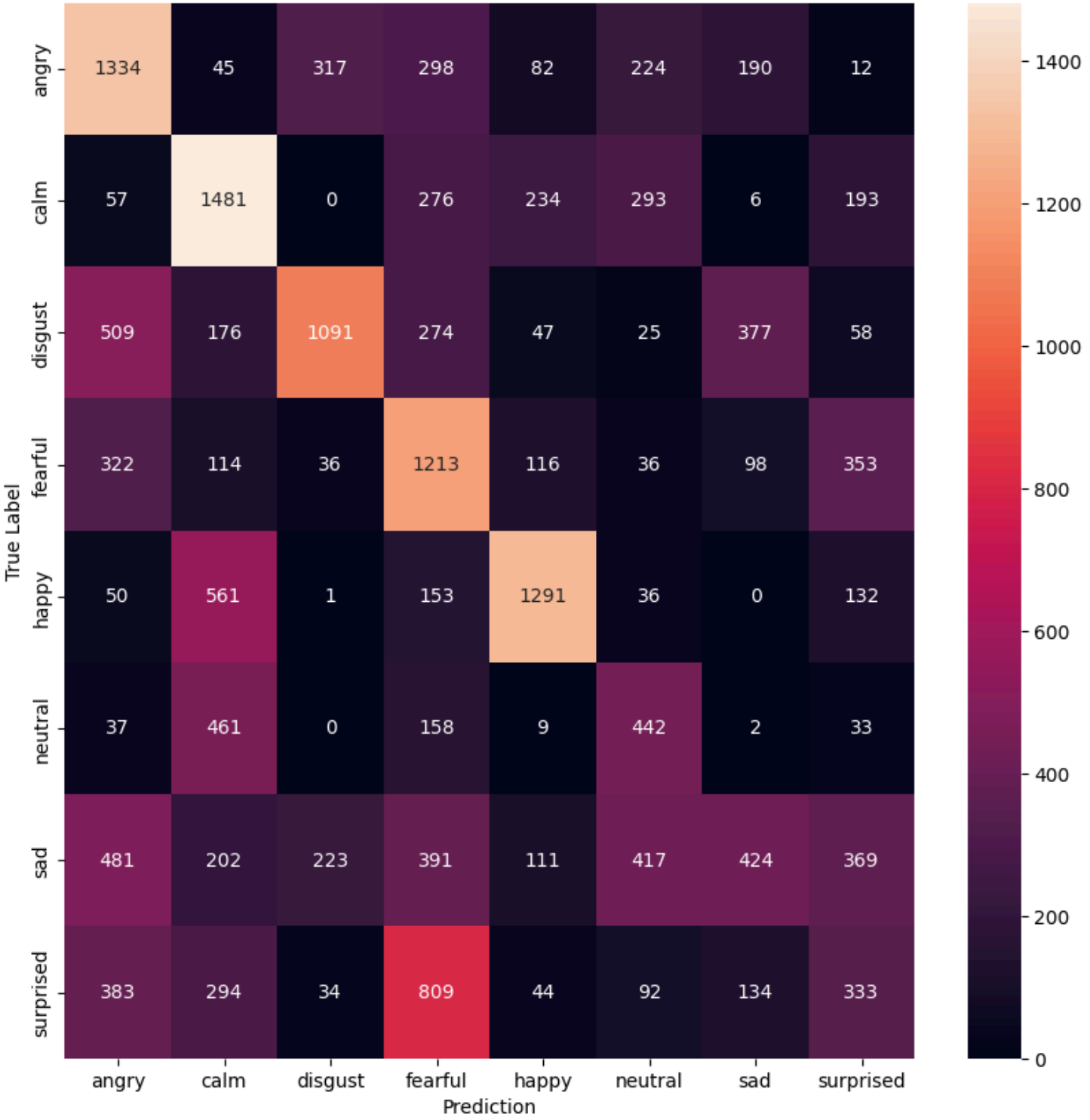
```
plt.yticks(fontsize=15)
plt.title('Test True Distribution', fontsize=20)
# plt.xlabel('Predicted class')
# plt.ylabel('Percentage')
plt.savefig(Path(model_path, f'{model._name}_trueDist.png'))
plt.show()
```



```
# Predicted Test Distribution
# unique, counts = np.unique(y_pred, return_counts=True)
counts = [np.count_nonzero(y_pred == idx) for idx in range(len(label_names))]
valued_arr = []
unique_idx = 0
for idx, name in enumerate(label_names):
    count = counts[idx]
    valued_arr.append(f'{name}\n({count})')

fig = plt.subplots(figsize=(20, 10))
plt.bar(valued_arr, counts)
plt.xticks(fontsize=15)
plt.yticks(fontsize=15)
plt.title('Test result distribution', fontsize=20)
# plt.xlabel('Predicted class')
# plt.ylabel('Percentage')
plt.savefig(Path(model_path, f'{model._name}_predDist.png'))
plt.show()
```


