

Class Challenge: Image Classification of COVID-19 X-rays

Task 2 [Total points: 30]

Setup

- This assignment involves the following packages: 'matplotlib', 'numpy', and 'sklearn'.
- If you are using conda, use the following commands to install the above packages:

```
conda install matplotlib
conda install numpy
conda install -c anaconda scikit-learn
```

- If you are using pip, use the following commands to install the above packages:

```
pip install matplotlib
pip install numpy
pip install sklearn
```

Data

Please download the data using the following link: [COVID-19 \(https://drive.google.com/file/d/1Y88tgqpQ1Pjko_7rntcPowOJs_QNOrJ-/view\)](https://drive.google.com/file/d/1Y88tgqpQ1Pjko_7rntcPowOJs_QNOrJ-/view).

- After downloading 'Covid_Data_GradientCrescent.zip', unzip the file and you should see the following data structure:

```
|--all
|-----train
|-----test
|--two
|-----train
|-----test
```

- Put the 'all' folder, the 'two' folder and this python notebook in the **same directory** so that the following code can correctly locate the data.

[20 points] Multi-class Classification

In [1]:

```
import os

import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.preprocessing.image import ImageDataGenerator

os.environ['OMP_NUM_THREADS'] = '1'
os.environ['CUDA_VISIBLE_DEVICES'] = '-1'
tf.__version__
```

Out[1]:

'2.3.1'

Load Image Data

In [2]:

```
DATA_LIST = os.listdir('all/train')
DATASET_PATH = 'all/train'
TEST_DIR = 'all/test'
IMAGE_SIZE = (224, 224)
NUM_CLASSES = len(DATA_LIST)
BATCH_SIZE = 10 # try reducing batch size or freeze more layers if your GPU runs out of memory
NUM_EPOCHS = 100
LEARNING_RATE = 0.0001 # start off with high rate first 0.001 and experiment with reducing it gradually
```

Generate Training and Validation Batches

In [31]:

```
train_datagen = ImageDataGenerator(rescale=1./255,rotation_range=50,featurewise_center = True,
                                   featurewise_std_normalization = True,width_shift_range=0.2,
                                   height_shift_range=0.2,shear_range=0.25,zoom_range=0.1,
                                   zca_whitening = True,channel_shift_range = 20,
                                   horizontal_flip = True,vertical_flip = True,
                                   validation_split = 0.2,fill_mode='constant')

train_batches = train_datagen.flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                  shuffle=True,batch_size=BATCH_SIZE,
                                                  subset = "training",seed=42,
                                                  class_mode="categorical")

valid_batches = train_datagen.flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                  shuffle=True,batch_size=BATCH_SIZE,
                                                  subset = "validation",
                                                  seed=42,class_mode="categorical")
```

Found 216 images belonging to 4 classes.
 Found 54 images belonging to 4 classes.

[10 points] Build Model

Hint: Starting from a pre-trained model typically helps performance on a new task, e.g. starting with weights obtained by training on ImageNet.

In [8]:

```
checkpoint_filepath = 'all/'
checkpoint = tf.keras.callbacks.ModelCheckpoint(checkpoint_filepath,
                                                monitor='val_accuracy',
                                                verbose=1,
                                                save_best_only=True,
                                                save_weights_only=True,
                                                mode='max')

vgg16 = tf.keras.applications.VGG16(weights='imagenet', include_top=False, input_shape = (224, 224, 3))
vgg16.trainable = False
model = tf.keras.models.Sequential([
    vgg16,
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(256, activation='relu', name='feature_dense'),
    tf.keras.layers.Dropout(0.25),
    tf.keras.layers.Dense(256, activation='relu'),
    tf.keras.layers.Dropout(0.25),
    tf.keras.layers.Dense(4, activation='softmax')
])
model.summary()
opt = tf.keras.optimizers.Adam(learning_rate=LEARNING_RATE)
model.compile(optimizer=opt,
              loss=tf.keras.losses.CategoricalCrossentropy(from_logits=False),
              metrics=['accuracy'])
```

Model: "sequential_2"

Layer (type)	Output Shape	Param #
vgg16 (Functional)	(None, 7, 7, 512)	14714688
flatten_2 (Flatten)	(None, 25088)	0
feature_dense (Dense)	(None, 256)	6422784
dropout_4 (Dropout)	(None, 256)	0
dense_3 (Dense)	(None, 256)	65792
dropout_5 (Dropout)	(None, 256)	0
dense_4 (Dense)	(None, 4)	1028
Total params: 21,204,292		
Trainable params: 6,489,604		
Non-trainable params: 14,714,688		

[5 points] Train Model

In [9]:

```
#FIT MODEL
STEP_SIZE_TRAIN=train_batches.n//train_batches.batch_size
STEP_SIZE_VALID=valid_batches.n//valid_batches.batch_size

history = model.fit(train_batches, epochs=100, validation_data=valid_batches,batch_size=5,
                    steps_per_epoch=STEP_SIZE_TRAIN, validation_steps = STEP_SIZE_VALID, callbac
ks=[checkpoint])
model.load_weights(checkpoint_filepath)
```

```
C:\Users\Soo Whan Park\Anaconda3\lib\site-packages\keras_preprocessing\image\image_data_generator.py:720: UserWarning: This ImageDataGenerator specifies `featurewise_center`, but it hasn't been fit on any training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '
C:\Users\Soo Whan Park\Anaconda3\lib\site-packages\keras_preprocessing\image\image_data_generator.py:739: UserWarning: This ImageDataGenerator specifies `zca_whitening`, but it hasn't been fit on any training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies ')
```

