Submitted by Navneet Das 3433 Comp A

***'
Mini Project 1 Deep Learning
Face Recogntion
'***

In [ ]:

```
import numpy as np # linear algebra
import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)

import os
for dirname, _, filenames in os.walk('/kaggle/input'):
    for filename in filenames:
        print(os.path.join(dirname, filename))
```

```
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject03.glasses.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject12.normal.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject02.leftlight.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject13.sad.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject06.leftlight.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject11.glasses.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject02.centerlight.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject14.sad.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject14.normal.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject04.surprised.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject01.happy.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject09.rightlight.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject15.rightlight.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject09.sad.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject15.sad.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject07.happy.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject12.rightlight.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject05.surprised.gif
/kaggle/input/opencv-facial-recognition-lbph/yalefaces/test/subject04.leftlight.gif
```

In [ ]:

```
pip install mtcnn
```

```
Collecting mtcnn
  Downloading mtcnn-0.1.1-py3-none-any.whl (2.3 MB)
     |████████████████████████████████| 2.3 MB 567 kB/s
Requirement already satisfied: keras>=2.0.0 in /opt/conda/lib/python3.7/site-packages (from mtcnn) (2.6.0)
Requirement already satisfied: opencv-python>=4.1.0 in /opt/conda/lib/python3.7/site-packages (from mtcnn) (4.5.4.60)
Requirement already satisfied: numpy>=1.14.5 in /opt/conda/lib/python3.7/site-packages (from opencv-python>=4.1.0->mtc
nn) (1.19.5)
Installing collected packages: mtcnn
Successfully installed mtcnn-0.1.1
WARNING: Running pip as the 'root' user can result in broken permissions and conflicting behaviour with the system pac
kage manager. It is recommended to use a virtual environment instead: https://pip.pypa.io/warnings/venv (https://pip.p
ypa.io/warnings/venv)
Note: you may need to restart the kernel to use updated packages.
```

In [ ]:

```
from matplotlib import pyplot as plt
import cv2
from PIL import Image

import mtcnn
from mtcnn.mtcnn import MTCNN
from matplotlib.patches import Rectangle

from os import listdir
from tqdm import tqdm
import pandas as pd
from sklearn.model_selection import train_test_split
import seaborn as sns
```

In [ ]:

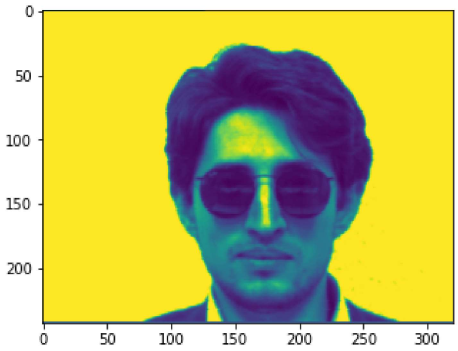
```
DIRECTORY = "../input/opencv-facial-recognition-lbph/yalefaces/"
DIRECTORY_train='../input/opencv-facial-recognition-lbph/yalefaces/train/'
DIRECTORY_test='../input/opencv-facial-recognition-lbph/yalefaces/test/'
```

1.Data Analysis

1) Data Sample

```
In [ ]: filename = "../input/opencv-facial-recognition-lbph/yalefaces/test/subject03.glasses.gif"
        pixels = plt.imread(filename)

        rgb_pixels = np.stack((pixels, pixels, pixels), axis=2)
        print(rgb_pixels.shape)
        plt.imshow(pixels)
        plt.show()
```

```
(243, 320, 3)
```



2) MTCNN

In [ ]:

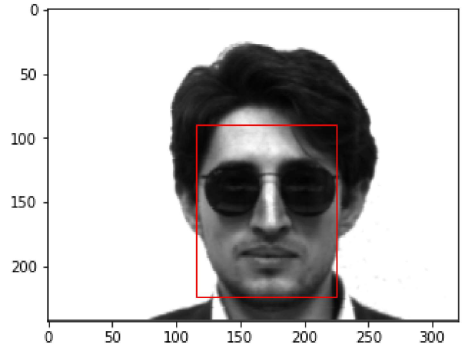
```
detector = MTCNN()

results = detector.detect_faces(rgb_pixels)
results
```

```
User settings:

   KMP_AFFINITY=granularity=fine,verbose,compact,1,0
   KMP_BLOCKTIME=0
   KMP_DUPLICATE_LIB_OK=True
   KMP_INIT_AT_FORK=FALSE
   KMP_SETTINGS=1
   KMP_WARNINGS=0

Effective settings:

   KMP_ABORT_DELAY=0
   KMP_ADAPTIVE_LOCK_PROPS='1,1024'
   KMP_ALIGN_ALLOC=64
   KMP_ALL_THREADPRIVATE=128
   KMP_ATOMIC_MODE=2
   KMP_BLOCKTIME=0
   KMP_CPUINFO_FILE: value is not defined
   KMP_DETERMINISTIC_REDUCTION=false
   KMP_DEVICE_THREAD_LIMIT=2147483647
   KMP_DISP_NUM_BUFFERS=7
   KMP_DUPLICATE_LIB_OK=true
   KMP_ENABLE_TASK_THROTTLING=true
   KMP_FORCE_REDUCTION: value is not defined
   KMP_FOREIGN_THREADS_THREADPRIVATE=true
   KMP_FORKJOIN_BARRIER='2,2'
   KMP_FORKJOIN_BARRIER_PATTERN='hyper,hyper'
   KMP_GTID_MODE=3
   KMP_HANDLE_SIGNALS=false
   KMP_HOT_TEAMS_MAX_LEVEL=1
   KMP_HOT_TEAMS_MODE=0
   KMP_INIT_AT_FORK=true
   KMP_LIBRARY=throughput
   KMP_LOCK_KIND=queuing
   KMP_MALLOC_POOL_INCR=1M
   KMP_NUM_LOCKS_IN_BLOCK=1
   KMP_PLAIN_BARRIER='2,2'
   KMP_PLAIN_BARRIER_PATTERN='hyper,hyper'
   KMP_REDUCTION_BARRIER='1,1'
   KMP_REDUCTION_BARRIER_PATTERN='hyper,hyper'
   KMP_SCHEDULE='static,balanced;guided,iterative'
   KMP_SETTINGS=true
   KMP_SPIN_BACKOFF_PARAMS='4096,100'
   KMP_STACKOFFSET=64
   KMP_STACKPAD=0
   KMP_STACKSIZE=8M
   KMP_STORAGE_MAP=false
   KMP_TASKING=2
   KMP_TASKLOOP_MIN_TASKS=0
   KMP_TASK_STEALING_CONSTRAINT=1
   KMP_TEAMS_THREAD_LIMIT=4
   KMP_TOPOLOGY_METHOD=all
   KMP_USE_YIELD=1
   KMP_VERSION=false
   KMP_WARNINGS=false
   OMP_AFFINITY_FORMAT='OMP: pid %P tid %i thread %n bound to OS proc set {%A}'
   OMP_ALLOCATOR=omp_default_mem_alloc
   OMP_CANCELLATION=false
   OMP_DEFAULT_DEVICE=0
   OMP_DISPLAY_AFFINITY=false
   OMP_DISPLAY_ENV=false
   OMP_DYNAMIC=false
   OMP_MAX_ACTIVE_LEVELS=1
   OMP_MAX_TASK_PRIORITY=0
   OMP_NESTED: deprecated; max-active-levels-var=1
   OMP_NUM_THREADS: value is not defined
   OMP_PLACES: value is not defined
   OMP_PROC_BIND='intel'
   OMP_SCHEDULE='static'
   OMP_STACKSIZE=8M
   OMP_TARGET_OFFLOAD=DEFAULT
   OMP_THREAD_LIMIT=2147483647
   OMP_WAIT_POLICY=PASSIVE
   KMP_AFFINITY='verbose,warnings,respect,granularity=fine,compact,1,0'

2021-12-06 14:52:23.044469: I tensorflow/core/common_runtime/process_util.cc:146] Creating new thread pool with defaul
t inter op setting: 2. Tune using inter_op_parallelism_threads for best performance.
2021-12-06 14:52:23.417070: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the MLIR Optimizat
```

```
ion Passes are enabled (registered 2)
```

```
Out[6]: [{'box': [115, 90, 110, 134],
          'confidence': 0.9997938275337219,
          'keypoints': {'left_eye': (147, 140),
           'right_eye': (198, 138),
           'nose': (174, 169),
           'mouth_left': (151, 192),
           'mouth_right': (195, 193)}}]
```

```
In [ ]: def draw_image_with_boxes(data, result_list):
            plt.imshow(data)
            ax = plt.gca()
            for result in result_list:
                x, y, width, height = result['box']
                rect = Rectangle((x, y), width, height, fill=False, color='red')
                ax.add_patch(rect)
            plt.show()

        draw_image_with_boxes(rgb_pixels, results)
```



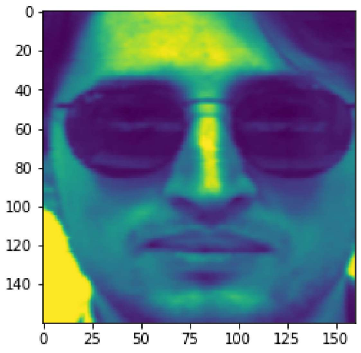
3) Extract and normalise the face pixels