Test result distribution
3500
3000
2500
2000
1500
1000
500
0
angry
(3173)
calm
(3334)
disgust
(1702)
fearful
(3572)
happy
(1934)
neutral
(1565)
sad
(1231)
surprised
(1483)

```
confusion_mtx = tf.math.confusion_matrix(y_true, y_pred)
fig, ax = plt.subplots(figsize=(10, 10))
sns.heatmap(confusion_mtx,
            xticklabels=label_names,
            yticklabels=label_names,
            annot=True, fmt='.4g')
plt.xlabel('Prediction')
plt.ylabel('True Label')
plt.savefig(Path(model_path, f'{model._name}_heat.png'))
plt.show()
```


angry
calm
disgust
fearful
happy
neutral
sad
surprised
True Label
1334 45 317 298 82 224 190 12
57 1481 0 276 234 293 6 193
509 176 1091 274 47 25 377 58
322 114 36 1213 116 36 98 353
50 561 1 153 1291 36 0 132
37 461 0 158 9 442 2 33
481 202 223 391 111 417 424 369
383 294 34 809 44 92 134 333
angry
calm
disgust
fearful
happy
neutral
sad
surprised
Prediction
1400
1200
1000
800
600
400
200
0

```
def multiclass_roc_auc_score(target, y_test, y_pred, average="macro"):
    # function for scoring roc auc score for multi-class
    lb = LabelBinarizer()
    lb.fit(y_test)
    y_test = lb.transform(y_test)
    y_pred = lb.transform(y_pred)

    if len(target) > 2:
        for (idx, c_label) in enumerate(target):

            fpr, tpr, thresholds = roc_curve(
                y_test[:, idx].astype(int),
                y_pred[:, idx]
            )
            c_ax.plot(
                fpr, tpr, label='%s (AUC:%0.2f)' % (c_label, auc(fpr, tpr))
            )
    else:
        fpr, tpr, thresholds = roc_curve(
                y_test,
                y_pred
        )
        c_ax.plot(
            fpr, tpr, label='Model (AUC:%0.2f)' % (auc(fpr, tpr)), color='#ff7f0e'
        )
    c_ax.plot(fpr, fpr, color='b', linestyle='--', label='Random Guessing')

    return roc_auc_score(y_test, y_pred, average=average)
```

```
# set plot figure size
fig, c_ax = plt.subplots(1, 1, figsize=(12, 8))

print('ROC AUC score:', multiclass_roc_auc_score(
    label_names,
    tf.reshape(y_true, (y_true.shape[0], 1)),
    tf.reshape(y_pred, (y_pred.shape[0], 1))
))

c_ax.legend()
c_ax.set_xlabel('False Positive Rate')
c_ax.set_ylabel('True Positive Rate')
plt.savefig(Path(model_path, f'{model._name}_ROC.png'))
plt.show()
```

ROC AUC score: 0.6686665117049038