Epoch 1/100
21/21 [=====] - ETA: 0s - loss: 2.3386 - accuracy: 0.2233
Epoch 00001: val_accuracy improved from -inf to 0.24000, saving model to allW
21/21 [=====] - 24s 1s/step - loss: 2.3386 - accuracy: 0.2233 - val_loss: 1.4334 - val_accuracy: 0.2400
Epoch 2/100
21/21 [=====] - ETA: 0s - loss: 1.6696 - accuracy: 0.1748
Epoch 00002: val_accuracy improved from 0.24000 to 0.28000, saving model to allW
21/21 [=====] - 24s 1s/step - loss: 1.6696 - accuracy: 0.1748 - val_loss: 1.4295 - val_accuracy: 0.2800
Epoch 3/100
21/21 [=====] - ETA: 0s - loss: 1.4390 - accuracy: 0.2670
Epoch 00003: val_accuracy improved from 0.28000 to 0.32000, saving model to allW
21/21 [=====] - 26s 1s/step - loss: 1.4390 - accuracy: 0.2670 - val_loss: 1.3384 - val_accuracy: 0.3200
Epoch 4/100
21/21 [=====] - ETA: 0s - loss: 1.5222 - accuracy: 0.2087
Epoch 00004: val_accuracy did not improve from 0.32000
21/21 [=====] - 28s 1s/step - loss: 1.5222 - accuracy: 0.2087 - val_loss: 1.4195 - val_accuracy: 0.2000
Epoch 5/100
21/21 [=====] - ETA: 0s - loss: 1.3983 - accuracy: 0.2961
Epoch 00005: val_accuracy improved from 0.32000 to 0.36000, saving model to allW
21/21 [=====] - 27s 1s/step - loss: 1.3983 - accuracy: 0.2961 - val_loss: 1.2719 - val_accuracy: 0.3600
Epoch 6/100
21/21 [=====] - ETA: 0s - loss: 1.3972 - accuracy: 0.3350
Epoch 00006: val_accuracy improved from 0.36000 to 0.50000, saving model to allW
21/21 [=====] - 26s 1s/step - loss: 1.3972 - accuracy: 0.3350 - val_loss: 1.3120 - val_accuracy: 0.5000
Epoch 7/100
21/21 [=====] - ETA: 0s - loss: 1.3875 - accuracy: 0.2864
Epoch 00007: val_accuracy did not improve from 0.50000
21/21 [=====] - 26s 1s/step - loss: 1.3875 - accuracy: 0.2864 - val_loss: 1.2724 - val_accuracy: 0.4600
Epoch 8/100
21/21 [=====] - ETA: 0s - loss: 1.3991 - accuracy: 0.2427
Epoch 00008: val_accuracy improved from 0.50000 to 0.56000, saving model to allW
21/21 [=====] - 27s 1s/step - loss: 1.3991 - accuracy: 0.2427 - val_loss: 1.2641 - val_accuracy: 0.5600
Epoch 9/100
21/21 [=====] - ETA: 0s - loss: 1.2930 - accuracy: 0.4078
Epoch 00009: val_accuracy did not improve from 0.56000
21/21 [=====] - 29s 1s/step - loss: 1.2930 - accuracy: 0.4078 - val_loss: 1.1943 - val_accuracy: 0.4800
Epoch 10/100
21/21 [=====] - ETA: 0s - loss: 1.2927 - accuracy: 0.3883
Epoch 00010: val_accuracy did not improve from 0.56000
21/21 [=====] - 28s 1s/step - loss: 1.2927 - accuracy: 0.3883 - val_loss: 1.1837 - val_accuracy: 0.5000
Epoch 11/100
21/21 [=====] - ETA: 0s - loss: 1.2880 - accuracy: 0.4029
Epoch 00011: val_accuracy did not improve from 0.56000
21/21 [=====] - 28s 1s/step - loss: 1.2880 - accuracy: 0.4029 - val_loss: 1.1386 - val_accuracy: 0.4800
Epoch 12/100
21/21 [=====] - ETA: 0s - loss: 1.2908 - accuracy: 0.3107
Epoch 00012: val_accuracy did not improve from 0.56000
21/21 [=====] - 29s 1s/step - loss: 1.2908 - accuracy: 0.3107 - val_loss: 1.1361 - val_accuracy: 0.4600
Epoch 13/100