In [ ]:

```
def extract_face_from_file(filename, required_size=(160, 160)):
    image = Image.open(filename)

    return extract_face(image, required_size)

def extract_face(image, required_size=(160, 160)):
    image = image.convert('RGB')
    pixels = np.asarray(image)
    results = detector.detect_faces(pixels)

    x1, y1, width, height = results[0]['box']

    x1, y1 = abs(x1), abs(y1)
    x2, y2 = x1 + width, y1 + height

    face = pixels[y1:y2, x1:x2]

    image = Image.fromarray(face)
    image = image.resize(required_size)
    face_array = np.asarray(image)
    gray_face = cv2.cvtColor(face_array, cv2.COLOR_BGR2GRAY)

    return gray_face

detector = MTCNN()

face_pixels = extract_face_from_file("../input/opencv-facial-recognition-lbph/yalefaces/test/subject03.glasses.gif")

plt.imshow(face_pixels)
```

Out[8]:

```
<matplotlib.image.AxesImage at 0x7f4e517775d0>
```



2.Data set ∽ 135 train datas and 30 test datas

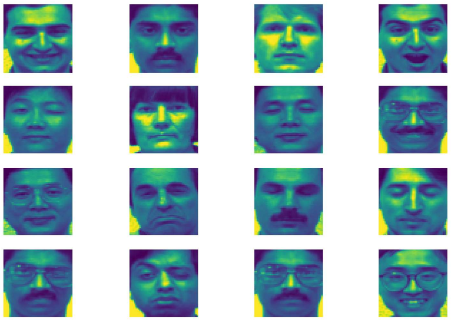
In [ ]:

```
def list_files(directory, contains):
    return list(f for f in listdir(directory) if contains in f)
```

In [ ]:

```
i = 1
faces = list()
for filename in tqdm(list_files(DIRECTORY_train, "subject")[0:16]):
    # path
    path = DIRECTORY_train + filename
    # get face
    face = extract_face_from_file(path)
    # plot
    plt.subplot(4, 4, i)
    plt.axis('off')
    plt.imshow(face)
    faces.append(face)
    i += 1
plt.show()
```

```
100%|██████████| 16/16 [00:09<00:00,  1.70it/s]
```



In [ ]:

```
filenames = pd.DataFrame(list_files(DIRECTORY_train, "subject"))

df_train = filenames[0].str.split(".", expand=True)
df_train["filename"] = filenames

df_train = df_train.rename(columns = {0:"subject", 1:"category"})
df_train['subject'] = df_train.subject.str.replace('subject' , '')
df_train.apply(pd.to_numeric, errors='coerce').dropna()
df_train['subject'] = pd.to_numeric(df_train["subject"])
df_train
```

Out[11]:

	subject	category	2	filename
0	15	happy	gif	subject15.happy.gif
1	13	noglasses	gif	subject13.noglasses.gif
2	1	normal	gif	subject01.normal.gif
3	15	surprised	gif	subject15.surprised.gif
4	14	wink	gif	subject14.wink.gif
...	...	...	...	...
130	5	sad	gif	subject05.sad.gif
131	3	surprised	gif	subject03.surprised.gif
132	4	sad	gif	subject04.sad.gif
133	7	normal	gif	subject07.normal.gif
134	2	surprised	gif	subject02.surprised.gif

135 rows × 4 columns

In [ ]:

```
filenames2 = pd.DataFrame(list_files(DIRECTORY_test, "subject"))

df_test = filenames2[0].str.split(".", expand=True)
df_test["filename"] = filenames2

df_test = df_test.rename(columns = {0:"subject", 1:"category"})
df_test['subject'] = df_test.subject.str.replace('subject' , '')
df_test.apply(pd.to_numeric, errors='coerce').dropna()
df_test['subject'] = pd.to_numeric(df_test["subject"])
df_test
```

Out[12]:

	subject	category	2	filename
0	3	glasses	gif	subject03.glasses.gif
1	12	normal	gif	subject12.normal.gif
2	2	leftlight	gif	subject02.leftlight.gif
3	13	sad	gif	subject13.sad.gif
4	6	leftlight	gif	subject06.leftlight.gif
5	11	glasses	gif	subject11.glasses.gif
6	2	centerlight	gif	subject02.centerlight.gif
7	14	sad	gif	subject14.sad.gif
8	14	normal	gif	subject14.normal.gif
9	4	surprised	gif	subject04.surprised.gif
10	1	happy	gif	subject01.happy.gif
11	9	rightlight	gif	subject09.rightlight.gif
12	15	rightlight	gif	subject15.rightlight.gif
13	9	sad	gif	subject09.sad.gif
14	15	sad	gif	subject15.sad.gif
15	7	happy	gif	subject07.happy.gif
16	12	rightlight	gif	subject12.rightlight.gif
17	5	surprised	gif	subject05.surprised.gif
18	4	leftlight	gif	subject04.leftlight.gif
19	10	sad	gif	subject10.sad.gif
20	6	happy	gif	subject06.happy.gif
21	8	rightlight	gif	subject08.rightlight.gif
22	13	sleepy	gif	subject13.sleepy.gif
23	3	leftlight	gif	subject03.leftlight.gif
24	5	sleepy	gif	subject05.sleepy.gif
25	10	centerlight	gif	subject10.centerlight.gif
26	8	normal	gif	subject08.normal.gif
27	1	gif	None	subject01.gif
28	7	leftlight	gif	subject07.leftlight.gif
29	11	happy	gif	subject11.happy.gif

In [ ]:

```
x_train=df_train.loc[:,['category','filename']]
x_test=df_test.loc[:,['category','filename']]
y_train=df_train.loc[:,['subject']]
y_test=df_test.loc[:,['subject']]
```

In [ ]:

```
y_train=y_train.to_numpy()
y_test=y_test.to_numpy()
```

In [ ]:

```
y_train = y_train.tolist()
y_test = y_test.tolist()
```

In [ ]:

```python
detector = MTCNN()

def load_dataset1(dataset):
    faces = list()
    for filename in tqdm(dataset["filename"]):
        path = DIRECTORY_train + filename
        # get face
        face = extract_face_from_file(path)
        faces.append(face)
    return np.asarray(faces)
```

In [ ]:

```python
detector = MTCNN()

def load_dataset2(dataset):
    faces = list()
    for filename in tqdm(dataset["filename"]):
        path = DIRECTORY_test + filename
        # get face
        face = extract_face_from_file(path)
        faces.append(face)
    return np.asarray(faces)
```

In [ ]:

```python
x_test = load_dataset2(x_test)
x_train = load_dataset1(x_train)

print(x_test.shape)
print(x_train.shape)
```

```
100%|██████████| 30/30 [00:17<00:00,  1.67it/s]
100%|██████████| 135/135 [01:17<00:00,  1.74it/s]

(30, 160, 160)
(135, 160, 160)
```

3. Convolutional Neural Network Model

In [ ]:

```python
TRAINING_DATA_DIRECTORY = "data/train"
TESTING_DATA_DIRECTORY = "data/test"
NUM_CLASSES = 15
EPOCHS = 25
BATCH_SIZE = 20
NUMBER_OF_TRAINING_IMAGES = 135
NUMBER_OF_TESTING_IMAGES = 30
IMAGE_HEIGHT = 160
IMAGE_WIDTH = 160
```

In [ ]:

```python
import os

def save_keras_dataset(setname, dataset, labels, per_class):
    data = sorted(list(zip(labels, dataset)), key=lambda x: x[0])

    j = 0
    for label, gray_img in tqdm(data):
        j = (j% per_class) + 1

        directory = f"data/{setname}/class_{label}/"
        if not os.path.exists(directory):
                os.makedirs(directory)
        cv2.imwrite(f"{directory}class_{label}_{j}.png",gray_img)
```

In [ ]:

```python
import shutil
shutil.rmtree(r'data', ignore_errors=True)

# Save datasets
save_keras_dataset("test", x_test, y_test, 3)
save_keras_dataset("train", x_train, y_train, 8)
```

```
100%|██████████| 30/30 [00:00<00:00, 1084.57it/s]
100%|██████████| 135/135 [00:00<00:00, 1877.72it/s]
```

In [ ]:

```
from tensorflow.keras.preprocessing.image import ImageDataGenerator
def data_generator():
    return ImageDataGenerator(
        rescale=1./255,

    )

def add_noise(img):
    """Add random noise to an image"""
    VARIABILITY = 35
    deviation = VARIABILITY*random.random()
    noise = np.random.normal(0, deviation, img.shape)
    img += noise
    np.clip(img, 0., 255.)
    return img
```

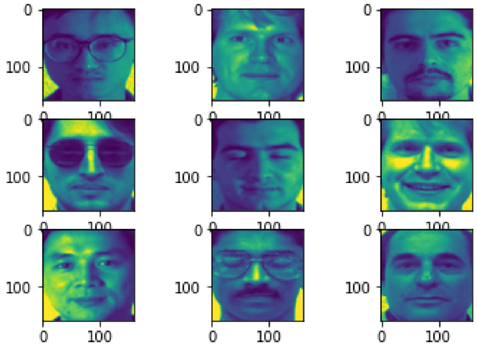
In [ ]:

```
training_generator = data_generator().flow_from_directory(
    TRAINING_DATA_DIRECTORY,
    target_size=(IMAGE_WIDTH, IMAGE_HEIGHT),
    batch_size=BATCH_SIZE,
    class_mode='categorical',
    color_mode='grayscale'
)

testing_generator = data_generator().flow_from_directory(
    TESTING_DATA_DIRECTORY,
    target_size=(IMAGE_WIDTH, IMAGE_HEIGHT),
    class_mode='categorical',
    color_mode='grayscale'
)

validation_generator = data_generator().flow_from_directory(
    TESTING_DATA_DIRECTORY,
    target_size=(IMAGE_WIDTH, IMAGE_HEIGHT),
    class_mode='categorical',
    color_mode='grayscale',
    shuffle=False
)
```

```
Found 120 images belonging to 15 classes.
Found 30 images belonging to 15 classes.
Found 30 images belonging to 15 classes.
```