21/21 [=====] - ETA: 0s - loss: 1.1756 - accuracy: 0.4417
Epoch 00013: val_accuracy did not improve from 0.56000
21/21 [=====] - 32s 2s/step - loss: 1.1756 - accuracy: 0.4417 - val_loss: 1.1594 - val_accuracy: 0.5200
Epoch 14/100
21/21 [=====] - ETA: 0s - loss: 1.2124 - accuracy: 0.4806
Epoch 00014: val_accuracy did not improve from 0.56000
21/21 [=====] - 30s 1s/step - loss: 1.2124 - accuracy: 0.4806 - val_loss: 1.0917 - val_accuracy: 0.5400
Epoch 15/100
21/21 [=====] - ETA: 0s - loss: 1.1365 - accuracy: 0.4806
Epoch 00015: val_accuracy did not improve from 0.56000
21/21 [=====] - 26s 1s/step - loss: 1.1365 - accuracy: 0.4806 - val_loss: 1.0398 - val_accuracy: 0.5600
Epoch 16/100
21/21 [=====] - ETA: 0s - loss: 1.1815 - accuracy: 0.3981
Epoch 00016: val_accuracy did not improve from 0.56000
21/21 [=====] - 26s 1s/step - loss: 1.1815 - accuracy: 0.3981 - val_loss: 1.0460 - val_accuracy: 0.5400
Epoch 17/100
21/21 [=====] - ETA: 0s - loss: 1.1585 - accuracy: 0.4515
Epoch 00017: val_accuracy did not improve from 0.56000
21/21 [=====] - 27s 1s/step - loss: 1.1585 - accuracy: 0.4515 - val_loss: 1.0350 - val_accuracy: 0.4800
Epoch 18/100
21/21 [=====] - ETA: 0s - loss: 1.1748 - accuracy: 0.4563
Epoch 00018: val_accuracy did not improve from 0.56000
21/21 [=====] - 27s 1s/step - loss: 1.1748 - accuracy: 0.4563 - val_loss: 1.0427 - val_accuracy: 0.5000
Epoch 19/100
21/21 [=====] - ETA: 0s - loss: 1.1208 - accuracy: 0.4903
Epoch 00019: val_accuracy improved from 0.56000 to 0.58000, saving model to allW
21/21 [=====] - 27s 1s/step - loss: 1.1208 - accuracy: 0.4903 - val_loss: 1.0154 - val_accuracy: 0.5800
Epoch 20/100
21/21 [=====] - ETA: 0s - loss: 1.1206 - accuracy: 0.4951
Epoch 00020: val_accuracy improved from 0.58000 to 0.60000, saving model to allW
21/21 [=====] - 27s 1s/step - loss: 1.1206 - accuracy: 0.4951 - val_loss: 0.9450 - val_accuracy: 0.6000
Epoch 21/100
21/21 [=====] - ETA: 0s - loss: 1.0926 - accuracy: 0.5194
Epoch 00021: val_accuracy improved from 0.60000 to 0.62000, saving model to allW
21/21 [=====] - 27s 1s/step - loss: 1.0926 - accuracy: 0.5194 - val_loss: 0.9506 - val_accuracy: 0.6200
Epoch 22/100
21/21 [=====] - ETA: 0s - loss: 1.0958 - accuracy: 0.4903
Epoch 00022: val_accuracy did not improve from 0.62000
21/21 [=====] - 27s 1s/step - loss: 1.0958 - accuracy: 0.4903 - val_loss: 1.0363 - val_accuracy: 0.5600
Epoch 23/100
21/21 [=====] - ETA: 0s - loss: 1.1169 - accuracy: 0.5146
Epoch 00023: val_accuracy did not improve from 0.62000
21/21 [=====] - 27s 1s/step - loss: 1.1169 - accuracy: 0.5146 - val_loss: 0.9716 - val_accuracy: 0.5800
Epoch 24/100
21/21 [=====] - ETA: 0s - loss: 1.0666 - accuracy: 0.5291
Epoch 00024: val_accuracy did not improve from 0.62000
21/21 [=====] - 27s 1s/step - loss: 1.0666 - accuracy: 0.5291 - val_loss: 0.9569 - val_accuracy: 0.5200
Epoch 25/100
21/21 [=====] - ETA: 0s - loss: 1.0513 - accuracy: 0.5728

Epoch 00025: val_accuracy did not improve from 0.62000
21/21 [=====] - 27s 1s/step - loss: 1.0513 - accuracy: 0.5728 - val_loss: 0.9730 - val_accuracy: 0.5400
Epoch 26/100
21/21 [=====] - ETA: 0s - loss: 1.0798 - accuracy: 0.4854
Epoch 00026: val_accuracy improved from 0.62000 to 0.64000, saving model to allW
21/21 [=====] - 27s 1s/step - loss: 1.0798 - accuracy: 0.4854 - val_loss: 0.8879 - val_accuracy: 0.6400
Epoch 27/100
21/21 [=====] - ETA: 0s - loss: 1.0385 - accuracy: 0.5194
Epoch 00027: val_accuracy did not improve from 0.64000
21/21 [=====] - 25s 1s/step - loss: 1.0385 - accuracy: 0.5194 - val_loss: 0.9006 - val_accuracy: 0.6000
Epoch 28/100
21/21 [=====] - ETA: 0s - loss: 1.0138 - accuracy: 0.5631
Epoch 00028: val_accuracy did not improve from 0.64000
21/21 [=====] - 26s 1s/step - loss: 1.0138 - accuracy: 0.5631 - val_loss: 0.8848 - val_accuracy: 0.5800
Epoch 29/100
21/21 [=====] - ETA: 0s - loss: 1.0282 - accuracy: 0.5243
Epoch 00029: val_accuracy did not improve from 0.64000
21/21 [=====] - 26s 1s/step - loss: 1.0282 - accuracy: 0.5243 - val_loss: 0.8677 - val_accuracy: 0.6400
Epoch 30/100
21/21 [=====] - ETA: 0s - loss: 0.9748 - accuracy: 0.5922
Epoch 00030: val_accuracy improved from 0.64000 to 0.68000, saving model to allW
21/21 [=====] - 26s 1s/step - loss: 0.9748 - accuracy: 0.5922 - val_loss: 0.8821 - val_accuracy: 0.6800
Epoch 31/100
21/21 [=====] - ETA: 0s - loss: 1.0010 - accuracy: 0.5437
Epoch 00031: val_accuracy did not improve from 0.68000
21/21 [=====] - 27s 1s/step - loss: 1.0010 - accuracy: 0.5437 - val_loss: 0.8406 - val_accuracy: 0.6000
Epoch 32/100
21/21 [=====] - ETA: 0s - loss: 1.0474 - accuracy: 0.4854
Epoch 00032: val_accuracy did not improve from 0.68000
21/21 [=====] - 26s 1s/step - loss: 1.0474 - accuracy: 0.4854 - val_loss: 0.8950 - val_accuracy: 0.6000
Epoch 33/100
21/21 [=====] - ETA: 0s - loss: 0.9262 - accuracy: 0.6019
Epoch 00033: val_accuracy did not improve from 0.68000
21/21 [=====] - 26s 1s/step - loss: 0.9262 - accuracy: 0.6019 - val_loss: 0.8413 - val_accuracy: 0.6400
Epoch 34/100
21/21 [=====] - ETA: 0s - loss: 0.9661 - accuracy: 0.5874
Epoch 00034: val_accuracy did not improve from 0.68000
21/21 [=====] - 27s 1s/step - loss: 0.9661 - accuracy: 0.5874 - val_loss: 0.8237 - val_accuracy: 0.6600
Epoch 35/100
21/21 [=====] - ETA: 0s - loss: 0.9836 - accuracy: 0.5922
Epoch 00035: val_accuracy did not improve from 0.68000
21/21 [=====] - 26s 1s/step - loss: 0.9836 - accuracy: 0.5922 - val_loss: 0.8259 - val_accuracy: 0.6600
Epoch 36/100
21/21 [=====] - ETA: 0s - loss: 0.9751 - accuracy: 0.5728
Epoch 00036: val_accuracy did not improve from 0.68000
21/21 [=====] - 30s 1s/step - loss: 0.9751 - accuracy: 0.5728 - val_loss: 0.8290 - val_accuracy: 0.6200
Epoch 37/100
21/21 [=====] - ETA: 0s - loss: 0.9312 - accuracy: 0.6165
Epoch 00037: val_accuracy did not improve from 0.68000

21/21 [=====] - 27s 1s/step - loss: 0.9312 - accuracy: 0.6165 - val_loss: 0.7949 - val_accuracy: 0.6200
Epoch 38/100
21/21 [=====] - ETA: 0s - loss: 0.9435 - accuracy: 0.5728
Epoch 00038: val_accuracy did not improve from 0.68000
21/21 [=====] - 27s 1s/step - loss: 0.9435 - accuracy: 0.5728 - val_loss: 0.7768 - val_accuracy: 0.6000
Epoch 39/100
21/21 [=====] - ETA: 0s - loss: 1.0196 - accuracy: 0.5583
Epoch 00039: val_accuracy did not improve from 0.68000
21/21 [=====] - 28s 1s/step - loss: 1.0196 - accuracy: 0.5583 - val_loss: 0.9256 - val_accuracy: 0.4800
Epoch 40/100
21/21 [=====] - ETA: 0s - loss: 0.9915 - accuracy: 0.5049
Epoch 00040: val_accuracy did not improve from 0.68000
21/21 [=====] - 27s 1s/step - loss: 0.9915 - accuracy: 0.5049 - val_loss: 0.8338 - val_accuracy: 0.6200
Epoch 41/100
21/21 [=====] - ETA: 0s - loss: 0.8859 - accuracy: 0.6408
Epoch 00041: val_accuracy did not improve from 0.68000
21/21 [=====] - 27s 1s/step - loss: 0.8859 - accuracy: 0.6408 - val_loss: 0.8276 - val_accuracy: 0.6400
Epoch 42/100
21/21 [=====] - ETA: 0s - loss: 0.8990 - accuracy: 0.6262
Epoch 00042: val_accuracy did not improve from 0.68000
21/21 [=====] - 27s 1s/step - loss: 0.8990 - accuracy: 0.6262 - val_loss: 0.7472 - val_accuracy: 0.6600
Epoch 43/100
21/21 [=====] - ETA: 0s - loss: 0.9218 - accuracy: 0.5971
Epoch 00043: val_accuracy did not improve from 0.68000
21/21 [=====] - 27s 1s/step - loss: 0.9218 - accuracy: 0.5971 - val_loss: 0.8746 - val_accuracy: 0.5600
Epoch 44/100
21/21 [=====] - ETA: 0s - loss: 0.8378 - accuracy: 0.5922
Epoch 00044: val_accuracy improved from 0.68000 to 0.70000, saving model to allW
21/21 [=====] - 26s 1s/step - loss: 0.8378 - accuracy: 0.5922 - val_loss: 0.7214 - val_accuracy: 0.7000
Epoch 45/100
21/21 [=====] - ETA: 0s - loss: 0.8776 - accuracy: 0.5874
Epoch 00045: val_accuracy did not improve from 0.70000
21/21 [=====] - 26s 1s/step - loss: 0.8776 - accuracy: 0.5874 - val_loss: 0.8565 - val_accuracy: 0.5800
Epoch 46/100
21/21 [=====] - ETA: 0s - loss: 0.8690 - accuracy: 0.6117
Epoch 00046: val_accuracy did not improve from 0.70000
21/21 [=====] - 27s 1s/step - loss: 0.8690 - accuracy: 0.6117 - val_loss: 0.8166 - val_accuracy: 0.5600
Epoch 47/100
21/21 [=====] - ETA: 0s - loss: 0.9360 - accuracy: 0.5583
Epoch 00047: val_accuracy did not improve from 0.70000
21/21 [=====] - 27s 1s/step - loss: 0.9360 - accuracy: 0.5583 - val_loss: 0.8277 - val_accuracy: 0.5600
Epoch 48/100
21/21 [=====] - ETA: 0s - loss: 0.9438 - accuracy: 0.5631
Epoch 00048: val_accuracy did not improve from 0.70000
21/21 [=====] - 28s 1s/step - loss: 0.9438 - accuracy: 0.5631 - val_loss: 0.7955 - val_accuracy: 0.6600
Epoch 49/100
21/21 [=====] - ETA: 0s - loss: 0.9146 - accuracy: 0.5874
Epoch 00049: val_accuracy did not improve from 0.70000
21/21 [=====] - 28s 1s/step - loss: 0.9146 - accuracy: 0.5874

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5874 - val_loss: 0.7211 - val_accuracy: 0.6800
Epoch 50/100
21/21 [=====] - ETA: 0s - loss: 0.8939 - accuracy: 0.6019
Epoch 00050: val_accuracy did not improve from 0.70000
21/21 [=====] - 27s 1s/step - loss: 0.8939 - accuracy: 0.
6019 - val_loss: 0.6644 - val_accuracy: 0.7000
Epoch 51/100
21/21 [=====] - ETA: 0s - loss: 0.8910 - accuracy: 0.5728
Epoch 00051: val_accuracy did not improve from 0.70000
21/21 [=====] - 27s 1s/step - loss: 0.8910 - accuracy: 0.
5728 - val_loss: 0.7582 - val_accuracy: 0.5800
Epoch 52/100
21/21 [=====] - ETA: 0s - loss: 0.9315 - accuracy: 0.5583
Epoch 00052: val_accuracy did not improve from 0.70000
21/21 [=====] - 27s 1s/step - loss: 0.9315 - accuracy: 0.
5583 - val_loss: 0.6740 - val_accuracy: 0.6600
Epoch 53/100
21/21 [=====] - ETA: 0s - loss: 0.8625 - accuracy: 0.6143
Epoch 00053: val_accuracy did not improve from 0.70000
21/21 [=====] - 28s 1s/step - loss: 0.8625 - accuracy: 0.
6143 - val_loss: 0.7258 - val_accuracy: 0.6600
Epoch 54/100
21/21 [=====] - ETA: 0s - loss: 0.7993 - accuracy: 0.6505
Epoch 00054: val_accuracy improved from 0.70000 to 0.72000, saving model to allw
21/21 [=====] - 27s 1s/step - loss: 0.7993 - accuracy: 0.
6505 - val_loss: 0.6933 - val_accuracy: 0.7200
Epoch 55/100
21/21 [=====] - ETA: 0s - loss: 0.9514 - accuracy: 0.5922
Epoch 00055: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.9514 - accuracy: 0.
5922 - val_loss: 0.7190 - val_accuracy: 0.7200
Epoch 56/100
21/21 [=====] - ETA: 0s - loss: 0.9133 - accuracy: 0.6068
Epoch 00056: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.9133 - accuracy: 0.
6068 - val_loss: 0.7271 - val_accuracy: 0.6400
Epoch 57/100
21/21 [=====] - ETA: 0s - loss: 0.8369 - accuracy: 0.5971
Epoch 00057: val_accuracy did not improve from 0.72000
21/21 [=====] - 28s 1s/step - loss: 0.8369 - accuracy: 0.
5971 - val_loss: 0.6821 - val_accuracy: 0.6400
Epoch 58/100
21/21 [=====] - ETA: 0s - loss: 0.8486 - accuracy: 0.5952
Epoch 00058: val_accuracy did not improve from 0.72000
21/21 [=====] - 28s 1s/step - loss: 0.8486 - accuracy: 0.
5952 - val_loss: 0.8126 - val_accuracy: 0.5800
Epoch 59/100
21/21 [=====] - ETA: 0s - loss: 0.8243 - accuracy: 0.5874
Epoch 00059: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.8243 - accuracy: 0.
5874 - val_loss: 0.7294 - val_accuracy: 0.6400
Epoch 60/100
21/21 [=====] - ETA: 0s - loss: 0.8393 - accuracy: 0.5922
Epoch 00060: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.8393 - accuracy: 0.
5922 - val_loss: 0.6873 - val_accuracy: 0.6800
Epoch 61/100
21/21 [=====] - ETA: 0s - loss: 0.8910 - accuracy: 0.5777
Epoch 00061: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.8910 - accuracy: 0.
5777 - val_loss: 0.6655 - val_accuracy: 0.7200
```

Epoch 62/100
21/21 [=====] - ETA: 0s - loss: 0.7639 - accuracy: 0.6699
Epoch 00062: val_accuracy did not improve from 0.72000
21/21 [=====] - 28s 1s/step - loss: 0.7639 - accuracy: 0.6699 - val_loss: 0.6862 - val_accuracy: 0.5800
Epoch 63/100
21/21 [=====] - ETA: 0s - loss: 0.8416 - accuracy: 0.6359
Epoch 00063: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.8416 - accuracy: 0.6359 - val_loss: 0.7034 - val_accuracy: 0.7000
Epoch 64/100
21/21 [=====] - ETA: 0s - loss: 0.7580 - accuracy: 0.6699
Epoch 00064: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.7580 - accuracy: 0.6699 - val_loss: 0.7071 - val_accuracy: 0.7000
Epoch 65/100
21/21 [=====] - ETA: 0s - loss: 0.7414 - accuracy: 0.6699
Epoch 00065: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.7414 - accuracy: 0.6699 - val_loss: 0.6752 - val_accuracy: 0.6400
Epoch 66/100
21/21 [=====] - ETA: 0s - loss: 0.7958 - accuracy: 0.6359
Epoch 00066: val_accuracy did not improve from 0.72000
21/21 [=====] - 26s 1s/step - loss: 0.7958 - accuracy: 0.6359 - val_loss: 0.6426 - val_accuracy: 0.6600
Epoch 67/100
21/21 [=====] - ETA: 0s - loss: 0.8149 - accuracy: 0.6262
Epoch 00067: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.8149 - accuracy: 0.6262 - val_loss: 0.6498 - val_accuracy: 0.6800
Epoch 68/100
21/21 [=====] - ETA: 0s - loss: 0.7391 - accuracy: 0.6602
Epoch 00068: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.7391 - accuracy: 0.6602 - val_loss: 0.7008 - val_accuracy: 0.6400
Epoch 69/100
21/21 [=====] - ETA: 0s - loss: 0.7439 - accuracy: 0.7087
Epoch 00069: val_accuracy did not improve from 0.72000
21/21 [=====] - 27s 1s/step - loss: 0.7439 - accuracy: 0.7087 - val_loss: 0.6210 - val_accuracy: 0.6600
Epoch 70/100
21/21 [=====] - ETA: 0s - loss: 0.8585 - accuracy: 0.6650
Epoch 00070: val_accuracy improved from 0.72000 to 0.78000, saving model to allW
21/21 [=====] - 30s 1s/step - loss: 0.8585 - accuracy: 0.6650 - val_loss: 0.6156 - val_accuracy: 0.7800
Epoch 71/100
21/21 [=====] - ETA: 0s - loss: 0.7872 - accuracy: 0.6553
Epoch 00071: val_accuracy did not improve from 0.78000
21/21 [=====] - 29s 1s/step - loss: 0.7872 - accuracy: 0.6553 - val_loss: 0.6508 - val_accuracy: 0.6800
Epoch 72/100
21/21 [=====] - ETA: 0s - loss: 0.7463 - accuracy: 0.6796
Epoch 00072: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7463 - accuracy: 0.6796 - val_loss: 0.6421 - val_accuracy: 0.6200
Epoch 73/100
21/21 [=====] - ETA: 0s - loss: 0.7459 - accuracy: 0.6553
Epoch 00073: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7459 - accuracy: 0.6553 - val_loss: 0.7670 - val_accuracy: 0.5400
Epoch 74/100

```
21/21 [=====] - ETA: 0s - loss: 0.8045 - accuracy: 0.6019
Epoch 00074: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.8045 - accuracy: 0.
6019 - val_loss: 0.6469 - val_accuracy: 0.6600
Epoch 75/100
21/21 [=====] - ETA: 0s - loss: 0.8168 - accuracy: 0.6650
Epoch 00075: val_accuracy did not improve from 0.78000
21/21 [=====] - 27s 1s/step - loss: 0.8168 - accuracy: 0.
6650 - val_loss: 0.7642 - val_accuracy: 0.6600
Epoch 76/100
21/21 [=====] - ETA: 0s - loss: 0.8108 - accuracy: 0.6699
Epoch 00076: val_accuracy did not improve from 0.78000
21/21 [=====] - 26s 1s/step - loss: 0.8108 - accuracy: 0.
6699 - val_loss: 0.6361 - val_accuracy: 0.7000
Epoch 77/100
21/21 [=====] - ETA: 0s - loss: 0.7078 - accuracy: 0.6845
Epoch 00077: val_accuracy did not improve from 0.78000
21/21 [=====] - 27s 1s/step - loss: 0.7078 - accuracy: 0.
6845 - val_loss: 0.6730 - val_accuracy: 0.6600
Epoch 78/100
21/21 [=====] - ETA: 0s - loss: 0.7055 - accuracy: 0.6650
Epoch 00078: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7055 - accuracy: 0.
6650 - val_loss: 0.6912 - val_accuracy: 0.6800
Epoch 79/100
21/21 [=====] - ETA: 0s - loss: 0.7922 - accuracy: 0.5825
Epoch 00079: val_accuracy did not improve from 0.78000
21/21 [=====] - 27s 1s/step - loss: 0.7922 - accuracy: 0.
5825 - val_loss: 0.6829 - val_accuracy: 0.6400
Epoch 80/100
21/21 [=====] - ETA: 0s - loss: 0.7379 - accuracy: 0.6990
Epoch 00080: val_accuracy did not improve from 0.78000
21/21 [=====] - 26s 1s/step - loss: 0.7379 - accuracy: 0.
6990 - val_loss: 0.6468 - val_accuracy: 0.7000
Epoch 81/100
21/21 [=====] - ETA: 0s - loss: 0.7813 - accuracy: 0.6553
Epoch 00081: val_accuracy did not improve from 0.78000
21/21 [=====] - 27s 1s/step - loss: 0.7813 - accuracy: 0.
6553 - val_loss: 0.7037 - val_accuracy: 0.6800
Epoch 82/100
21/21 [=====] - ETA: 0s - loss: 0.7438 - accuracy: 0.6699
Epoch 00082: val_accuracy did not improve from 0.78000
21/21 [=====] - 26s 1s/step - loss: 0.7438 - accuracy: 0.
6699 - val_loss: 0.6667 - val_accuracy: 0.7000
Epoch 83/100
21/21 [=====] - ETA: 0s - loss: 0.7605 - accuracy: 0.6505
Epoch 00083: val_accuracy did not improve from 0.78000
21/21 [=====] - 27s 1s/step - loss: 0.7605 - accuracy: 0.
6505 - val_loss: 0.6900 - val_accuracy: 0.7000
Epoch 84/100
21/21 [=====] - ETA: 0s - loss: 0.8253 - accuracy: 0.6408
Epoch 00084: val_accuracy did not improve from 0.78000
21/21 [=====] - 29s 1s/step - loss: 0.8253 - accuracy: 0.
6408 - val_loss: 0.6860 - val_accuracy: 0.6000
Epoch 85/100
21/21 [=====] - ETA: 0s - loss: 0.7752 - accuracy: 0.6068
Epoch 00085: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7752 - accuracy: 0.
6068 - val_loss: 0.6131 - val_accuracy: 0.7600
Epoch 86/100
21/21 [=====] - ETA: 0s - loss: 0.7241 - accuracy: 0.6796
```

Epoch 00086: val_accuracy did not improve from 0.78000
21/21 [=====] - 27s 1s/step - loss: 0.7241 - accuracy: 0.6796 - val_loss: 0.6149 - val_accuracy: 0.6400
Epoch 87/100
21/21 [=====] - ETA: 0s - loss: 0.8031 - accuracy: 0.6476
Epoch 00087: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.8031 - accuracy: 0.6476 - val_loss: 0.6504 - val_accuracy: 0.6600
Epoch 88/100
21/21 [=====] - ETA: 0s - loss: 0.6733 - accuracy: 0.7136
Epoch 00088: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.6733 - accuracy: 0.7136 - val_loss: 0.5885 - val_accuracy: 0.6800
Epoch 89/100
21/21 [=====] - ETA: 0s - loss: 0.7349 - accuracy: 0.6796
Epoch 00089: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7349 - accuracy: 0.6796 - val_loss: 0.6573 - val_accuracy: 0.7200
Epoch 90/100
21/21 [=====] - ETA: 0s - loss: 0.6834 - accuracy: 0.7233
Epoch 00090: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.6834 - accuracy: 0.7233 - val_loss: 0.6496 - val_accuracy: 0.6400
Epoch 91/100
21/21 [=====] - ETA: 0s - loss: 0.7662 - accuracy: 0.6505
Epoch 00091: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7662 - accuracy: 0.6505 - val_loss: 0.5490 - val_accuracy: 0.7600
Epoch 92/100
21/21 [=====] - ETA: 0s - loss: 0.7122 - accuracy: 0.6602
Epoch 00092: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7122 - accuracy: 0.6602 - val_loss: 0.7861 - val_accuracy: 0.5800
Epoch 93/100
21/21 [=====] - ETA: 0s - loss: 0.7158 - accuracy: 0.7000
Epoch 00093: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7158 - accuracy: 0.7000 - val_loss: 0.6617 - val_accuracy: 0.6800
Epoch 94/100
21/21 [=====] - ETA: 0s - loss: 0.7512 - accuracy: 0.6893
Epoch 00094: val_accuracy did not improve from 0.78000
21/21 [=====] - 28s 1s/step - loss: 0.7512 - accuracy: 0.6893 - val_loss: 0.6097 - val_accuracy: 0.6800
Epoch 95/100
21/21 [=====] - ETA: 0s - loss: 0.8400 - accuracy: 0.6165
Epoch 00095: val_accuracy improved from 0.78000 to 0.80000, saving model to allw
21/21 [=====] - 27s 1s/step - loss: 0.8400 - accuracy: 0.6165 - val_loss: 0.5982 - val_accuracy: 0.8000
Epoch 96/100
21/21 [=====] - ETA: 0s - loss: 0.8106 - accuracy: 0.6165
Epoch 00096: val_accuracy did not improve from 0.80000
21/21 [=====] - 27s 1s/step - loss: 0.8106 - accuracy: 0.6165 - val_loss: 0.5691 - val_accuracy: 0.7200
Epoch 97/100
21/21 [=====] - ETA: 0s - loss: 0.7276 - accuracy: 0.6650
Epoch 00097: val_accuracy did not improve from 0.80000
21/21 [=====] - 30s 1s/step - loss: 0.7276 - accuracy: 0.6650 - val_loss: 0.6533 - val_accuracy: 0.6200
Epoch 98/100
21/21 [=====] - ETA: 0s - loss: 0.7188 - accuracy: 0.7233
Epoch 00098: val_accuracy did not improve from 0.80000

```
21/21 [=====] - 29s 1s/step - loss: 0.7188 - accuracy: 0.7233 - val_loss: 0.6412 - val_accuracy: 0.7600
Epoch 99/100
21/21 [=====] - ETA: 0s - loss: 0.6552 - accuracy: 0.7573
Epoch 00099: val_accuracy did not improve from 0.80000
21/21 [=====] - 28s 1s/step - loss: 0.6552 - accuracy: 0.7573 - val_loss: 0.6052 - val_accuracy: 0.6600
Epoch 100/100
21/21 [=====] - ETA: 0s - loss: 0.7052 - accuracy: 0.6990
Epoch 00100: val_accuracy did not improve from 0.80000
21/21 [=====] - 28s 1s/step - loss: 0.7052 - accuracy: 0.6990 - val_loss: 0.6348 - val_accuracy: 0.6600
```

Out[9]:

<tensorflow.python.training.tracking.util.CheckpointLoadStatus at 0x1c58007fa90>

[5 points] Plot Accuracy and Loss During Training

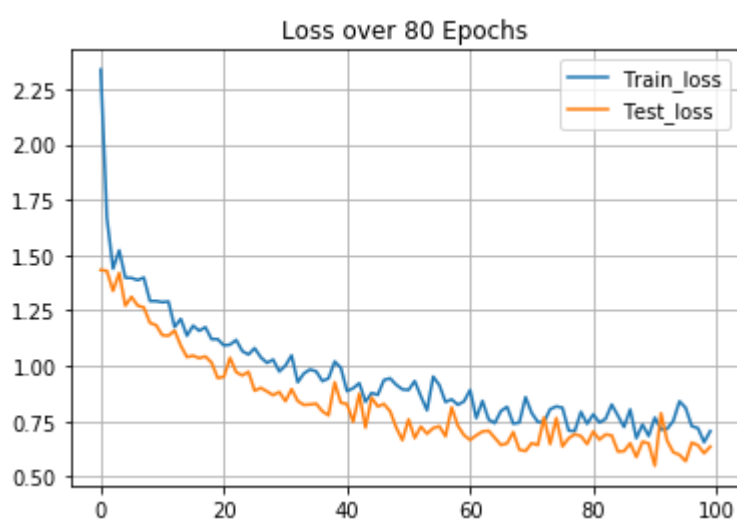
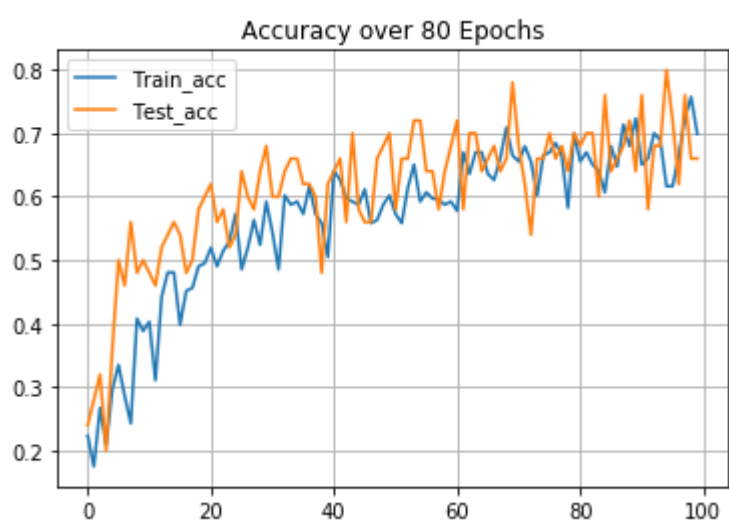
There is a typo in the plot title, it should be 100 epochs

In [10]:

```
import matplotlib.pyplot as plt

plt.title('Accuracy over 80 Epochs')
plt.plot(history.history['accuracy'], label='Train_acc')
plt.plot(history.history['val_accuracy'], label='Test_acc')
plt.legend(loc='upper left')
plt.grid(True)
plt.show()

plt.title('Loss over 80 Epochs')
plt.plot(history.history['loss'], label='Train_loss')
plt.plot(history.history['val_loss'], label='Test_loss')
plt.legend(loc='upper right')
plt.grid(True)
plt.show()
```



Testing Model

In [30]:

```
vgg16.trainable = True
test_datagen = ImageDataGenerator(rescale=1. / 255)

eval_generator = test_datagen.flow_from_directory(TEST_DIR,target_size=IMAGE_SIZE,
                                                  batch_size=1,shuffle=True,seed=42,class_mode=
"categorical")
eval_generator.reset()
x = model.evaluate_generator(eval_generator,steps = np.ceil(len(eval_generator)),
                             use_multiprocessing = False,verbose = 1,workers=1)

print('Test loss:', x[0])
print('Test accuracy:',x[1])
```

Found 36 images belonging to 4 classes.

36/36 [=====] - 4s 107ms/step - loss: 0.7923 - accuracy:
0.6667

Test loss: 0.7922794818878174

Test accuracy: 0.6666666865348816