In [ ]:

```
sample_images = testing_generator.next()[0]

f, xyarr = plt.subplots(3,3)
xyarr[0,0].imshow(sample_images[0])
xyarr[0,1].imshow(sample_images[1])
xyarr[0,2].imshow(sample_images[2])
xyarr[1,0].imshow(sample_images[3])
xyarr[1,1].imshow(sample_images[4])
xyarr[1,2].imshow(sample_images[5])
xyarr[2,0].imshow(sample_images[6])
xyarr[2,1].imshow(sample_images[7])
xyarr[2,2].imshow(sample_images[8])
plt.show()
```



In [ ]:

```
import keras
class MCDropout(keras.layers.Dropout):
    def call(self, inputs):
        return super().call(inputs, training=True)
```

In [ ]:

```
from tensorflow.keras import models
from tensorflow.keras.layers import Activation, ZeroPadding2D, MaxPooling2D, Conv2D, Flatten, Dense, Dropout
from tensorflow.keras import regularizers, constraints

model = models.Sequential()

model.add(Conv2D(32, kernel_size=(3, 3), activation='linear', input_shape=(IMAGE_WIDTH, IMAGE_HEIGHT, 1), padding='same
model.add(MaxPooling2D((2, 2)))

model.add(Conv2D(64, (3, 3), activation='relu', kernel_regularizer=regularizers.l2(l2=0.01)))
model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Conv2D(128, (3, 3), activation='relu', kernel_regularizer=regularizers.l2(l2=0.01)))
model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Flatten())

model.add(Dense(512, activation='relu', kernel_initializer="glorot_uniform", kernel_regularizer=regularizers.l2(l2=0.01

model.add(MCDropout(rate=0.5))

model.add(Dense(NUM_CLASSES, activation='softmax', kernel_initializer="glorot_uniform"))
```

In [ ]:

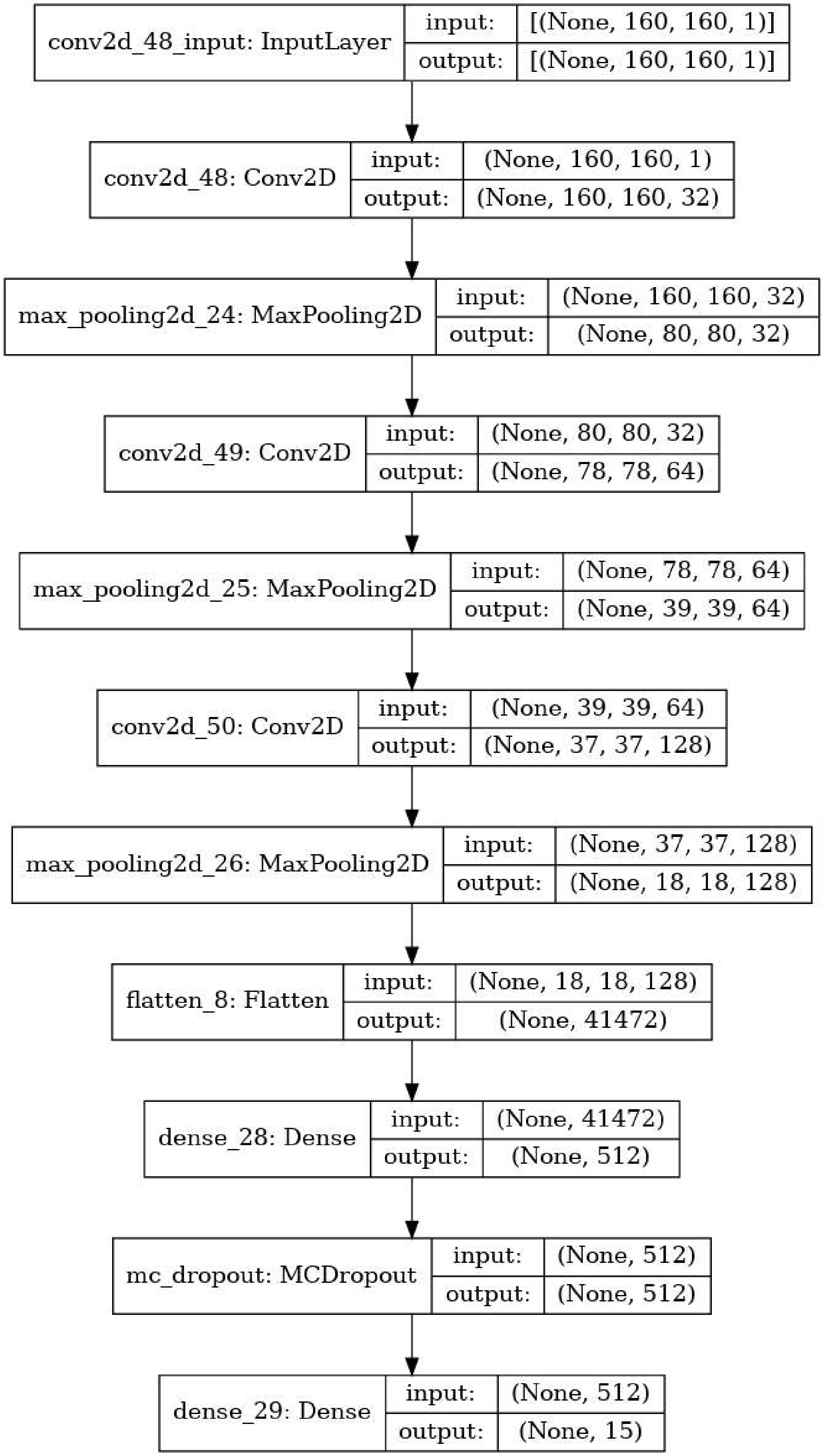
```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_48 (Conv2D)           (None, 160, 160, 32)      320       
_________________________________________________________________
max_pooling2d_24 (MaxPooling (None, 80, 80, 32)        0         
_________________________________________________________________
conv2d_49 (Conv2D)           (None, 78, 78, 64)        18496     
_________________________________________________________________
max_pooling2d_25 (MaxPooling (None, 39, 39, 64)        0         
_________________________________________________________________
conv2d_50 (Conv2D)           (None, 37, 37, 128)       73856     
_________________________________________________________________
max_pooling2d_26 (MaxPooling (None, 18, 18, 128)       0         
_________________________________________________________________
flatten_8 (Flatten)          (None, 41472)             0         
_________________________________________________________________
dense_28 (Dense)             (None, 512)               21234176  
_________________________________________________________________
mc_dropout (MCDropout)       (None, 512)               0         
_________________________________________________________________
dense_29 (Dense)             (None, 15)                7695      
=================================================================
Total params: 21,334,543
Trainable params: 21,334,543
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

```
from keras.utils.vis_utils import plot_model
plot_model(model, show_shapes=True, show_layer_names=True)
```

Out[28]:



conv2d_48_input: InputLayer	input:	[(None, 160, 160, 1)]
	output:	[(None, 160, 160, 1)]
conv2d_48: Conv2D	input:	(None, 160, 160, 1)
	output:	(None, 160, 160, 32)
max_pooling2d_24: MaxPooling2D	input:	(None, 160, 160, 32)
	output:	(None, 80, 80, 32)
conv2d_49: Conv2D	input:	(None, 80, 80, 32)
	output:	(None, 78, 78, 64)
max_pooling2d_25: MaxPooling2D	input:	(None, 78, 78, 64)
	output:	(None, 39, 39, 64)
conv2d_50: Conv2D	input:	(None, 39, 39, 64)
	output:	(None, 37, 37, 128)
max_pooling2d_26: MaxPooling2D	input:	(None, 37, 37, 128)
	output:	(None, 18, 18, 128)
flatten_8: Flatten	input:	(None, 18, 18, 128)
	output:	(None, 41472)
dense_28: Dense	input:	(None, 41472)
	output:	(None, 512)
mc_dropout: MCDropout	input:	(None, 512)
	output:	(None, 512)
dense_29: Dense	input:	(None, 512)
	output:	(None, 15)

In [ ]:

```
from tensorflow.keras import optimizers, losses
from tensorflow.keras.callbacks import EarlyStopping
early_stopping = EarlyStopping()

model.compile(
    loss=losses.CategoricalCrossentropy(from_logits=True),
    optimizer=optimizers.Adam(learning_rate=0.0003),
    metrics=["accuracy"]
)

history = model.fit(
    training_generator,
    steps_per_epoch=(NUMBER_OF_TRAINING_IMAGES//BATCH_SIZE ),
    epochs=EPOCHS,
    validation_data=testing_generator,
    shuffle=True,
    validation_steps=(NUMBER_OF_TESTING_IMAGES//BATCH_SIZE),
#     callbacks=[early_stopping]
)
```

```
Epoch 1/25
```

```
/opt/conda/lib/python3.7/site-packages/keras/backend.py:4847: UserWarning: "`categorical_crossentropy` received `fro
logits=True`, but the `output` argument was produced by a sigmoid or softmax activation and thus does not represent lo
gits. Was this intended?"
  '"`categorical_crossentropy` received `from_logits=True`, but '
```

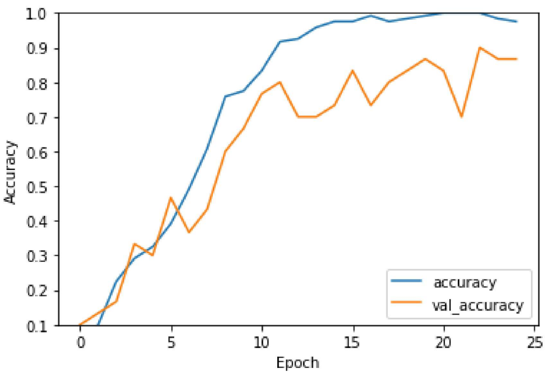
```
6/6 [==============================] - 4s 453ms/step - loss: 13.0665 - accuracy: 0.0583 - val_loss: 11.2362 - val_ac
racy: 0.1000
Epoch 2/25
6/6 [==============================] - 2s 402ms/step - loss: 10.2653 - accuracy: 0.1000 - val_loss: 8.9813 - val_accur
acy: 0.1333
Epoch 3/25
6/6 [==============================] - 2s 406ms/step - loss: 8.2131 - accuracy: 0.2250 - val_loss: 7.3162 - val_accura
cy: 0.1667
Epoch 4/25
6/6 [==============================] - 2s 415ms/step - loss: 6.6801 - accuracy: 0.2917 - val_loss: 6.0057 - val_accura
cy: 0.3333
Epoch 5/25
6/6 [==============================] - 3s 494ms/step - loss: 5.5678 - accuracy: 0.3250 - val_loss: 4.9027 - val_accura
cy: 0.3000
Epoch 6/25
6/6 [==============================] - 2s 405ms/step - loss: 4.6911 - accuracy: 0.3917 - val_loss: 4.3338 - val_accura
cy: 0.4667
Epoch 7/25
6/6 [==============================] - 2s 399ms/step - loss: 4.0437 - accuracy: 0.4917 - val_loss: 3.9233 - val_accura
cy: 0.3667
Epoch 8/25
6/6 [==============================] - 2s 408ms/step - loss: 3.4352 - accuracy: 0.6083 - val_loss: 3.6407 - val_accura
cy: 0.4333
Epoch 9/25
6/6 [==============================] - 2s 414ms/step - loss: 2.8870 - accuracy: 0.7583 - val_loss: 3.1343 - val_accura
cy: 0.6000
Epoch 10/25
6/6 [==============================] - 2s 402ms/step - loss: 2.6277 - accuracy: 0.7750 - val_loss: 2.8893 - val_accura
cy: 0.6667
Epoch 11/25
6/6 [==============================] - 2s 401ms/step - loss: 2.3975 - accuracy: 0.8333 - val_loss: 2.5442 - val_accura
cy: 0.7667
Epoch 12/25
6/6 [==============================] - 2s 412ms/step - loss: 2.1244 - accuracy: 0.9167 - val_loss: 2.5290 - val_accura
cy: 0.8000
Epoch 13/25
6/6 [==============================] - 2s 410ms/step - loss: 1.9782 - accuracy: 0.9250 - val_loss: 2.5517 - val_accura
cy: 0.7000
Epoch 14/25
6/6 [==============================] - 2s 402ms/step - loss: 1.8054 - accuracy: 0.9583 - val_loss: 2.5473 - val_accura
cy: 0.7000
Epoch 15/25
6/6 [==============================] - 2s 402ms/step - loss: 1.7525 - accuracy: 0.9750 - val_loss: 2.3258 - val_accura
cy: 0.7333
Epoch 16/25
6/6 [==============================] - 2s 399ms/step - loss: 1.6347 - accuracy: 0.9750 - val_loss: 1.9473 - val_accura
cy: 0.8333
Epoch 17/25
6/6 [==============================] - 2s 406ms/step - loss: 1.5042 - accuracy: 0.9917 - val_loss: 2.3997 - val_accura
cy: 0.7333
Epoch 18/25
6/6 [==============================] - 3s 485ms/step - loss: 1.4579 - accuracy: 0.9750 - val_loss: 1.8285 - val_accura
cy: 0.8000
Epoch 19/25
6/6 [==============================] - 2s 403ms/step - loss: 1.3716 - accuracy: 0.9833 - val_loss: 1.9576 - val_accura
cy: 0.8333
Epoch 20/25
6/6 [==============================] - 2s 402ms/step - loss: 1.3164 - accuracy: 0.9917 - val_loss: 1.7942 - val_accura
cy: 0.8667
Epoch 21/25
6/6 [==============================] - 2s 405ms/step - loss: 1.2431 - accuracy: 1.0000 - val_loss: 1.6066 - val_accura
cy: 0.8333
Epoch 22/25
6/6 [==============================] - 2s 405ms/step - loss: 1.1756 - accuracy: 1.0000 - val_loss: 1.8609 - val_accura
cy: 0.7000
Epoch 23/25
6/6 [==============================] - 2s 401ms/step - loss: 1.1020 - accuracy: 1.0000 - val_loss: 1.4665 - val_accura
cy: 0.9000
Epoch 24/25
6/6 [==============================] - 2s 412ms/step - loss: 1.0746 - accuracy: 0.9833 - val_loss: 1.5058 - val_accura
cy: 0.8667
Epoch 25/25
6/6 [==============================] - 2s 399ms/step - loss: 1.0788 - accuracy: 0.9750 - val_loss: 1.5114 - val_accura
cy: 0.8667
```

In [ ]:

```python
plot_folder = "plot"
plt.plot(history.history['accuracy'], label='accuracy')
plt.plot(history.history['val_accuracy'], label='val_accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.ylim([0.1, 1])
plt.legend(loc='lower right')
```

Out[30]:

```
<matplotlib.legend.Legend at 0x7f4e041a0790>
```

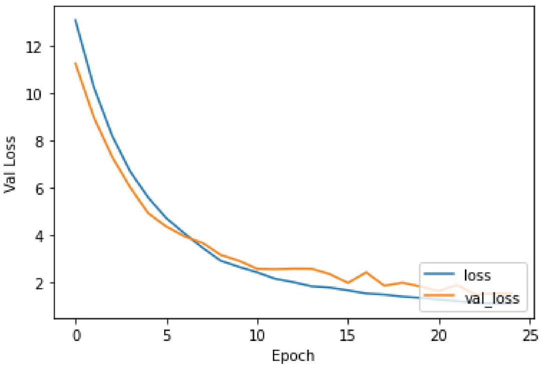


In [ ]:

```python
plot_folder = "plot"
plt.plot(history.history['loss'], label='loss')
plt.plot(history.history['val_loss'], label='val_loss')
plt.xlabel('Epoch')
plt.ylabel('Val Loss')
plt.legend(loc='lower right')
```

Out[31]:

```
<matplotlib.legend.Legend at 0x7f4dff2e3c10>
```



In [ ]:

```
from sklearn.metrics import classification_report, confusion_matrix, precision_recall_fscore_support

Y_pred = model.predict(validation_generator)
y_pred = np.argmax(Y_pred, axis=1)
print(classification_report(validation_generator.classes, y_pred))
print(validation_generator.classes)
print(y_pred)
print('Confusion Matrix')
print(confusion_matrix(validation_generator.classes, y_pred))
```

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00         2
           1       1.00      1.00      1.00         2
           2       0.50      0.50      0.50         2
           3       1.00      1.00      1.00         2
           4       0.67      1.00      0.80         2
           5       1.00      1.00      1.00         2
           6       0.67      1.00      0.80         2
           7       0.67      1.00      0.80         2
           8       1.00      0.50      0.67         2
           9       1.00      0.50      0.67         2
          10       0.67      1.00      0.80         2
          11       1.00      0.50      0.67         2
          12       1.00      1.00      1.00         2
          13       1.00      1.00      1.00         2
          14       1.00      0.50      0.67         2

    accuracy                           0.83        30
   macro avg       0.88      0.83      0.82        30
weighted avg       0.88      0.83      0.82        30

[ 0  0  1  1  2  2  3  3  4  4  5  5  6  6  7  7  8  8  9  9 10 10 11 11
 12 12 13 13 14 14]
[ 0  0  1  1  2 10  3  3  4  4  5  5  6  6  7  7  2  8  9  4 10 10  6 11
 12 12 13 13 14  7]
Confusion Matrix
[[2 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
 [0 2 0 0 0 0 0 0 0 0 0 0 0 0 0]
 [0 0 1 0 0 0 0 0 0 0 1 0 0 0 0]
 [0 0 0 2 0 0 0 0 0 0 0 0 0 0 0]
 [0 0 0 0 2 0 0 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 2 0 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 0 2 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 0 0 2 0 0 0 0 0 0 0]
 [0 0 1 0 0 0 0 0 1 0 0 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 1 0 0 0 0 0]
 [0 0 0 0 0 0 0 0 0 0 2 0 0 0 0]
 [0 0 0 0 0 0 1 0 0 0 0 1 0 0 0]
 [0 0 0 0 0 0 0 0 0 0 0 0 2 0 0]
 [0 0 0 0 0 0 0 0 0 0 0 0 0 2 0]
 [0 0 0 0 0 0 0 1 0 0 0 0 0 0 1]]
```

In [ ]: